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Electronic Nose Technology Based on Odor Diagnosis in Biopharmaceutical Test

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Odor dominates more in the quality inspection of traditional Chinese herbal medicines. This paper focuses on what's effect the electronic nose technology has played if applied in biopharmaceutical test based on odor diagnosis. There are some methods such as literature and data analysis, tests that are used for study. On the basis of brief introduction to the electronic nose technology, the electronic nose PEN3 acquires the overall information of the volatile odor from the miscible Chinese herbal medicines of three typical families. The eigenvalues extracted by the Principal Component Analysis (PCA) act as the input values for mode recognition method to test the three groups of miscible medicine materials. The results reveal that only the Amomum villosum in the training set samples is misjudged, the correct rate reaches 93.23%, and the rest are all 100%. It is suggested that the electronic nose technology can realize the test on miscible Chinese herbal medicines, thus providing a new idea for testing the biopharmaceuticals.

1. Introduction

Biopharmaceuticals can be classified by different approaches such as their structure, source, physiological function and usages (Voss et al, 2014). They include human tissue, animal tissue, plant tissue, microorganism and marine life from the angle of drug sources, while the traditional Chinese herbal medicine is an important part of plant tissue sources (Wilson and Baietto, 2011). It is not good, however, that there are many kinds of traditional Chinese herbal medicines which are easily confused. In recent years, driven by the interests, a large number of counterfeit and shoddy products have emerged in the market. In this context, how to discriminate the quality of traditional Chinese herbal medicine has become the focus of widespread concern and study.

Since a long time ago, medical experts and scholars have generally evaluated the variety and quality of traditional Chinese herbal medicines with sense organs (Sibila et al., 2014), but this greatly suffers more misleading behaviors that derive from subjective experience of the reviewers and the external environment, so that it falls short of what's required by modern medicine for the test on them more scientifically and normatively. Odor is one of the important features used for discriminating the quality and class of traditional Chinese herbal medicines (Xu et al., 2008). Electronic nose technology (Schiffman et al., 1997) works on the principle that simulates human olfaction and automatically identifies all kinds of odors. It consists of a set of chemical sensors and identification analysis software. Thanks to its simple operation, objective and accurate evaluation criterian, and fast test process, it has great potential in the field of comprehensive evaluation on odor information. With the advancement of fuzzy technology and computational neural network, the insight into sensitive materials makes electronic nose technology tend to be perfect and mature. By far, it has already found wider and wider application in many fields such as food, medical care and environment (Scott et al., 2006). Looking back domestic and foreign literature (Baldwin et al., 2011), it is discovered that there are few studies on the application of electronic nose technology in the classification and test of traditional Chinese herbal medicines, which implies that this field is still in its infancy.

Based on the above analysis, this paper selects the miscible traditional Chinese herbal medicines of three typical families, Compositae, Umbelliferae and Zingiber as the study objects (Wilson et al., 1997), with the electronic nose technology based on odor diagnosis as the test means, applies PEN3 electronic nose to collect and analyze the volatile components from the test samples, and extract and filtrate the eigenvalues of

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samples using the Principal Component Analysis (PCA). In turn, the BP neural network enables the mode recognition method to discriminate the test samples. It turns out that the electronic nose technology based on the odor diagnosis can achieve good discrimination and identification for easily miscible traditional Chinese herbal medicines.

2. Electronic nose technology

2.1 Principle and construction of electronic nose technology

The principle of electronic nose technology is to simulate the mechanism of human recognition of odors. It is designed as a bionic olfactory system that integrates the sensor and mode recognition technologies (Khan et al., 2006). It generally includes two parts: gas sensor array and pattern recognition system (Itokazu et al., 1998). Among them, the gas sensor is the key part of the electronic nose since it assumes an important task to convert the odor information from the samples into measurable information (Furton et al., 2002). Currently, metal oxide semiconductor sensors, quartz crystal gas sensors, electrochemical gas sensors, etc. are widely applied types (Jato et al., 1996). Mode recognition system is one of the key factors for electronic nose to correctly discriminate odor. It can simulate human behaviors to classify odors. There are several major MD methods including the Support Vector Machine (SVM), BP neural network and the cluster analysis (Taylor et al., 2017). This paper selects the portable electronic nose system PEN3 produced in Germany, as shown in Figure 1, which allows several functions such as special sampling system, the bundled software WinMaster with modeling function and simple and quick discriminant answer mode, as well as basical data analysis.

