Review Article

ELECTRONIC TONGUE: A NEW TASTE SENSOR

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ABSTRACT

Taste has an important role in the development of oral pharmaceutical formulation. With respect to patient acceptability and compliance, taste is one of the prime factors determining the market penetration and commercial success of oral formulations, especially in pediatric medicine. Taste assessment is one important quality-control tool for evaluating taste-masked formulations. Hence, pharmaceutical industries invest time, money and resources into developing palatable and pleasant-tasting products. The primary method for the taste measurement of a drug substance or a formulation is by human sensory evaluation. However, this method is impractical for early stage drug development because they are expensive, time consuming and the taste of a drug candidate may not be important to the final product. Therefore, taste-sensing analytical devices, which can detect tastes, have been replacing the taste panelists. The taste sensors can be considered as a valuable tool in the evolution of bitterness intensity in function of time, which is essential in the selection of an optimal formulation. A recent development in the taste masking field is the introduction of electronic tongues, which mimic the human gustatory system. This technology has major potential in taste masking studies. The electronic tongue is a potential analytical tool to assess the masking effect of non-medicinal ingredients on the bitterness of pure medicinal compound. The electronic tongues having more numbers of applications and show great solutions to many biomedical problems. The electronic tongue is useful for a wide variety of industries ranging from environmental control to blood analysis. The present review describes different aspect of new analytical tool - electronic tongue.

Keywords: Electronic tongue, Taste, multichannel Taste sensors, Taste masking.

INTRODUCTION

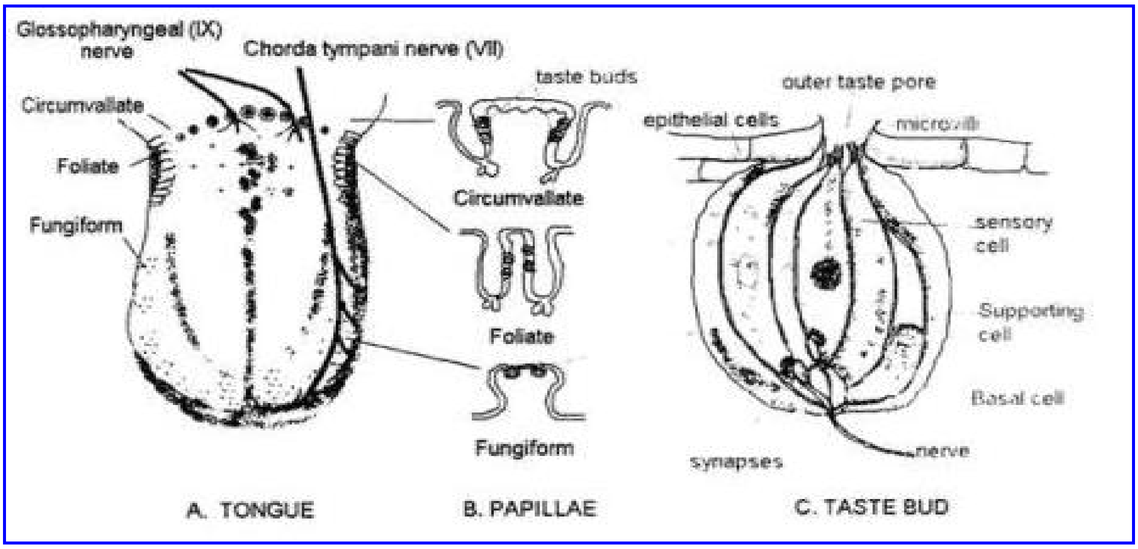
There is a lack of medicines suitable for children and several problems are related to paediatric formulations. Developing medicines for children is often more challenging, expensive and commercially less attractive than developing them for adults. Tablets, the most common dosage form for adults, are generally easy and cheap to manufacture while liquids, the most common paediatric dosage forms, are often problematic. The taste of compound can be perceived only when it is dissolved[1]. Several factors need to be considered when developing paediatric formulations. Adequate testing is confounded by the requirement that the formulation of the drug meets the unique needs of children. One such need is that the medicine be palatable[2, 3.] Active pharmaceutical ingredients may taste bitter and/or irritate the mouth and throat and thus are aversive not only to children but too many adults. Children generally have a stronger preference to sweet and greater rejection to bitter than adults[4.] Undesirable taste is one of several important formulation problems that are encountered with certain drugs[5]. The problem of bitter and obnoxious taste of is a challenge to the pharmacist in the present scenario. In mammals taste buds are located throughout the oral cavity, in the pharynx, the laryngeal epiglottis and at the entrance of the eosophagus. The tongue is like a kingdom divided into principalities by sensory talent. The sweet sensations are easily detected at the tip whereas bitterness is most readily detected at the back of the tongue. Sour sensation occurs at the side of the tongue. It is generally agreed that there are a small number of primary taste qualities that are detected by specialized receptors in the tongue and other parts of the oral cavity[6, 7]. Western civilization recognizes only four basic tastes: Sweet, Sour, Salty and Bitter. The Japanese add a fifth taste called Umami for monosodium glutamate. Taste papillae can be seen on the tongue as little red dots, or raised bumps, particularly at the front of the tongue. These ones are actually called "fungiform" papillae, because they look like little button mushrooms. There are three other kinds of papillae, foliate, circumvallate and the non-gustatory filiform. Taste buds, on the other hand, are collections of cells on these papillae and cannot be seen by the naked eye as shown in figure 1.

