



Original Research Article (Experimental)

## Challenges in using electronic tongue to study *rasa* of plants: I. Finding the right tool for the right job



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## ABSTRACT

There is growing interest in understanding how ayurveda, the indigenous medical system of India, uses plants for therapeutic purpose. The aim of this two parts article is to explore how the analytical technique of Electronic tongue (E-tongue) can be used for studying *rasa*, one of the major ayurvedic parameter in the study of medicinal and nutritional plants. Although E-tongue is widely used in pharmaceutical, food and beverage industries for objective evaluation of taste, its use in plants from an ayurvedic perspective is novel. This first of the two parts article introduces the technique of E-tongue, positioning it in context for the following part. The latter discusses crucial control experiments required prior using E-tongue for studies on medicinal plants from an ayurvedic standpoint.

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## 1. Introduction

Ayurveda, the indigenous medical system of India, is perhaps the longest unbroken health tradition in the world with textual and theoretical backing for its clinical practices [1–3]. Although the importance of scientific validation of ayurveda is raised time and again, this concept is not entirely unknown to ayurveda [4]. But times have changed and there is a definite need to contextualise the understanding of the ayurvedic concepts without losing its core principles, strength and relevance. Ayurveda should take advantage of the many analytical tools modern science has brought in its wake and use them to understand and contemporise its knowledge base. There is much value in ayurveda that can be strengthened by modern analytical tools to place it on a strong scientific footing, the need of the hour. One such area is *Dravyaguna Vijñān*, considered the counterpart of modern pharmacology but infact dealing with properties and actions of substances, including drugs, medicinal and nutritional plants.

Ayurveda, with its long history of using plants, has well-defined parameters to understand and explain the therapeutic and nutritional attributes of plants [5–7]. The concept of *rasa*, generally

taken to represent taste as a sensory perception, plays an important role in ayurvedic pharmacology and dietetics. For example, Ayurveda has categorised all physical substances including plants under six *rasas*: *madhura* (sweet), *amlā* (sour), *lavana* (salty), *katu* (hot), *tikta* (bitter) and *kashāyā* (astringent). Each plant part can have one or a combination of *rasas* [5,6].

There are many fundamental questions in *Dravyaguna Vijñān* that offer scope for in-depth research. For example - (i) is *rasa* a chemical sensory perception (taste) only or a concept beyond? (ii) can *rasa* be measured objectively? (iii) if yes, can this be an ayurveda relevant quality assessment and standardisation parameter for medicinal plants? (iv) can a methodology to fingerprint the *rasa* based classification of medicinal plants be devised?. Answers to questions like these will be of fundamental importance to ayurvedic fraternity since it will facilitate validation and therapeutic use of medicinal plants (known and unknown) based on ayurvedic definitions and parameters. There are no studies till date in world literature addressing these fundamental issues.

Bulk of the current research on medicinal plants used in ayurveda focuses on chemical and pharmacological analyses to identify and isolate the active principles. Such studies have their own relevance and importance in the context of modern pharmacology and medicine. However, it is pertinent to note that ayurveda uses plant parts in their native form making studies on single isolated molecules redundant from its stance. At the same time, parameters such

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as *rasa* are used till date by ayurvedic physicians to understand the medicinal attributes of plants and decide their therapeutic usage.

Electronic tongue (E-tongue) is an analytical instrument for studying and fingerprinting the organoleptic property of taste objectively. Although E-tongue is conventionally used in pharmaceutical, and food and beverage industries [8–11], this two parts article explores for the first time, the possibility of addressing the ayurvedic concept of *rasa* using E-tongue. Essential preliminary and standardisation studies with the intent of using E-tongue to study plants from an ayurvedic perspective are presented in these articles.

This first part introduces the technique of E-tongue. The following part outlines the experimental challenges to be taken cognisance of in the unconventional use of E-tongue to study plants from the ayurvedic perspective. This study will be an extremely important first step towards the scientific understanding of the ayurvedic concept of *rasa* in terms of contemporary scientific terminologies and the experimental possibility of *rasa*-based ayurvedic classification and understanding of plants.

## 2. Measurement of taste

Of the five human senses (sight, sound, smell, taste, and touch), only smell and taste are chemical (and also sensory) in nature. Perception of taste however depends not only on the chemicals present but also their interaction with different taste receptors in the tongue and the transduction of the sensory signals to brain. The molecules in the sample interact with the taste receptors, from where responses are sent to brain, which in turn processes the signals using pattern recognition leading to the final sensory perception. In a nutshell, the gustatory system receives, transduces, integrates and processes the taste stimuli/information [12].

In human tongue, each taste bud has a number of taste receptors, each one of them sensing multiple chemical substances simultaneously. These receptors are known as semi-selective and cross-reactive. In an effort to mimic the gustatory system, cross-reactive sensors have been developed. Conventional sensors such as H<sup>+</sup> ion-selective (pH) electrode are analyte (H<sup>+</sup> ion) specific whereas the cross-reactive or differential sensors allow each sensor to be receptive to a number of analytes. The molecules in the sample interact with the sensors producing electric potentials akin to the physiological action potentials produced by interaction of the tastants with taste buds. Mimicking the response of human taste receptors, each of the sensors detect the same analytes but differently. All the sensor responses are integrated and interpreted by a pattern recognition algorithm.

