Analytica Chimica Acta 919 (2016) 11–19

Contents lists available at ScienceDirect

Analytica Chimica Acta

journal homepage: www.elsevier.com/locate/aca

# Visualized attribute analysis approach for characterization and quantification of rice taste flavor using electronic tongue

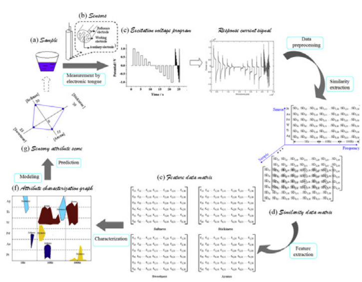
Lin Lu [a], Xianqiao Hu [a], Shiyi Tian [b], Shaoping Deng [b], Zhiwei Zhu [a, *]

[a] *Rice Product Quality Supervision and Inspection Center, Ministry of Agriculture, China National Rice Research Institute, Hangzhou 310006, China*
[b] *College of Food Science and Biotechnology, Zhejiang Gongshang University, Hangzhou 310035, China*

## HIGHLIGHTS

- Multifrequency large-amplitude pulse voltammetric electronic tongue was used.
- A visualized attributive analysis approach was created as an efficient tool for data processing.
- Rice taste flavor attribute was determined and predicted.
- The attribute characterization graph was represented for visualization of the interactive response.

## GRAPHICAL ABSTRACT



## ARTICLE INFO

*Article history:*
Received 30 October 2015
Received in revised form
8 March 2016
Accepted 10 March 2016
Available online 23 March 2016

*Keywords:*
Voltammetric electronic tongue
Attributive analysis
Data preprocessing
Modeling

## ABSTRACT

This paper deals with a novel visualized attributive analysis approach for characterization and quantification of rice taste flavor attributes (softness, stickiness, sweetness and aroma) employing a multifrequency large-amplitude pulse voltammetric electronic tongue. Data preprocessing methods including Principal Component Analysis (PCA) and Fast Fourier Transform (FFT) were provided. An attribute characterization graph was represented for visualization of the interactive response in which each attribute responded by specific electrodes and frequencies. The model was trained using signal data from electronic tongue and attribute scores from artificial evaluation. The correlation coefficients for all attributes were over 0.9, resulting in good predictive ability of attributive analysis model preprocessed by FFT. This approach extracted more effective information about linear relationship between electronic tongue and taste flavor attribute. Results indicated that this approach can accurately quantify taste flavor attributes, and can be an efficient tool for data processing in a voltammetric electronic tongue system.


## 1. Introduction

Electronic tongue recently plays an indispensable role in rapidly determination for chemical substances and sensory properties. It devotes to collect response signal of the liquid, and extract useful data to relate with analytical properties through appropriate multivariate analysis methods such as pattern recognition and models, in virtue of sensitive and selective sensors [1]. For instance, the electronic tongue has been applied for identification and quantitative analysis of tea [2,3], water [4,5], wine [6,7], fish [8] and meat [9]. Electronic tongues based on various electrochemical techniques such as potentiometry [10,11], voltammetry [12,13], impedance spectroscopy [14,15] have been developed. Electronic tongue based on voltammetry has been used widely in food safety and quality control because of its sensitivity and simplicity. Multifrequency large-amplitude pulse voltammetric electronic tongue

* Corresponding author.
*E-mail address:* 615834652@qq.com (Z. Zhu).

http://dx.doi.org/10.1016/j.aca.2016.03.019

[16,17] has been developed and applied in many studies.

An array of sensors is the key part of electronic tongue, which determines the stability and accuracy of data acquisition. However, generally sensors from voltammetric electronic tongue have the existence of interference [18]. Each electrode usually provides a drifting signal that is falsely proportional to the set of species in the system. An appropriate electrochemical procedure and data preprocessing can eliminate the drift of signal. The signals from multifrequency large-amplitude pulse voltammetric electronic tongue can be obtained by the determination of sensor that consists of non-specific metallic electrodes in several frequency segments, resulting to the performance of interactive response. It has been reported that some models or tools such as PLS-Discriminant Analysis (PLS-DA), Linear Discriminant Analysis (LDA), Support Vector Machine (SVM) and Artificial Neural Networks (ANNs) [19] were universally implemented to analyze the data of electronic tongue for discrimination and quantification. However, the mentioned models or tools cannot elaborate the interactive response namely that of certain electrodes and frequencies respond to one ingredient or attribute. Hence, an appropriate approach for clearly characterizing the interactive response should be demanded.

