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CLASSIFICATION IDENTIFICATION OF ABALONE FLAVORING LIQUIDS BASED ON METAL SENSOR ARRAY

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ABSTRACT

In order to identify abalone flavoring liquids with different tastes and guarantee uniformity quality of instant abalone with the same taste, a sensor array composed of seven metal electrodes is constituted to test the taste quality of the abalone flavoring liquids. Five solutions which represented five basic tastes like salty, fresh, sour, bitter and sweet are tested by the sensor array to identify its identification ability in basic tastes. One-way analysis of variance, principal component analysis and probabilistic neural network algorithm are used to evaluate the recognition effect of this sensor array on basic tastes. The result shows that this sensor array has excellent identification ability on basic tastes. Then the sensor array is used to identify abalone flavoring liquids with five different tastes. The principal component analysis is used to achieve dimensionality reduction of measured data, and three principal components employed as the input neurons of the probabilistic neural network. The result shows that this sensor array has a good performance on abalone flavoring liquid identification and the correct identification rate is 92%.

1. Introduction

With the expansion of the seafood consumption market, the instant abalone product is accepted by more and more consumers due to its unique flavor, convenient to eat, resistant to storage and nutrient retain comprehensively (Liu et al., 2013). The taste quality of instant abalone product is mainly determined by abalone flavoring liquid adding in precooking process. At present, the taste quality of the abalone flavoring liquid is mainly evaluated by two methods: manual tasting and traditional physical and chemical test. However, manual tasting is based on the experience of the valuator, so the result has some disadvantages of strong subjectivity and poor repeatability. On the other hand, the traditional physical and chemical testing method can only be used to analyze the content of certain components.

The comprehensive information resulted from the interactions between different tasty substances can't be reflected by the result (Liu, 2012).

Relatively comprehensive and objective results can obtain when using a sensor array for gustatory analysis in the food industry. In recent years, sensor arrays are widely used in food industry. In foreign countries, Ghosh et al used five kinds of precious metal (Au, Ir, Pd, Pt, Cd) to constitute a sensor array, quickly determined the content of thea rubigin and thea flavin in black tea and at last estimated it

(Ghosh et al, 2012). Apetrei and his partners used a screen-printed electrode modified with polypyrrole, qualitatively and quantitatively analyzed the content of phenolic compound in virgin olive oil (Apetrei, 2013). At home, Muyan Zhou et al used 6 electrodes (Pt, Au, Pd, W, Ti and Ag) to constitute a sensor array, distinguished rice wine in different type, region, brand, vintage (Zhou et al, 2012 and Zhou et al, 2013). Zhenbo Wei et al constituted a sensor array with Au, Ag, Pt and Pd electrodes to detect the quality index of yogurt (Wei et al, 2013).

At present, researches of abalone products are focus on the processing technology, the taste quality of them catches less attention. Therefore, this paper proposes a method to constitute a sensor array with metal electrodes to identify the basic taste substances and present its identification ability to basic tastes. After that this sensor array is used to identify abalone flavoring liquids with different tastes, in order to effectively control the taste and guarantee uniformity quality of the products.

2. Materials and methods

2.1. Experiment equipment and test parameters

CHI620B electrochemical workstation and multi-channel selection instrument, Shanghai Chenhua Instrument Co., Ltd.; Nine metal disk electrodes with a diameter of 2mm (Ag, Au, Pd, Pt, W, Ti, Ni, Zn, Al) are used as working electrode, Two 1 × 10 mm platinum wire electrodes are used as reference electrode and auxiliary electrode respectively, this three types of electrode constitute a sensor array, Tianjin Aida Hengsheng Technology Co., Ltd.; HJ-2B multihead magnetic heating stirrer, Changzhou Guohua Electric Co., Ltd.; KQ-2200DB ultrasonic cleaning machine, Kunshan Ultrasonic Cleaning Equipment Co., Ltd.; JA1003B electronic balance, Shanghai Yueping Scientific Instrument Co., Ltd.; A computer is used for data collection and analysis.

The detecting system used in this experiment is composed of a sensor array, a data acquisition device and a computer. The output weak signals from the sensor array are collected by an electrochemical workstation, and then are sent to the computer to process. Thus a complete taste detecting system is constituted.

