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A CASE STUDY

Electronic tongue and their applications in food industry

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ABSTRACT

Technology's impact on food safety and quality is reflected in higher throughputs, increased efficiencies and superior outcomes. Electronic tongue (e-tongue) instrumental systems were designed to minimize human olfactory and taste sensory organs and are consisted of an array of sensors. Various efforts have been made by scientists to predict the sensory profile of food articles with instrumental measurement. The aim of the review here is to determine the applicability of e-tongue in food industry to replace traditional methods of sensory analysis. Involvement of electronics methods for the improvement of sensory methods is due to increased attention of all world towards food safety.

KEY WORDS : E-tounge, Coffee, Beer, Fruit juice, Sensors

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INTRODUCTION

Now-a-days, food safety problems caused due to food contamination have received great attention due to harmful effects on the health (Xiaobo *et al.*, 2016 and Fussell *et al.*, 2014). For development of new food product, sensory parameters like taste, texture and appearance are preferred. Theses parameters are helpful to decide the acceptance of food for consumption in market. Taste is one of the most important sensory attribute for determination of its acceptability. The senses of taste have always been used in monitoring and judging the quality of foods. The use of human subjects to distinguish between different tastes is as old as the human civilization. Unfortunately, there are several problems associated with human panelists. Health risk is also associated with tasting of certain chemicals and tasting may be dependent on human mood and adaptability

Due to improper security measures for food safety the antibiotics residues in food creates a potential hazard for the consumer and may cause several consequences such as bacterial resistance and allergic side effects (Oliveira *et al.*, 2007; Zacco *et al.*, 2007 and Wang *et al.*, 2016). So there is need for development of simple, low-cost, sensitive and rapid methods for detection of residues and for monitoring of freshness in food. There are some electronics methods based on sensor technology to measure food safety e.g. e-nose, e-tounge etc. In the era of sensor technology, evolution of e-tongue has initiated renaissance in sensory assessment of foods. These are tools that have been introduced recently, inspired in the mode in which mammalians recognise food through the senses of olfaction and taste (Toko, 2000). These techniques are especially appealing when it is important to characterise complex attributes of the whole sample rather than to know the exact concentration of certain analytes.

An easy way to build up an e-tongue is through the use of a set of electrodes using potentiometric or voltammetric (Holmin *et al.*, 2001) electrochemical techniques. In fact, several electronic tongues based on electrochemical sensors have been developed (Gallardo *et al*., 2005). Among them, those relying in potentiometric measurements have been the most widely used employing for instance ion-selective electrodes (Mimendia *et al*., 2010). A suggestive alternative to avoid the employment of membrane-containing sensors is the use of simple metallic wires as suitable electrodes in electronic tongue devices (Lvova *et al*., 2006). Electronic tongues with metallic electrodes are very simple to prepare and easy to use. The response with this kind of electrodes in the potentiometric mode is based on the spontaneous polarisation of the metals and other elementsin the presence of certain chemical species (Soto *et al*.,2006). In relation to the latter, for instance, freshness in pork has been evaluated by means of simple solid electrodes (*i.e*. Pt, CuS and Ag_2S) able to detect certain compounds responsible for the initialstage of the process of putrefaction of meat (Kaneki *et al*., 2004).

Principle and structure :

The electronic tongue is an instrument that measures and compares tastes. There are several measurement principles that have the potential to be used in electronic tongues. A wide variety of chemical sensors can be employed into the designing of electronic tongues such as electrochemical (potentiometric, voltammetric, impedimetric), optical or enzymatic sensors (biosensors). Generally, electrochemical measurement systems are used for analytical purposes in a number of applications.

Fig. 1 shows the structural configuration of electronic tongue with a clear vision. Basically as we know parameters responsible for taste are detected by human taste receptors, and based on the same mechanism sensors of electronic instruments detect the same dissolved taste in terms of organic and inorganic compounds each. Each sensor uses specific information and the resultant information from all the sensors generate a particular data. This step is achieved by the e-tongue's statistical software which interprets the sensor data into taste patterns. The data is amplified for better results and can be recorded for further use. Results obtained by the e- tongue shows more accuracy as compare to the results obtained by sensory.