Rice (Oryza sativa L.) consumed by over half of the world's population has been analyzed by electronic tongue in previous studies. The detecting sensor consists of electrodes made of lipid membranes was applied to evaluate physicochemical and sensory properties of brown rice and milled rice [20]. It has been shown that the correlation between sensor response and sensory property was determined using the system with specific sensor combinations one by one. It would be time-consuming for the quantification of sensory property, and not suitable for non-specific sensor in voltammetric electronic tongue. The similarity analysis combined with ANN has been developed for an electronic tongue system to predict rice sensory quality [21], however, the interactive response during sensors cannot be figured out. Based on the above work, rice taste flavor attributes can be regarded as the valid objects for new analysis approach, which must simultaneously do the interactive response characterization and the highly accurate quantification.

In this study, a new visualized attribute analysis approach was developed for multifrequency large-amplitude pulse voltammetric electronic tongue to predict the softness, stickiness, sweetness and aroma attribute of rice taste flavor. The feature data matrix after preprocessing was extracted, and characterized in an attribute characterization graph for visualizing the interactive response. Then the modeling and prediction was conducted, and attribute scores obtained from the model were compared with those from artificial evaluations.

## 2. Materials and methods

### 2.1. Samples and treatment

Two hundred and seventy indica rice samples harvested from three provinces (Guangdong, Jiangsu, Zhejiang) of China in 2013 were used in this study. Besides, one control rice sample collected in Guangdong was used.

All paddy samples were stored in the environment of 20% relative humidity. Samples were dehulled using a Satake Testing Husker (Model THU35B, Satake Engineering Co., Ltd, Japan) and milled with a McGill Mill. Two hundred grams of milled rice were soaked with 1.6 volumes of water for 30 min, steamed for 20 min, after that, cooled for 40 min at room temperature.

### 2.2. Electronic tongue

A multifrequency large-amplitude pulse voltammetric electronic tongue used in this experiment was composed of a sensor, a multifrequency large-amplitude pulse scanner (MLAPS) and a computer. The sensor of the electronic tongue was a standard three-electrode system including six different metallic electrodes (platinum-Pt, gold-Au, palladium-Pd, wolfram-W, titanium-Ti and silver-Ag; diameter 2 mm) working electrodes, an Ag/AgCl electrode as the reference electrode and a platinum electrode as the auxiliary electrode, as shown in Fig. 1b. The MLAPS [17] connected to the sensors was controlled by the computer. The computer was applied to display the potential pulses and to record the response currents.

### 2.3. Measurement procedure

Each cooked rice sample (2.0 g) was dried at 105 °C for 30 min, and ground into powder. Then the powder was soaked in 50 mL chemical saliva for 15 min, and filtered. The filtrate was used for subsequent measurements.

Before testing, the sensor of electronic tongue was stabilized in 0.01 mol $L^{-1}$ KCl by pulse voltammetry for few minutes. The potential waveforms of three frequency segments −1 Hz, 10 Hz and 100 Hz (the corresponding step lengths were 1 s, 0.1 s and 0.01 s, respectively) were displayed. In excitation voltage program, the scan was conducted from 1 V to −1 V with a potential step of 0.2 V for each frequency segment. Before starting the next segment, a step of 0 V was carried on for 5 s. A response current signal (Fig. 1c) was measured between the working electrode and the auxiliary electrode when a voltage was applied over the working electrode and the reference electrode. There were ten pulse intervals for one sensor for each frequency segment in excitation voltage program, that is, the response current signal for one sensor for each frequency segment had ten signal cycles. The response signals were used for subsequent analysis.

After each sample measurement, the sensor was electrochemically washed, that is, all electrodes were soaked in deionized water for 30 s, and then washed by a potential scanning.

### 2.4. Artificial evaluation of rice taste flavor

Artificial evaluations of rice taste flavor were carried out after cooked rice prepared. The cooked rice sample (10 g each) was placed on a ceramic bowl and presented to panelists. A group consisted of ten skilled panelists from 25 to 50 years old. Four rice taste flavor attributes including softness, stickiness, sweetness and aroma needed to be evaluated in this stage. The definition for each attribute is showed as followed: the 'softness' means the force used to bite through rice; the 'stickiness' means the degree of adhesion of rice; the 'sweetness' means the sweet-flavor sensed when chewed; the 'aroma' means the good odor intensity of rice. There were different score scales for four taste flavor attributes. The score ranges of softness, stickiness, sweetness and aroma were from 10 points (hard) to 30 points (soft), 10 points (weak) to 30 points (strong), 10 points (weak) to 25 points (strong), 5 points (weak) to 15 points (strong), respectively. Each attribute of each sample was scored in the corresponding score range, in comparison with the reference sample which was the control sample mentioned in Section 2.1. In this work, the reference sample which is regarded as possessing stable sensory properties has 20, 20, 17 and 10 points for softness, stickiness, sweetness and aroma, respectively.

Each taste flavor attribute score (AS) of each sample was calculated as the average score of valid attribute evaluations in which score deviations from the average were less than 10 points.