Figure 1: PEN3 electronic nose

2.2 Electronic nose data treatment method

2.2.1 Feature extraction

The purpose of feature extraction (Zhou et al., 2017) is to compress the dimension of the feature space, reduce the data redundancy, and define a set of features that most faithfully represent original signals and are most useful for classification. It includes linear and nonlinear, supervised and unsupervised methods. This paper takes the supervised linear classification technique, the Principal Component Analysis (PCA), as study case, whose main idea is to reduce the dimensions, that is to say, several variables that can reflect the original information are found from new ones generated by the linear combination as constructed in order to analyze the problem.

2.2.2 Mode recognition method of BP neural network

BP neural network (Yang et al., 2013) is a multi-layer feedforward neural network trained by the error inverse propagation algorithm. It has a basic network topology structure including the input, hidden and output layers. The algorithm includes data forward transfer and error signal backward propagation. The BP neural network features that it can be learned and stored without the involvement of mathematical equations that reveal and describe the input-output mode mapping relationship beforehand.

3. Traditional Chinese herbal medicine test based on electronic nose technology

3.1 Material selection

Three groups of the traditional Chinese herbal medicines of Asteraceae, Umbelliferae and Zingiberaceae, which have similar appearances, odor characteristics and easy to be confused by non-professionals, are chosen as test materials, they are namely White Atractylodes and Atractylodes lancea, Radix Peucedani and Notopterygium incisum, Yizhiren and Amomum villosum.

3.2 Feature extraction and selection of easily miscible herbs

3.2.1 Sample and analysis

The electronic nose PEN3 is applied to test and analyze three groups and six kinds of miscible traditional Chinese herbal medicines. As shown in Figure 2-6, there are the response characteristics of 10 sensors for electronic nose.

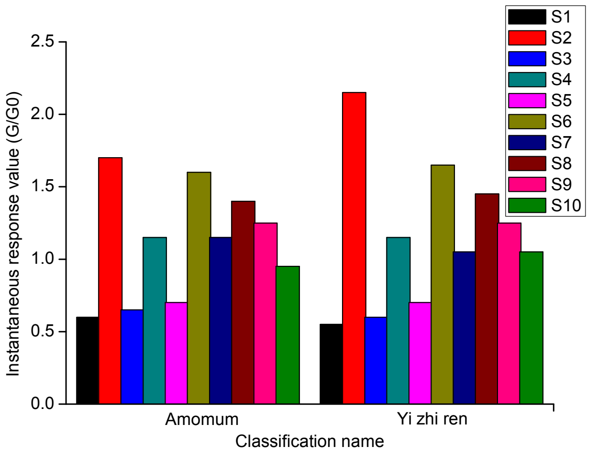

Figure 2: Response bar graph of PEN3 to Amomum and Yizhiren

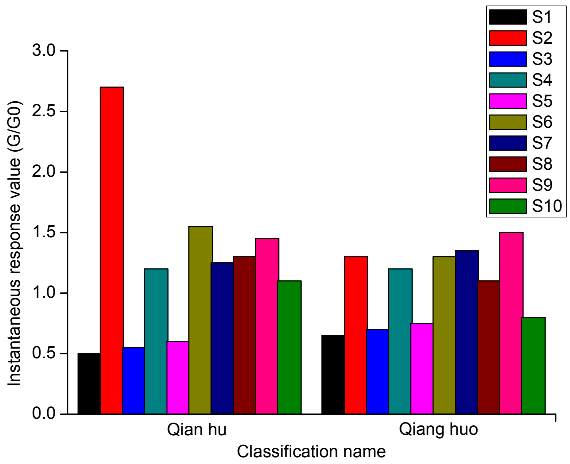

Figure 3: Response bar graph of PEN3 to Radix Peucedani and Qianghuo

It is known from Figure 2 that the sensor 2 has a stronger response to Amomum villosum and bitter cardamom, especially for the latter, and relatively closed responses to the rest of them, which shows that Amomum villosum and bitter cardamom have a higher similarity. Moreover, the volatile components of bitter cardamom contain more nitrogen oxides. As shown in Figure 3, the sensors S2 and S6 all have stronger responses to the Radix Peucedani and Notopterygium incisum than other materials, while the rest of the sensors have basically consistent response values. It is suggested that there is a great difference between Amomum villosum and bitter cardamon. The S2 and S6 response values to the Radix Peucedani show that the nitrogen oxide and methane component takes up a higher percentage of volatile components.