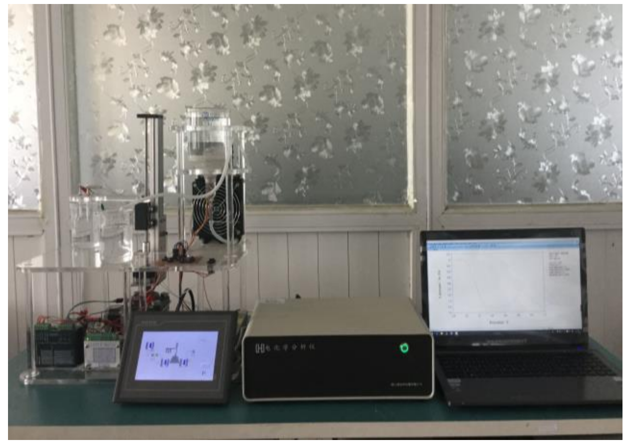


Figure 1. Detecting system

The electrode should be polished with a polishing cloth and aluminum oxide polishing powder when used for the first time, and it will be polished by polishing powder from coarse to fine, until the surface is smooth as a mirror. After that the electrode would be cleaned by ultrasonic with ethanol and deionized water and drew with filter papers. The working electrode would be polished with a polishing cloth without polishing powder in each measure. The auxiliary electrode and the reference electrode should be cleaned with deionized water and dried with filter papers(Tian, 2007).

The experiment is carried out under the condition of room temperature is 23 ℃. The reaction surface of working electrode immerse in sample 10mm deep. Cyclic voltammetry is used as the detecting method, its initial voltage is -0.8V, low voltage is -0.8V, high voltage is 0.6V, terminative voltage is 0.6V, scanning rate is 0.1v/s, sampling interval is 0.001V, data collecting frequency is 50Hz and sensitivity is e^{-5}～e^{-3} (Men et al., 2013).

2.2. Materials and reagents

Drugs represented basic tastes are: sucrose represents sweet taste, sodium chloride represents salty taste, lemon acid represents sour taste, monosodium glutamate represents fresh taste, magnesium sulfate represents bitter taste. Drugs are analytical reagent made from Da Mao chemical reagent factory. Deionized water is used to prepare solutions with the concentration are 1%. Each sample is 80ml.

In order to maintain the original taste of seafood, the component of abalone flavoring liquid is simple. It mainly contains salt, monosodium glutamate, bone soup and other accessories. Manufacturers usually adjust the recipe according to the demands of customers. In this experiment, abalone flavoring liquids with five different tastes are used to test the identification ability of the sensor array. The recipe list of abalone flavoring liquid with five different tastes is shown in tab1. Condiments are dissolved in 100ml deionized water according to recipe list to make testing samples. All samples are prepared 20 minutes before the experiment and placed at the environment of 23 ℃.

Table 1. Recipe list of abalone flavoring liquid with 5 different tastes

Content	Salt	Monosodium Glutamate	Vinegar	Sugar
1 Light	1g	0.5g	0	0.5g
2 Sweet and fresh	1g	2g	0	3g
3 Salt and fresh	3g	2g	0	0
4 Sour and sweet	1g	0.5g	2ml	3g
5 Sour and fresh	1g	2g	2g	0

Note: the brand and kind of condiments: salt is natural salt made from China National Salt Industry Corporation, monosodium glutamate is made from Henan Lotus Gourmet Powder Co. Ltd, vinegar is white vinegar made from Shanghai DingFeng brewing food Co. Ltd., sugar is white granulated sugar made from Guangzhou Overseas Chinese sugar Co. Ltd.

2.3. Data processing method

One-way analysis of variance (One-Way ANOVA) is used to distinguish which group has a significant difference among the dependent variable groups, that is to do multiple comparison of mean value.

Principal Component Analysis (PCA) is a kind of data dimension reduction method, which is used to convert high dimensional data into a low one, and keep the characteristics of the original data as much as possible (Lu et al., 2013). The new variables of PCA are known as the principal components, which can be used to describe the sample space. PCA is executed by Statistical Product and Service Solutions (SPSS) software.

Probabilistic Neural Network (PNN) is a parallel algorithm developed from Bayesian criteria, and the Bayesian criteria are based on non-parameter estimation of probability density function (Liu, J.J et al., 2012). The PNN is executed by Matlab software.

