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AI-Enabled Taste Sensing: Electronic Tongue Technologies for Food, Pharmaceutical, and Biomedical Applications

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Abstract

The electronic tongue (e-tongue) is an analytical instrument that uses an array of chemical sensors with broad, overlapping (partially selective) responses and multivariate pattern-recognition algorithms to classify and quantify the taste-related properties of liquid samples. From its first conceptual formulations in the 1990s, when simple lipid/polymer membranes, metallic electrodes, and voltametric cells dominated the scene, the e-tongue has seen its analytical toolbox diversified and its practical applications extended to beverage and pharmaceutical industries. However, with the recent availability of machine learning and deep learning algorithms, the e-tongue has entered a new stage of development where the analytical power is distributed not only in the sensor part but also in the computational layer. This chapter aims to provide a critical review of artificial intelligence (AI)-assisted taste sensing and its applications in the food, pharmaceutical, and biomedical fields.

The chapter first introduces the principles of taste perception, based on which the e-tongue was originally designed, and discusses the concept of global selectivity, sensor arrays, and multivariate calibration/models. A thematic literature review follows, highlighting trends in both sensor and data-analysis technologies, and the main section compares different transduction principles

(potentiometric, voltametric, impedimetric, optical, piezoelectric, bioelectronic), data-analysis pipelines from pre-processing to interpretability, and applications from beverage tasting to biomedical screening. The key message is that the e-tongue is better seen as a substitute for human panels on a given chemical space and with a given set of samples. The limitations and challenges include sensor drift, the lack of portability, insufficient datasets for AI training, and limited validation and standardization. The final section outlines the future directions for e-tongue research.

Keywords: electronic tongue; taste sensor; lipid/polymer membrane; chemometrics; machine learning; taste masking; food authentication; biomedical sensing

1. Introduction

1.1 Background

Taste is one of the oldest senses that evolved in nature to allow an organism to assess the caloric content and toxicity of food. It also plays a role in determining dietary preferences in humans and can even affect the ingestion of drugs (Chandrashekar et al., 2006; Yarmolinsky et al., 2009; Figure 1). The five basic taste qualities recognized in humans – sweet, sour, salty, bitter, umami – originate from the taste buds on the tongue surface via specialized receptors that respond to chemically diverse tastants (Chandrashekar et al., 2006; Yarmolinsky et al., 2009). In addition to the taste quality, other aspects of flavor arise from the texture, temperature, vision, and smell of food (Spence, 2015). For most of the history of science, the only way to characterize the taste of a substance was to submit it to human or animal tastee, and the latter is far from being an optimal method – it is expensive, tedious, and unreliable, especially for highly toxic or unpleasant tasting compounds such as many pharmaceuticals (Spence, 2015; Kobayashi et al., 2010). These limitations created the need for objective, reproducible, and convenient analytical methods for taste characterization that are fit