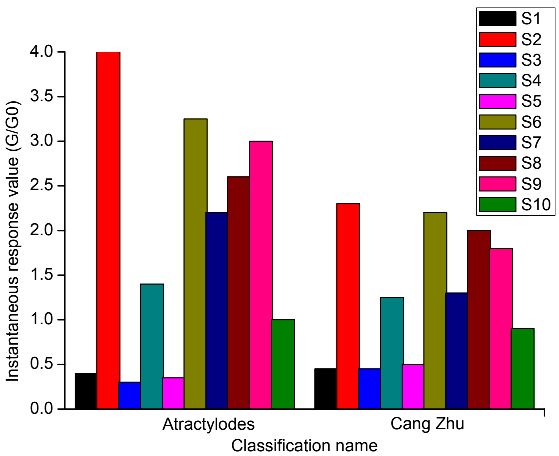

Figure 4: Response histogram of PEN3 to Atractylodes and Cang Zhu

As shown in Figure 4, sensors S2, S6, S7, and S8 are more sensitive to White Atractylodes and Atractylodes lancea, and their response characteristics are significantly different. It is suggested that their difference is higher than that of the first two groups of miscible herbs. Compared with Atractylodes lancea, the contents of methane, ethanol, sulfide and nitrogen oxides are higher.

3.2.2. Feature extraction and filtration

The scores of the first five components in the three miscible medicine materials are taken for the next classification and discrimination analysis. The electronic nose PEN3 analyzes the original feature vector generated by the response value. Figure 5-7 are PCA analysis of three kinds of miscible herbs.

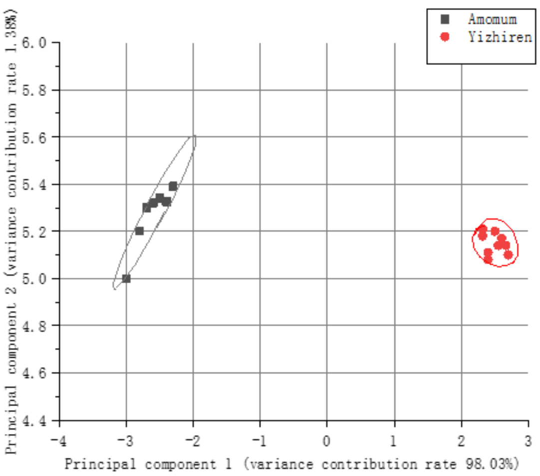

Figure 5: Analysis of the main components of Amomum and Yizhiren

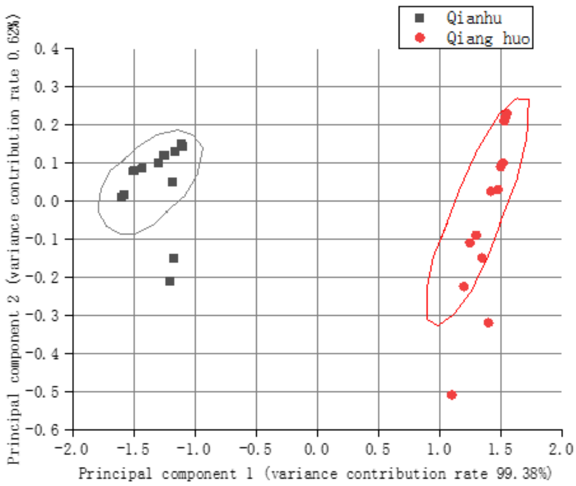

Figure 6: Analysis of the main components of Radix Peucedani and Qianghuo

It is known from the figure that among the three groups of miscible medicine materials, the concentration of bitter cardamon is the highest, but other samples are not high and distributed more dispersedly to be basically a band shape. It is basically possible to distinguish various group of medicinal materials.

