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Analytical Methods

Application of a voltammetric electronic tongue and near infrared spectroscopy for a rapid umami taste assessment

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ABSTRACT

The relationships between sensory attribute and analytical measurements, performed by electronic tongue (ET) and near-infrared spectroscopy (NIRS), were investigated in order to develop a rapid method for the assessment of umami taste. Commercially available umami products and some aminoacids were submitted to sensory analysis. Results were analysed in comparison with the outcomes of analytical measurements. Multivariate exploratory analysis was performed by principal component analysis (PCA). Calibration models for prediction of the umami taste on the basis of ET and NIR signals were obtained using partial least squares (PLS) regression. Different approaches for merging data from the two different analytical instruments were considered. Both of the techniques demonstrated to provide information related with umami taste. In particular, ET signals showed the higher correlation with umami attribute. Data fusion was found to be slightly beneficial – not so significantly as to justify the coupled use of the two analytical techniques.

1. Introduction

Evaluation of taste attributes of food products as well as quality assessment are important for both marketing purposes and consumer interest. In fact, sensory characteristics of food are not only the main factor involved in determining the consumer choices but they are also recognised as able to influence food digestion and absorption and to have effects on health and well-being (Clark, 1998).

All of the five human senses are involved in determining food acceptance, but taste and flavour play a major role, a reason for which food manufacturers usually invest many resources in optimising such features.

As for taste, four primary types are traditionally recognised, i.e. sweet, sour, salty and bitter. More recently, umami (Ikeda, 1908) has been proposed as the fifth basic taste, described as savouriness or capability of enhancing flavours (Yamaguchi & Ninomiya, 2000). It contributes to increase the palatability of food and to make it acceptable and appetising, enhancing the pleasant salty sensation. Umami taste is typically imparted by monosodium glutamate (MSG) and 5′-ribonucleotides, such as inosine 5′-monophosphate disodium salt (IMP) and guanosine 5′-monophosphate disodium salt (GMP) (Kuninaka, 1964) and their synthetic derivatives (Beksan et al., 2003; Cairoli et al., 2008). Glutamate and nucleotides are naturally present in many foods, such as meat, fish, cheese, mushrooms and a number of vegetables, in which they enhance taste and palatability. Over the years, the occurrence of other compounds able to elicit umami taste sensations has been reported. In particular, many peptidic compounds, the so-called umami peptides, have been isolated and characterised from various savoury food products, such as cheese (Gómez-Ruiz, Taborda, Amigo, Ramos, & Molina, 2007), soy sauce (Lioe, Takara, & Yasuda, 2006) and other products from Asian gastronomy. Numerous peptides generated by enzymatic hydrolysis from either vegetable (EVP) or animal proteins (EAP) (Aaslyng et al., 1998; Bagnasco et al., 2013; Fujimaki, Arai, Yamashita, Kato, & Noguchi, 1973; Maehashi, Matsuzaki, Yamamoto, & Udaka, 1999) have been studied for their role to elicit an intense umami or savory taste.

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Sensory panels represent the traditional way to perform taste assessments. This makes evaluations time-consuming, fragmentary, and expensive. Thus, the possibility of obtaining a rapid and low-cost instrumental assessment of tastes has become, in the last decade, an important analytical issue. In particular, assessment of umami taste is of interest for evaluation of flavour enhancer formulations.

In the present work, two rapid analytical techniques, namely the electronic tongue (ET) and near-infrared spectroscopy (NIRS), were evaluated with respect to umami taste assessment, and performance of both of the methods was compared.

The so-called electronic tongues (Toko, 2000; Vlasov, Legin, & Rudnitskaya, 2002), typically based on arrays of non-selective electrochemical sensors coupled with chemometric methods, demonstrated to be useful tools to evaluate taste properties of several substances. Furthermore, such analytical devices were successfully employed to recognise and discriminate various foodstuffs on the basis of characteristics not strictly related to taste, such as geographical origin or manufacturing process (He et al., 2009; Legin et al., 2003; Oliveri, Baldo, Daniele, & Forina, 2009). A variety of sensors, from optical to mass spectrometry-based, has been employed in the design of electronic tongues, but the electrochemical devices are the most commonly used. Among them, potentiometric sensors have been widely employed and demonstrated to be a valid tool to evaluate the five primary tastes using artificial solutions obtained by solving in water basic taste substances (such as glucose, citric acid or HCl, NaCl, $MgCl_2$ or quinine-HCl and glutamic acid) and to classify amino acids on the basis of their tastes (Toko, 2000). Voltammetric sensors have also been employed to characterise liquid samples, generally on the basis of several properties including taste (Scampicchio, Benedetti, Brunetti, & Mannino, 2006; Winquist, Wide, & Lundstrom, 1997). They are in general advantageous because of their high selectivity, sensitivity, signal-to-noise ratio and various modes of measurements.