These taste buds contain very sensitive nerve endings, which produce and transmit electrical impulses via the seventh, ninth and tenth cranial nerves to those areas of the brain, which are devoted to the perception of taste[8].

Electronic Tongue (E- Tongue)

Taste has an important role in the development of oral pharmaceuticals, with respect to patient acceptability and compliance, and is one of the prime factors determining the market penetration and commercial success of oral formulations, especially in pediatric medicine. Hence, pharmaceutical industries invest time, money and resources into developing palatable and pleasant-tasting products and industries adopt various taste-masking techniques to develop an appropriate formulation. Taste assessment is one important quality-control parameter for evaluating taste-masked formulations. Any new molecular entity, drug or formulation can be assessed using in vitro or in vivo methods for taste. In vivo approaches include human taste panel studies, electrophysiological methods and animal preference studies. Several innovative in vitro drug release studies utilizing taste sensors, specially designed apparatus and drug release by modified pharmacopoeial methods have been reported in the literature for assessing the taste of drugs or drug products. The multichannel taste sensor, also known as the electronic tongue is claimed to determine taste in a similar manner to biological taste perception in humans. Furthermore, such taste sensors have a global selectivity that has the potential to classify an enormous range of chemicals into several groups on the basis of properties such as taste intensities and qualities.

Figure 1: Structure of tongue



How can the formulation scientist streamline the development paradigm for achieving palatability? A tool that has recently become available is the "electronic tongue"[9-14]. The electronic tongue, which was introduced in 1995[15] and which can be considered as a promising device in quantitative and qualitative analysis of multispecies solutions. An Electronic Tongue is an instrument which comprises of electrochemical cell, sensor array and appropriate pattern recognition system, capable of recognizing simple or complex soluble non-volatile molecules which forms a taste of a sample. The sensor array consists of broadly tuned (non-specific) potentiometric metal based electrodes that are treated with a variety of common anion of a salt in solution – chemical materials. The use of an electronic tongue to taste test active compounds has gathered interest and experimental support in recent years[16, 17, 18]. This area has been reviewed extensively[19,20]. The advantages of this approach include its speed, relatively low cost, and lack of risk[21].

A taste sensor with global selectivity is composed of several kinds of lipid/polymer membranes for transforming information of taste substances into an electric signal. The output of this electronic tongue shows different patterns for chemical substances which have different taste qualities, such as saltiness and sourness. The taste of foodstuffs such as beer, sake, coffee, mineral water, milk and vegetables can be discussed quantitatively using the electronic tongue, which provides the objective scale for the human sensory expression.

The electronic tongue provided valuable information about the evolution of bitterness intensity in function of time, which was essential for selecting of the optimal formulation among pellets having different coating thickness. Based on these data quinine sulphate taste-masked pellets are proposed in pediatrics as alternative to tablet breaking and can be used as flexible dosage form for dose adaptation to a child's body weight, provided that a simple system for accurate dosing is available[22] .Usually electronic tongues are composed of an array of chemical sensors and pattern recognition system[23]. During the last years electronic tongue systems have taken the advantage of different measuring principles including potentiommetry, voltammetry, amperometry.

