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ORIGINAL CONTRIBUTION

An Exploration of Glassy Carbon and Carbon Paste Sensors for Voltammetric Electronic Tongue

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ABSTRACT

In this work, two different forms of carbonaceous electrode have been studied as sensors in a voltammetric electronic tongue. Glassy carbon and carbon paste electrode are considered for floral classification of honey samples. Cyclic voltammetry is applied to study the response of both the electrodes. Multivariate data analysis: PCA is used to evaluate the transient response. Response from carbon paste electrode in combination with PCA shows 97.14% variance with separability index of 15.78 as compared to glassy carbon electrode with 93.99% variance and 11.85 separability index. The carbon paste electrodes are inexpensive, easy to prepare and shows better electrochemical reactivity in floral identification.

Keywords- Honey, Electronic tongue, Glassy carbon electrode, Carbon paste electrode.

1. INTRODUCTION

Development of promising sensor instrument has always been of prime importance for complex liquid analysis. Different types of chemical sensors can be used in the sensor arrays operative in the electronic tongue. Depending on various sensing principles, sensors are employed in electronic tongues [1]. Thus response of electronic tongue to classifying quality of one or another kind depends upon its principle and sensing material.

A voltammetric electronic tongue often uses an array of metal electrodes based on gold, iridium, platinum, rhodium, palladium as working electrode in standard three-electrode configuration. Voltammetric sensors can be chemically modified with different sensitivity by chemical modification [2]. Carbon paste electrodes have been used as a substitute for noble metals, depending upon the support electrolyte and can be used at both positive and negative potential range [3]. Moreover, modification of carbonaceous is easy to prepare, inexpensive and easy to handle [8-9]. The carbonaceous materials are pervasive in multicomponent electrochemical analysis due to its easy availability and wide potential range [10-14]. They are available in wide forms depending upon its composition and are used as working electrode in cyclic voltammetry studies. Among all glassy carbon and carbon paste are widely held of all other forms of carbon electrode material.

Over the past few years, several attempts have been made to study the classification of honey based on botanical origin by electronic tongue using different electrodes [4-8].

In this work, we investigate glassy carbon electrode and carbon paste electrode in floral discrimination of honey based on cyclic voltammetry. Using the transient response

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obtained by cyclic voltammetry as input information, principal component analysis (PCA) is performed as exploratory method for discrimination of four different floral types of honey samples [20].

2. EXPERIMENTATION

2.1. Materials

Graphite powder (99%) is obtained from Lobachemie. Paraffin oil is purchased from Merck. All chemicals are of analytical grade and used without additional purification. Double distilled water is used in the experiments. Glassy carbon electrode is purchased from Edaq.

2.2. Electrode preparation

The carbon paste electrode is prepared by thoroughly hand mixing 1mg of graphite powder with 0.2 ml of paraffin oil as a binder in a mortar and pestle. It is mixed well for about 20 min until a uniformly wetted paste is obtained. The carbon paste is packed into the hole of the electrode body of glass tube with a spatula. Electrical contact is made with a copper wire. The surface of both carbon paste electrode is smoothed and rinsed carefully with double-distilled water prior to each measurement.

2.3. Sample collection and preparation

A total of 40 samples are investigated in this work. All samples which are shown in Table 1 are collected from local apiary in the Bankura district of West Bengal, India. These samples are divided into four groups of floral type: 10 Eucalyptus, 10 Leechi, 10 Kholisa and 10 Til samples.

Table 1: Samples collected for experiment

Floral origin	**Geographical origin**	**Season of Collection**	**No. of samples**
Eucalyptus	Joypur jungle	Dec-Jan	20
Litchi	Malda	Oct-Nov	20
Til	Simlapal		20
Kholisa	Simlapal		20

Each 20gm of sample is placed in hot water bath until dry. The sample is cooled in a 25°C for approximately 15min. Voltammetric measurements of honey samples are implemented after each test sample of 20% (dry matter basis) is dissolved in 100ml de-ionized water and mechanically stirred for 0.5 min [7].

2.4. Electronic Tongue Measurements

The voltammetric technique involves a standard three electrode setup [16-17]. Electrochemical experiment is performed in a potentiostat commercially available electronic tongue (Gamry Instruments Inc.).The working electrode is glassy carbon and carbon paste electrode considered sequentially, the reference electrode is Ag/AgCl (saturated KCl, Gamry Instruments Inc.) and the counter electrode is of platinum [18-19].

For glassy carbon, cyclic voltammograms is registered from -0.4 up to 0.7 V at a scan rate of 0.2V/s and for carbon paste electrode voltammograms is registered from -0.45 up to 0.7 V at a scan rate of 0.3V/s. All the experiments were done at room temperature (25 ± 1°C).

3. RESULTs AND DISCUSSION

Data analysis is performed on 40 samples using PCA for both the electrodes. The number of data points generated from glassy carbon electrodes is 720 and 383 data points for carbon paste electrode. The data set for 40 honey samples forms a data matrix of 40X 720 for glassy carbon and 40X 383 for carbon paste electrode. All the data analysis has been performed using Matlab version 7.13 (Mathworks). Figure.1 and Figure.2 shows the cyclic voltammograms using glassy carbon and carbon paste electrode respectively.

Figure.3-4. displays PCA plot of 40 honey samples for glassy carbon and carbon paste electrode. As shown in Fig.3. PC1 & PC2 explains 93.99 % variance for glassy carbon electrode & 97.14 % variance for CPE electrode. The PCA plot of carbon paste electrode indicates 4 distinct clusters with respect to floral type. The class separability index for glassy carbon is 11.85 whereas for unmodified carbon paste electrode is 15.78. Thus improvement shows carbon paste electrode respond better for floral classification.