Spectroscopy in the near infrared region has become a widespread method to predict compositional and qualitative characteristics of a variety of foodstuffs, mainly on the basis of a great number of characteristics (Haiyan & Yong, 2007). In particular, NIR spectroscopy was successfully used to predict several sensory attributes of different products, such as apples (Mehinagic et al., 2003), Cheddar cheese (Downey et al., 2005), meat (Andrés et al., 2007), coffee (Ribeiro, Ferreira, & Salva, 2011) and wine (Cozzolino et al., 2006). Moreover, NIR spectroscopy is a non-destructive method, so it offers considerable advantages over other analytical techniques in terms of easiness of sample handling and pre-treatments.

The purpose of the present study was to study correlations between umami attributes of different commercially available flavour enhancer formulations and instrumental analytical measurements. In order to increase information quality and to evaluate synergism effects, data fusion strategies were applied to combine the data from ET and NIRS and the results were compared and discussed.

2. Materials and methods

2.1. Reagents and samples

According to the chemical nature of the most common umami compounds, samples analysed were aminoacids/peptides and ribonucleotides, embracing both monomeric (aminoacids and ribonucleotides) and complex samples, i.e. mixtures of oligopeptides produced by extraction and hydrolysis of proteins from vegetable (soybean, wheat, corn, rice) or animal sources (beef, crab). In order to perform a reliable taste evaluation, a number of aminoacids known to have a different taste profile were included as well in the sample set (Table 1).

All aminoacids were obtained from Sigma (Milan, Italy), while the complex samples are commercially available products and were kindly provided from New Foods Industry Spa (Bussolengo, Verona, Italia), Ohly® (Amburgo, Germania) and DSM Food Specialties Italy Spa (Segrate, Milano, Italia). Product specifications of each commercial sample, as provided by the manufacturer, are reported in the Electronic Supporting Material (S1).

Unless otherwise stated, all reagents were purchased from Sigma (Milano, Italy) and were of analytical grade.

0. 5 g of each solid sample were dissolved in 100 mL of deionised water, to have a 0.5% solution by weight, or lower, in the case of a partial solubility. Each solution was then filtered through paper filter. Aliquots of 25 mL were submitted to ET analysis, while smaller aliquots were used to fill cuvettes for spectroscopic measurements.

2.2. Sensory analysis

The sensory profiling was carried out at the Sensory Laboratory of the Special Company for Professional Training and Technological and Commercial Promotion of the Chamber of Commerce of Savona (Albenga, Italy). At least six subjects participated in the descriptive analysis as panellists. The subjects had variable experiences of descriptive analysis. In order to identify the minimum concentration for defining the taste threshold, samples were prepared as 0.1%, 0.5% and 1% solutions in deionised water. Aliquots (20 mL) of each sample, equilibrated at room temperature (20 ± 2 °C), were presented to the panellists in a disposable plastic cup coded with random numbers. The presentation order of the samples was randomised to minimize the presentation order effect. The subjects were previously trained until consensus was reached to evaluate the five basic tastes (sweet, bitter, sour, salty and umami). The sensory attributes were evaluated using a quantitative descriptive analysis method, based on "sip and spit" procedure. In more detail,

Table 1
Sample description and codification.

Sample	Sample id
Alanine	ALA
Arginine	ARG
Asparagine	ASN
Aspartic acid	ACASP
Glycine	GLY
Glutamic acid	ACGLU
Glutamine	GLN
Histidine	HIS
Isoleucine	ILE
Leucine	LEU
Lysine	LYS
Methionine	MET
Monosodium glutamate	MSG
Phenylalanine	PHE
Proline	PRO
Threonine	THR
Tryptophan	TRP
Valine	VAL
BCA G	BCA_G
Broth cube	BROTH_CUBE
BVA	BVA
ELP	ELP
FLAV-R-MAX	FLAV_R_MAX
FLAV-R-OUND LS	FLAV_R_OUND
FLAV-R-TIDE LS	FLAV_R_TIDE
Kombu seaweed broth	SEAWEED
MAXAROME PLUS	MAX_PLUS
MAXAROME PURE	MAX_PURE
MAXAROME STANDARD	MAX_STD