Such devices have been mainly used in the field of food analysis: for classification of wine[24], beer[25], tea and herbal products[26], tomato samples[27], coffee[28], and milk[29]. An electronic tongue was also applied in the analysis of industrial samples (fermentation samples[30]) and in environment monitoring (water quality analysis [31], identification on toxic substances like heavy metals[32] and plant samples[33]). Evaluation of a taste sensor instrument (electronic tongue) for use in formulation development. The examples demonstrate the electronic tongue's utility in characterizing bitterness and taste masking of the bitterness[34-44].

EQUIPMENT

Two electronic tongue systems are commercially available: the taste sensing system SA402B (Insent Inc., Atsugi-chi, Japan) and the ASTREE e-tongue (Alpha M.O.S, Toulouse, France)[20]. Both measure changes in electronic potential while investigating liquid samples but the underlying sensor technologies are different. The taste sensing system SA402B is equipped with lipid membrane sensors[45-49] whereas the ASTREE uses chemical field effect transistor technology. In addition other taste sensing systems are under development as for example a Voltametric electronic tongue[20]. To date several studies have been performed using electronic tongues[36,50,51]. The electronic tongue made of following parts.

- **Working Electrode**

The working electrode is an innert material such as Gold, Platinum, Glassy Carbon, iridium and rhodium etc. In these cases, the working electrode serves as a surface on which the electrochemical takes place. It places where redox reaction occur. Surface area should very less (few mm2) to limit current flow

- **Reference Electrode**

An Ag/ AgCl reference electrode is used in measuring the working electrode potential. A reference electrode should have a constant electrochemical potential as long as no current flows through it.

- **Auxillary electrode**

A stainless steel counter electrode is a conductor that completes the cell circuit. It is generally inert conductor. The current flow into the solution via the working electrode leaves the solution via the counter electrode. It does not role in the redox reaction.

A relay box is used, enabling the working electrodes to be connected consecutively to form four standard three-electrode configurations. The potential pulses/steps are applied by a potentiostat which is controlled by a PC. The PC is used to set and control the pulses, measure and store current responses and to operate the relay box. The set-up[52] is illustrated in Figure 2.

WORKING

The electronic tongue initially developed by the University of Texas consists of a light source, a sensor array and a detector. The light source shines onto chemically adapted polymer beads arranged on a small silicon wafer, which is known as a sensor chip. These beads change colour on the basis of the presence and quantity of specific chemicals. The change in colour is captured by a digital camera and the resulting signal converted into data using a video capture board and a computer as shown in Figure 3. The technology can be applied to the measurement of a range of chemical compounds, from the simple, such as calcium carbonate in water, through to complex organic compounds, such as haemoglobin in blood and proteins in food. Moreover, it is helpful in discriminating mixtures of analytes, toxins and/or bacteria in medical, food/beverage and environmental solutions. Vusion, Inc. is developing a chemical analyzer and sensor cartridge, based upon the electronic tonguetechnology of University of Texas, that can instantly analyze complex chemical solutions. The analyzer consists of a customized housing into which the sensor cartridge can be placed and exposed to liquid chemicals within a process plant[53].