As for the electronic tongue with each electrode, the current values corresponding to 10 voltage values in the voltammograms are chosen as the features in radar plot in Figure.5 for glassy carbon and carbon paste electrode. Radar plots are used to observe whether pattern difference is developed between two different electrodes applied to honey samples.

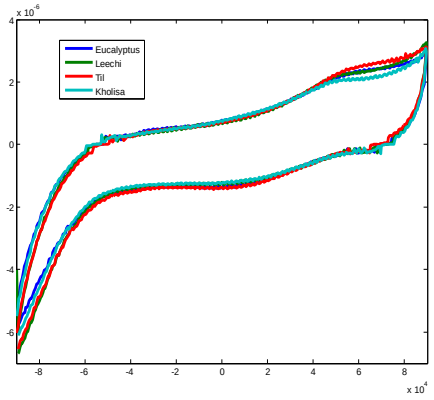

FIGURE.1. CYCLIC VOLTAMMOGRAM OF FOUR DIFFERENT FLORAL TYPE OF HONEY USING GLASSY CARBON ELECTRODE

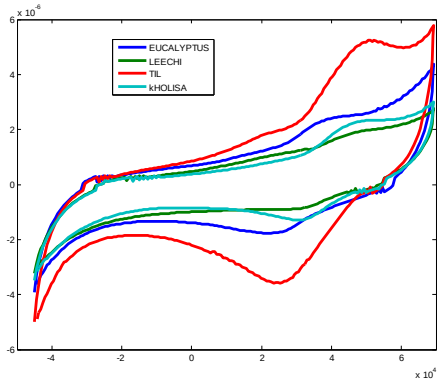

Figure.2. Cyclic voltammogram of four different floral type of honey using carbon paste electrode.

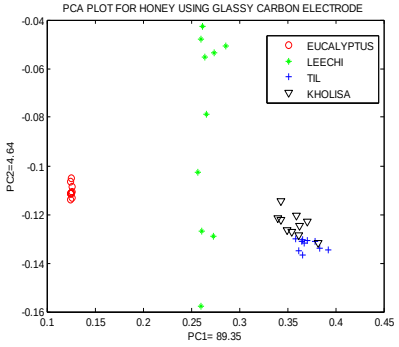

Figure.3. Two-dimensional plot of the first two principal components scores of honey samples using glassy carbon electrode

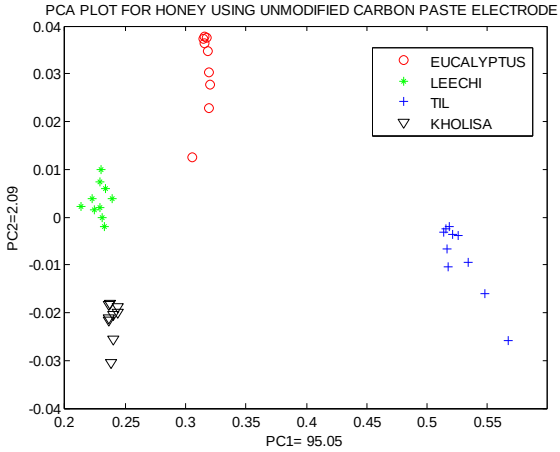

Figure.4. Two-dimensional plot of the first two principal components scores of honey samples using carbon paste electrode

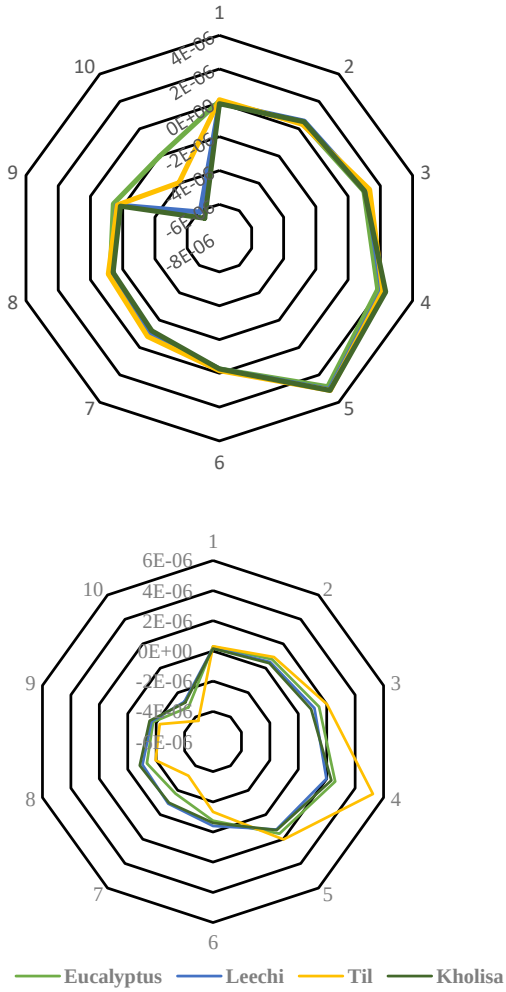

Figure.5. Radar graph of Electronic Tongue for glassy carbon electrode and carbon paste electrode.

4. CONCLUSION

Voltammograms obtained when CPE electrodes are immersed in different floral type of honey shows redox peaks for individual sample. The complex components present in the electrolytic solution have substantial influence on the peak positions. It is due to diffusion of various analyte on the surface of carbon paste electrode that occur during oxidation and reduction.

Two different carbon based electrode are studied for floral identification. Experimental results of PCA reveals carbon paste electrode have better clustering capability as compared to glassy carbon electrode for floral classification of honey.

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