Applications of E-tongue in food technology:

Coffee industry :

Several efforts have been made by researchers to predict the sensory profile of coffee by instrumental measurement

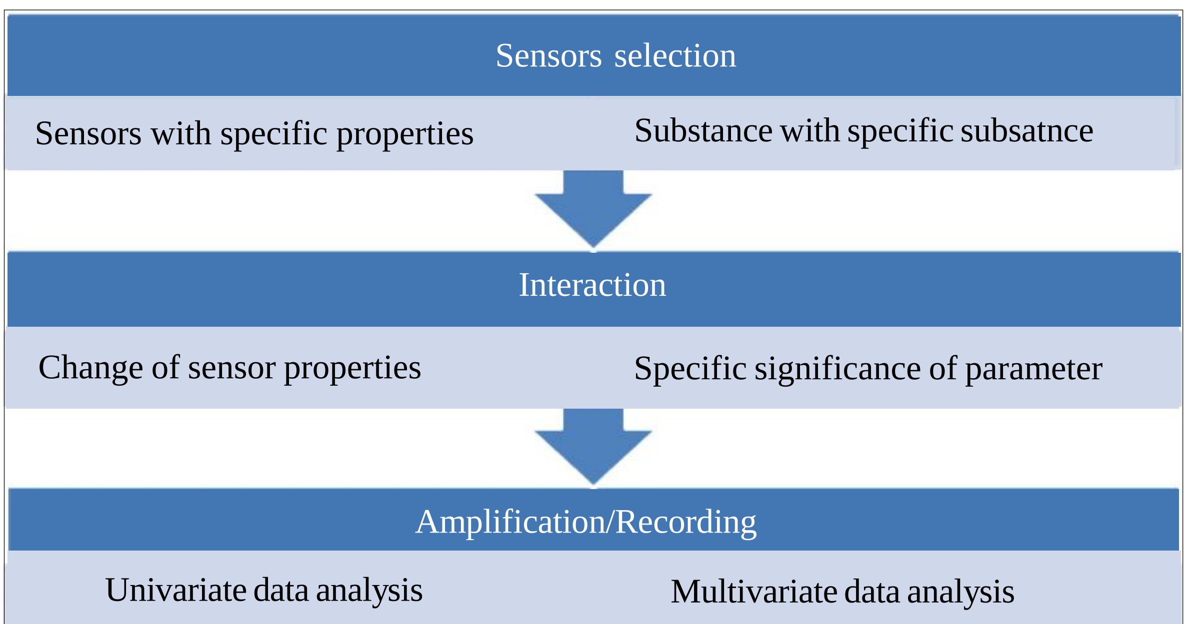

Fig. 1 : Block diagram show basic principle of electronic taste sending system

results. The electronic tongue distinguished the pure origin and the blended coffee samples. The aroma analysis did not find significant differences among the various coffee samples; primarily, the components formed during roasting were measured. Promising models were developed by the instrumental measurement results to predict definite sensory attributes (Varvolgyi *et al.*, 2014). Bitterness is a major parameter of coffee taste. When looking for the components extracted from coffee, responsible for the bitterness, the Alpha MOS ASTREE E-tongue is a convenient tool, as a sensory panel is not always suitable for the testing of components extracted for R and D purpose (Anonymous, 2017).

Dairy industry:

The main purpose of electronic tongues is quali- tative analysis and thus, several works on the appli- cation of electronic tongue devices in recognition, classification or identification of milk and fermented milk samples have been reported. In an experiment attempted to the goal of fermented milk samples' classification, a hybrid electronic tongue based on voltammetric, potentiometric and conductometric measurements was used. The hybrid tongue sepa- rated all six samples analysed, while the nature of micro-organisms in different fermentations reflected in the PCA. The measurement situation was enlightened from different positions and by combining information from different origins, an additional dimension of information was added showing the great importance of the system in many fields (Winquist *et al.*, 2000). Winquist *et al.* (2005) used a specially designed voltammetric electronic tongue inserted directly on-line in dairy industry process line. Electronic tongue signals combined with multivariate statistics represent rapid and efficient tools for classification, discrimination, recognition and identification of samples, as well as for the prediction of concentrations of different compounds. A wide variety of sensors can be employed into the design of these instrumental systems, especially that of electronic tongues, offering numerous practical applications (Tudorkalit *et al*., 2014).