## 3. Electronic tongue

E-tongue is used for objective evaluation of taste using electrochemical sensors, which operate by reacting with the chemicals in the sample solution and producing an electrical signal. The instrument uses an array of non-specific sensors with cross-sensitivity towards different compounds in a solution and a multivariate analysis based method of pattern recognition. The array of sensors in E-tongue thus obtain information not from an individual compound but from all compounds involved in a particular taste, in other words the overall information of taste in the sample.

## 4. Basic principles

Fig. 1 shows the E-tongue instrument used in this study. The equipment consists of three main components: autosampler,

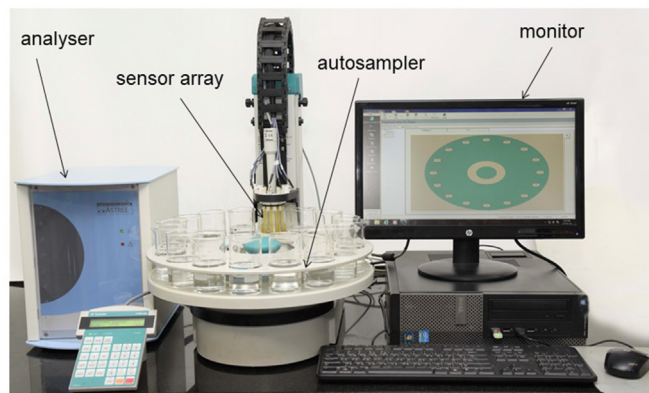


Fig. 1. Astree Electronic tongue showing the autosampler, sensor array and analyser/data processing unit, the three major components in the instrument.

sensor array, and analyser/data processing unit. The autosampler holds the beakers with samples and has a movable arm (Fig. 2). The sensors and the reference electrode are attached to the movable arm which also has a stirrer (Fig. 3). Programmable sequence is used for running the experiments. The signals from the sensors immersed in the sample are sent to the analyser and evaluated using chemometric software package.

There are seven sensors in the array (Fig. 3), each of which is a Chemical modified Field Effect Transistor (ChemFET) [9]. The sensors are coated with membranes permeable to specific molecules associated with different tastes and are in direct contact with the sample. Interaction of the sensors with dissolved compounds in a sample changes the charge density and ion distribution of the

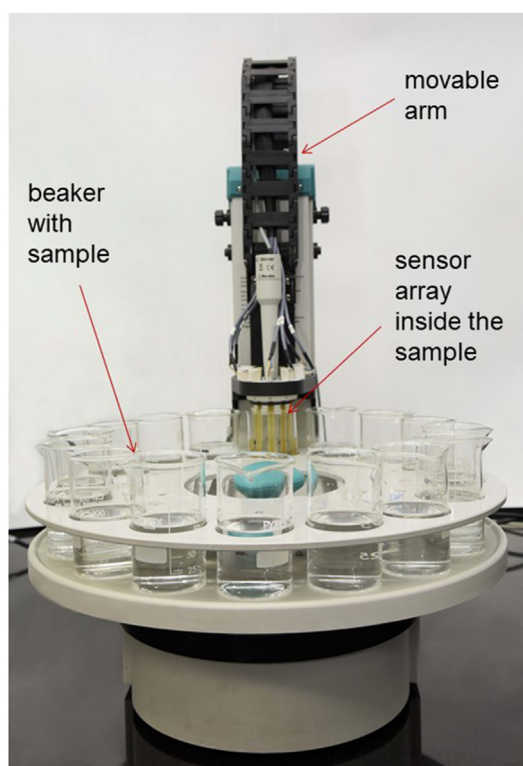
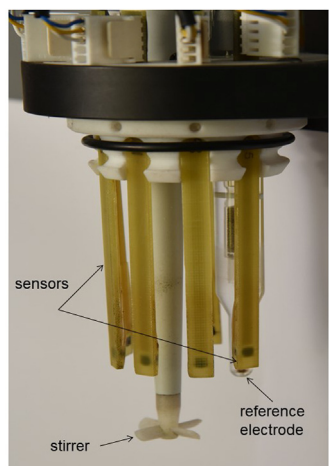


Fig. 2. The autosampler in the Astree Electronic tongue showing the sequentially positioned beakers with samples, the sensor array inside the sample and the movable arm.



**Fig. 3.** Zoomed image of the sensors, reference electrode and stirrer in the Astree Electronic tongue.

membrane surface. This creates an electric potential difference in the sensor, which is measured with respect to the reference electrode. The complex response of all the sensors in the form of electrical signals is then analysed using multivariate statistical analysis.