In order to evaluate the identification result of each sample, correct rate is defined as:

$$C_R=(n-N_w)/n\times 100\% \qquad (1)$$

In equation (1), C_R is the correct rate of identification; n is the number of samples; N_w is the misclassification number of samples.

3. Results and discussions

3.1.Basic tastes identification

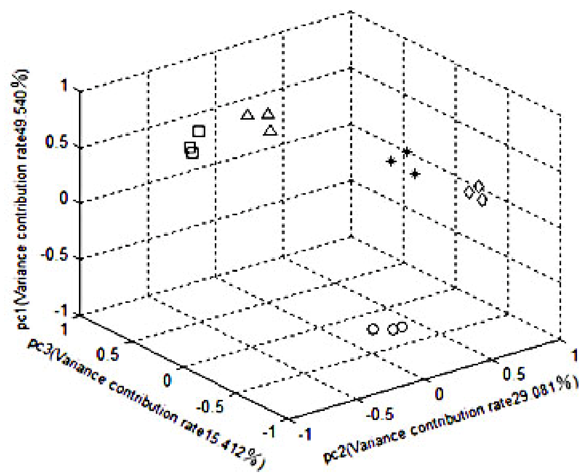
3.1.1. A sensor response to basic tastes

Detecting accuracy of the system is decided by response performances of the sensor, which are based on stability of the sensor to the same sample and distinguish ability of the sensor to the different sample (Zeng et al., 2013). Five duplicate samples are prepared for each basic taste. A response current peak for potential excitation signals is used as the eigenvalue of a basic taste sample. The standard deviation (STDEV) of response signal to the same taste is calculated for each sensor. Except Al and Zn electrodes, the STDEV values of other electrodes are all below 0.5%. It means that the stability of them is very good. The STDEV values of Al and Zn electrodes are about 5%. It means that they are instable. Therefore Al and Zn electrodes are removed from the sensor array. The response of each sensor to different taste substances has some difference. The method of least significant difference (LSD) for multiple comparisons is used to analyze measured data of seven electrodes (Ag, Au, Pd, Pt, Ni, Ti and W) that have a good stability. In this way, the distinguish ability of sensor for basic tastes can be recognized. The result shows that Ni electrode can commendably distinguish five kinds of basic tastes, and Ag, Pt and W electrodes can clearly distinguish salty, sweet and bitter tastes, Au electrode has a good identification ability for salty, sweet and fresh tastes, Pd electrode can distinguish sour, sweet and fresh tastes significantly, Ti electrode can only identify sweet taste. So it is difficult to make a distinct identification based on a single sensor, and it requires a comprehensive consideration of the impact of each sensor. Seven sensors (Ag, Au, Pd, Pt, Ni, Ti and W) are used to constitute a sensor array. Measured data of the sensor array are used for further analysis by means of PCA.

3.1.2. Principal component analysis of basic tastes

Three duplicate samples are prepared for each basic taste. Each sample is detected for 5 times. The response current peak of the sensor is taken as the measured data of the sample, and takes the average of 5 times measured data as the eigenvalue of a sample. That is obtaining 15 groups of 7 dimensional data. Bartlett spherical degree is used to test these data, the F value is less than 0.001, and the KMO testing coefficient is 0.695, greater than 0.5. That is to say that the data are reliable and valid. They can be used for PCA.

Fig.2 shows the results of PCA of basic taste substances. It intuitively presents relative position of the 15 groups of 7 dimensional data in 3 dimensional spaces. In the space of pc1＞0, only contains salty and sweet taste substances, and the rest taste substances are in the space of pc1＜0. Fresh taste substance is in the second quadrant of the plane consisted of pc1 and pc2, sour and bitter taste substances are in the third quadrant, close to each other. So the first three principal components should be retained for completely represents the sample characteristics. The variance contribution rates of the first three principal components are 49.54%, 29.081% and 15.412% respectively, and the cumulative contribution rate is 93.997%, which means the original information can be retained more than 93.997%.