Fruit juice industry:

Consumer preference for juice largely depends on flavor quality, therefore, ensuring consistent flavor quality is of vital importance to juice processors. In an earlier study, an electronic tongue system (e-tongue) has been used to differentiate between orange juice made from healthy fruit and from fruit affected by the citrus greening or Huanglongbing (HLB) disease. Raithore *et al.* (2015) investigated the reaction of an e-tongue system to the main chemicals in orange juice that impact flavour and health benefits and are also impacted by HLB. Orange juice was spiked with sucrose (0.2–5.0 g/100 ml), citric acid (0.1%–3.0% g/100 ml) and potassium chloride (0.1–3.0 g/100 ml) as well as the secondary metabolites nomilin (1–30 µg/ml), limonin (1–30 µg/ml), limonin glucoside (30–200 µg/ml), hesperidin (30–400 µg/ml) and hesperetin (30–400 µg/ml).

Meat industry:

Meat freshness is a rather complex concept, which includes different microbiological, physico-chemical and biochemical attributes and that is related with two different processes. One, desired,is known as aging that is determined by the period of storage that meat (especially beef meat) needs in order to reach the optimum state of consumption; whereas the other, also related with storage, deals with meat spoilage due to bacterial growth and autolysis traditionally, there have been two methods to evaluate meat freshness; one consists of a sensory test controlling organoleptic attributes with the help of experts and the other is the chemical or biochemical determination of the concentration of target bioindicators. The former is rapid but expensive, whereas for the latter a large number of reported studies try to relate freshness and the concentration or presence of certain species. The electronic tongue consists of a set of six electrodes made of Au, Ag, Cu, Pb, Zn and C, and a reference electrode. Through the use of various multivariate analysis techniques, such as: PCA and two types of artificial neural networks (*i.e.* multilayer perceptron (MLP) and fuzzy ARTMAP) it was found that it is possible to determine the time elapsed in relation to the degradation of the loin by using simple potentiometric measurements. Additionally, in the same pork sample used to measure redox potentials with the electronic tongue, the following parameters were also determined; pH, microbial count, concentrations of inosine 50-monophosphate(IMP), inosine (Ino) and hypoxanthine (Hx). Through the use of PLS analysis, it was found a rather good correlation between pH and the potentiometric data. Also a remarkable correlation was observed between the measures carried out with the electronic tongue and the so-called K-index that simultaneously measures the variation in the adenosine triphosphate (ATP) degradation products. These, results suggest that this simple, or a similar electronic tongue, could be useful for the undemanding qualitative or semi-quantitative evaluation of freshness in meat samples in a wide range of situations (Luis *et al.,* 2011).

Olive oil industry:

The organoleptic characterisation and the physico-chemical analysis of extra virgin olive oils (EVOOs) are crucial for their commercial classification in accordance with International olive oil council (IOOC) regulations. At the present time, the sensorial analysis carried out by a panel of trained tasters is the only homologated method for the organoleptic evaluation of virgin olive oils (Xiaobo and Povey, 2016; Fussell and Sharman, 2014 and Wang *et al*., 2016). But the cost price of the formation and training of a panel, the impossibility to evaluate large number of samples, the delay of results for several days and the certain degree of subjectivity have lead to the development of alternative electronic methods to assess the colour, the aroma and the taste of oils. The advantages of electronic systems in comparison with the human senses include higher objectivity and invariable response with time that contribute to the success of routine analysis.

Conclusion:

Although, human tasters and sensory assessment of food cannot be substituted by an instrument, many studies have shown that e- tongue poses as an excellent non-destructive method for the determination of both toxic and non-toxic food products. Their wide application can be found in the food industry, where they can be employed in the identification and classification of products, monitoring of the ripening process (in cheese industry) and determination of the optimal ripening time, monitoring of food spoilage, shelf-life determination of food as well as detection of adulteration of food. The main advantage of e-tongue is continuous monitoring of product quality from the field to different stages of processing along with being simple and convenient to use.

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