### 5. Correlation between E-Tongue and human taste panel

The technique of E-tongue was developed to mimic the human tongue in taste perception. A number of studies have therefore been reported in the literature correlating taste identification by E-tongue with human tongue [13–16]. Wang and Xiao in their work on white chrysanthemum [13] had used 10 well-trained taste panelists and found very strong positive correlation (95% predicted score with a correlation coefficient of 0.9768) between the sensory scores by trained panelists and E-tongue measurements. In addition, all the test samples were correctly classified according to the known taste groups by both methods. Liu et al. in their study on bitterness of berberine hydrochloride, had compared taste prediction by E-tongue with that by the taste panel, and reported an accurate prediction of the bitterness intensity by human tongue ( $R > 0.99$ ) [14]. Other studies comparing the response of E-tongue and the sensory panel in the prediction of bitterness and sweetness [15,16] have also demonstrated strong correlation between the two methods ( $R^2 > 0.96$ ) using Partial Least Squares regression (PLS).

### 6. Prediction specificity by E-Tongue

A number of studies have reported the accuracy of prediction by E-tongue by comparing the sensor data with that from classic chemometric techniques [17–19]. For example, Kirsanov et al. have used the predictive power of PLS models to predict the accuracy of electronic tongue data in acids, spicy and astringent tastes [17], and have concluded that E-tongue is a very promising tool for chemical and sensory characterisation. Rudnitskaya et al. have reported a high prediction accuracy of E-tongue when compared with conventional chemical analysis of the samples [18]. Fuzzy evaluation of E-tongue output have also been reported using cloud model by Liu et al. [19] to study the conformability and accuracy of the data derived from E-tongue.

## 7. Conclusion

Ayurveda is poised for high growth but appropriate technologies which can showcase its scientific rationale are required to support this growth. In times of yore, the ayurvedic *vaidyas* themselves collected the plant materials from natural habitat to prepare the drugs resulting in very minimal chance and use of unauthentic and adulterant raw materials. It is a much changed scenario now. Currently, the collection and distribution of medicinal plants are mainly carried out by unskilled labourers, drug dealers, profiteering traders, and others inexperienced and ignorant of medicinal plants. Furthermore, commercialisation and increase in demand for ayurvedic medicines have also brought into sharp focus the need for quality assessment and standardisation. Although conventional methods of identification of chemicals such as HPLC are currently used for quality and standardisation checks, they may not be the most appropriate techniques for the multi-ingredient and complex matrix that the ayurvedic formulations are.

A major difference between ayurvedic and allopathic medicines is their composition. Ayurvedic medicines have complex mixtures of natural products or extracts with multiple constituents whereas allopathic drugs have active ingredients, which are generally single molecules. The analysis of the latter is generally performed by separate techniques such as HPLC or GC/MS to isolate and identify active ingredients, which can then be easily quantified. But the same techniques are not suitable for very complex mixtures as used in ayurvedic medicines. It is hence imperative to take cognisance of the parameters conventionally used in ayurveda. Traditionally and even till date, ayurvedic physicians use *rasa*/taste of substances as an important parameter to understand the medicinal and therapeutic properties of plants and food items. Hence, there is an urgent need to comprehend the scientific rationale of these ayurvedic parameters and develop methodologies for their objective measurement.

An analytical method enabling study of taste in complex mixtures is E-tongue, a distinctive feature of which is mimicking the human sensory perception of taste. The electrical signals produced by the sensors are akin to the physiological signals produced by taste receptors in human tongue. E-tongue mimics the gustatory system by reacting differently to the various chemicals associated with taste thus reflecting the macroscopic sensory taste characteristics of the sample. The sensor responses are converted to a fingerprint of taste providing an objective scale for the human sensory perception.

The non-specificity of E-tongue sensors is a major advantage in study of complex matrix like plant extracts. The uniqueness of this technique is the recognition of taste at macroscopic sensory level and not in the microscopic identification of individual chemicals in the sample. This is important because in the perception of taste discrimination, minute differences in chemical structures may not be very critical. Chemical analysis will only provide information limited to the chemical composition of the sample and will not reflect perception of taste in totality.

Although perception of taste is partially subjective, tools such as E-tongue opens up the possibility of studying ayurvedic concepts such as *rasa* objectively. The concept of taste from an ayurvedic standpoint using E-tongue is novel. There are major challenges to overcome while trying to adapt E-tongue to study complex plant matrices. The following 2nd part article addresses some of the experimental challenges in such studies and draws attention to the need and importance of experimental factors to be taken care of. After rigorous validation and testing, E-tongue could offer a promising tool to study *rasa* of medicinal plants. It raises many interesting possibilities such as monitoring batch to batch consistency of medicines, identifying *rasa* of unknown plants,

adulteration check, gradation of taste for the same plant type but from different geographical regions and *rasa* based fingerprint of ayurveda plants, all from an ayurvedic perspective. Studies like these are likely to add new dimensions to ayurvedic pharmacology. The prospects are truly stimulating.

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#### Conflict of interest

None.

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