Figure 2: E- tongue equipment

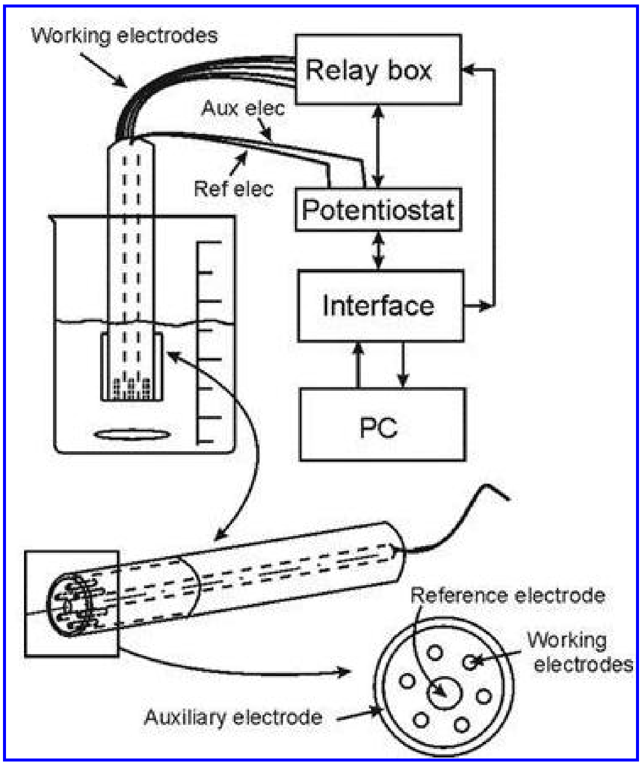
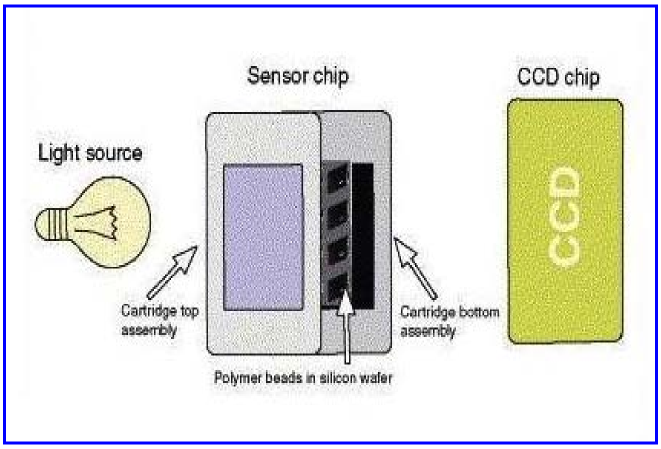


Figure 3: Working of e- tongue



APPLICATIONS

Electronic tongue have been used extensively to evaluate the taste-masking efficiency in solution formulation to compare the bitterness intensity of formulations and drug substances during pharmaceutical research and product development[36,17]. These sensors are safe, sensitive, reproducible, durable, fast and cost-effective, and require almost no sample preparation. The methodology is easy to speed up and optimize, and is well accepted and established for almost all dosage forms [54]. The taste sensor is of great value to both the food and pharmaceutical industries, in quality control and in assisting the automation of production[48]. When the taste of an oral medicine, other than a liquid medicine, is recognized by using such a taste sensor, the taste is measured by completely dissolving or suspending the oral medicine in water, which is impractical and undesirable.

1. Electronic Tongues have several applications in various industrial areas: the pharmaceutical industry, food and beverage sector, etc. It can be used to:
2. Analyze flavor ageing in beverages (for instance fruit juice, alcoholic or non alcoholic drinks, flavored milks...)
3. Quantify bitterness or “spicy level” of drinks or dissolved compounds (e.g. bitterness measurement and prediction of teas)
4. Quantify taste masking efficiency of formulations (tablets, syrups, powders, capsules, lozenges...)
5. Analyze medicines stability in terms of taste
6. Benchmark target products.

ARTIFICIAL TASTE

The electronic tongue uses taste sensors to receive information from chemicals on the tongue and send it to a pattern recognition system. The result is the detection of the tastes that compose the human palate. The type of taste that is generated is divided into five categories sourness, saltiness, bitterness, sweetness, and umami (deliciousness). Sourness, which includes hydrochloric acid, acetic acid and citric acid is created by hydrogen ions. Saltiness is registered as sodium chloride, sweetness by sugars, bitterness, which includes chemicals such as quinine and caffeine, is detected through magnesium chloride, and umami by monosodium glumate from seaweed, disodium in meat/fish/mushrooms.

CONCLUSION

The electronic tongue has a new concept of global selectivity. What is important in recognition of taste is not discrimination of minute differences in molecular structures, but to transform molecular information contained in interactions with biological membranes into several kinds of groups, i.e., taste intensities and qualities. This is high-level function, where intelligent sensing is required. In this meaning, the taste sensor is essentially an intelligent sensor to reproduce the taste sense, which is a complex, comprehensive sense of humans. The electronic tongue can differentiate between tastes, but in a very few cases it ranked masking agents in a different order than that determined by human volunteers.

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