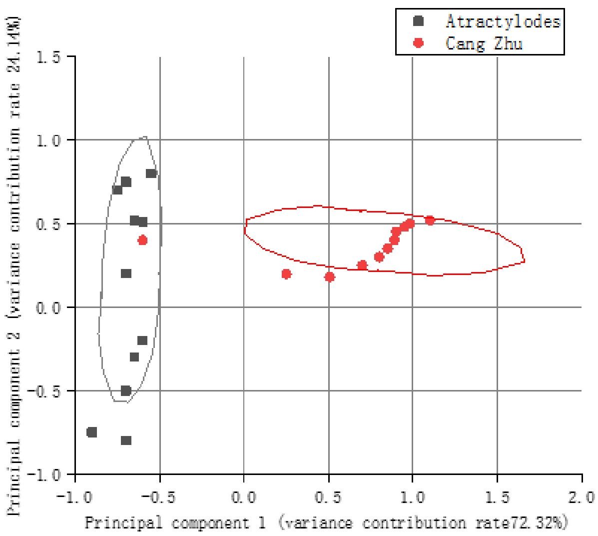

Figure 7: Analysis of the main components of Atractylodes and Cang Zhu

3.3 Discriminant analysis of miscible medicine materials by BP neural network

When the BP neural network is used, the number of dimensions (5) of eigenvectors of each sample are regarded as the neurons in the network input layer, and the number of varieties of samples (2) as the number

of neurons in the output layer. When the neurons in hidden layer are determined as 10 by trial-and-error method, the network performance is the best, so that the network topology is finally determined as 5-10-2.
Take the scores of the first five components of miscible medicine materials and the two miscible medicine materials as the input and output values of the network, the BP neural network can discriminate and analyze the three miscible medicine materials. During the test, each of the medicine materials are taken for 30 repetitive tests performed for 180 times in total, and divided into two parts by the ratio of 1:1, i.e. the training and the test sets. The judgment accuracy of training and the test sets is given in Table 1.

Table 1: Network training and test results

Medicinal name	The accuracy of the judgment of the training set	Test set judgment accuracy
Yi zhi ren	100%	100%
Amomum	100%	93.23%
Qian hu	100%	100%
Qiang huo	100%	100%
Atractylodes	100%	100%
Cang Zhu	100%	100%

As shown in the table, only the Amomum villosum in the test set has a correct rate of 93.23%, and the remaining correct rates all have reached 100%.

Table 2: Network test results

	Yizhiren	Amomum	Qian hu	Qiang huo	Atractylodes	Cang Zhu
Yi zhi ren	15	0	0	0	0	0
Amomum	2	13	0	0	0	0
Qian hu	0	0	15	0	0	0
Qiang huo	0	0	0	15	0	0
Atractylodes	0	0	0	0	15	0
Cang Zhu	0	0	0	0	0	15

The test results in Table 2 show that two samples of Amomum villosum are misjudged, the volatile components of the two are very close, and the similarity between the two is also very high.

4. Conclusion

Based on the analysis of pertinent literature at home and abroad, and in combination with the characteristics of China's pharmaceuticals industry, three groups of miscible Chinese herbal medicines are taken for making the study on the application of electronic nose technology in biopharmaceutical testing based on odor diagnosis. The specific conclusions are derived as follows:
(1) PEN3 electronic nose is used to acquire the overall information of volatile odor of three groups and six kinds of confusing herbs, and a response histogram is plotted for miscible medicine materials. There are 8 attribute subsets obtained to reflect their response characteristics.
(2) The PCA analysis method is applied to determine the feature vector used for mode recognition analysis as the score value of the first five principal components.
(3) The BP neural network detects three groups and six kinds of miscible herbs. The results show that except for the amomum villosum, the discrimination accuracy of the other samples is 100%, which shows that the electronic nose technology can achieve the inspection on the miscible Chinese herbal medicines.

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Polygonatum kingianum Coll. et Hemsl Adaptive Seedbed Establishment Technology for High-Altitude Hilly Areas, 2018 Yunnan Education Department Scientific Research Fund (2018JS272); The Study of combustion and system performance in low-power ORC biomass furnace, Yunnan Younth Fund (2017FD080)

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