○ Magnesium sulfate ◇ Lemon acid □ Sucrose
* Monosodium glutamate △ Sodium chloride

Figure 2. PCA results of basic taste substances

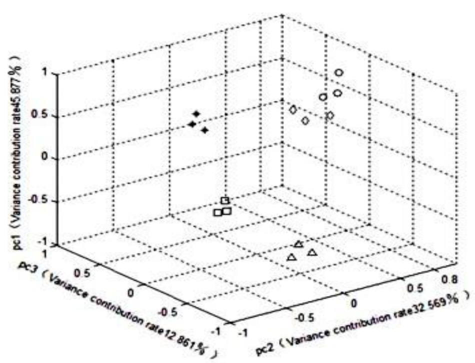
3.1.3. PNN construction of basic tastes

Five kinds of basic taste substances are tested in experiment. The response current peak of sensor is taken as the measured value of the sample. Three duplicate samples are prepared for each basic taste. Each sample is detected for 5 times. That is obtaining 75 groups of 7 dimensional data. 50 groups are chosen as the training set and the other 25 groups are used as the testing set. The training set is used to construct a probabilistic neural network and the testing set is used to test it. The input neurons are 3, which are the first three principal components resulted from PCA of 75 groups data of basic taste samples. The output neurons are 5, which are represented five kinds of basic tastes. The experiment verifies that the optimal smoothing parameter (spread) is 1.5. After network training, the data groups in testing set are correctly classified in their categories respectively. It means that the correct identification rate of PNN is 100%. This sensor array has excellent identification ability for basic taste substances, so it can be used for identification of abalone flavoring liquid.

3.2. Identification of abalone flavoring liquid

3.2.1. PCA of abalone flavoring liquid

Abalone flavoring liquids with five different tastes are prepared according to the recipe list shown in tab.1. A sensor array consisted of seven kinds of electrodes is used to test these five kinds of abalone flavoring liquid. Three duplicate samples are prepared for each abalone flavoring liquid. Each sample is detected for 5 times. The response current peak of sensor is taken as the measured value of the sample, and takes the average of 5 times measured data as the eigenvalue of a sample. That is obtaining 15 groups of 7 dimensional data. These data are analyzed by means of PCA, and the first three principal components are retained. The variance contribution rates of the first three principal components are 45.877%, 32.569% and 12.861% respectively, and the cumulative contribution rate is 91.307%.



○ Light ◇Sweet and fresh □Salt and fresh
* Sour and sweet △Sour and fresh

Figure 3. PCA results of abalone flavoring liquid in five different tastes

The distribution of the first three principal components in three dimensional spaces is shown in Fig.3. Each point represents a sample. There are three points in the figure to represent a same sample of abalone flavoring liquid. The points represented a same taste sample are close to each other. The points represented different taste samples have some distance. It suggests that these five different tastes abalone flavoring liquid can be distinguished commendably by the sensor array.

3.2.2. PNN Classified identification of abalone flavoring liquid

In order to identify the abalone flavoring liquids with five different tastes by PNN, the response current peak of sensor is taken as the measured value of the sample. Three duplicate samples are prepared for each tastes of abalone flavoring liquid. Each sample is detected for 5 times. That is obtaining 75 groups of 7 dimensional data. 50 groups are chosen as the training set and the other 25 groups are used as the testing set. The training set is used to construct a probabilistic neural network and the testing set is used to test it .The input neurons are 3, which are the first three principal components resulted from PCA of 75 groups data of abalone flavoring liquid samples. The output neurons are 5, which are represented five different tastes of abalone flavoring liquid. Other parameters are the same as the above mentioned PNN used for basic tastes recognition. After network training, the data groups in testing set are correctly classified in their categories except for one group of light taste and one group of salt and fresh taste. The correct identification rate of PNN is 92%. The result shows that the sensor array has excellent identification ability for 5 different tastes of abalone flavoring liquid.

4. Conclusions

(1) STDEV and One-way ANOVA are used to analyze the detecting signals of metal electrodes for basic taste substances. The metal electrodes which do not have good stability and distinguish ability are removed from the sensor array. The selected sensor array is used for identification of basic taste substances. PCA and PNN algorithm are used to analyze the measured data. The result shows that the sensor array has excellent identification ability for basic taste substances.

(2) The sensor array is used for classification identification of five different tastes of abalone flavoring liquid. The first three principal components are retained. The cumulative contribution rate of the first three principal components is 91.307%. The distribution of the first three principal components in three dimensional spaces can be represented intuitively by a three-dimensional diagram of PCA. The retained first three principal components are used as the input neurons of PNN. The output neurons are 5, which represents the five different tastes of abalone flavoring liquid. The constructed PNN is used to identify the abalone flavoring liquids. The correct identification rate of PNN is 92%.

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