Application of electronic tongue in isotonic sports drinks characterization and differentiation during storage

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Summary

The electronic tongue or taste sensor system, comprised of seven potentiometric sensors, was applied as a tool in isotonic sports drinks analyses and characterization. Recently, electronic tongue systems showed large potential in food quality control, and for the first time it was used in isotonic sports drinks differentiation. The ability of the electronic tongue to differentiate between isotonic sports drinks samples and to monitor isotonic sports drinks during shelf life was evaluated by PCA analysis. The obtained results showed that the electronic tongue system was capable of differentiating between differently flavoured isotonic sports drinks samples and was able to monitor the changes in isotonic sports drinks samples during storage. High correlations of the developed PLS models between the observed sensory taste attributes (sweet, sour, bitter taste intensity and chemical senses intensity) and physicochemical parameters (electrical conductivity, refractometric value, pH value) and predicted values of sensory taste attributes and physicochemical parameters evaluated by electronic tongue, confirmed the performance of the electronic tongue and also indicate that the electronic tongue system can be used for rapid evaluation of sensory taste attributes and physicochemical parameters of isotonic sports drinks.

Keywords: electronic tongue, isotonic sports drinks, sensor array

Introduction

Sport drinks are mainly designed to replace fluid and provide carbohydrates (Amendola et al., 2004). Athletes have been the greatest consumers of many of these products and their habits may be followed by other groups of individuals, mainly those who exercise in gyms regularly (Morrison et al., 2004; Erdman et al., 2006; Lavalli Goston and Toulson Davisson Correia, 2010).
Sports beverages accounted for the largest share of sports nutritional 2000 retail sales (Sloan, 2002). In 2009, functional sodas, waters, and sports/energy drinks racked up to a 4 % increase of sales over the prior year, but the lowest growth rate since they came onto the market. Today, makers of functional beverages are serving up multiple benefits in a single product. Energy is second only to taste on the list of reasons for buying a functional beverage. Low-calorie/low-sugar, sugar-free, naturally sweetened, all natural, and longlasting are all on the list of key attributes that consumers seek in energy beverages (Sloan, 2010).
Consumption of beverages containing electrolytes and carbohydrates can help sustain fluidelectrolyte balance and exercise performance (ACSM, 2007). The composition of the consumed fluids can be important. The Institute of Medicine provided general guidance for composition of ‘‘sports beverages’’ for persons performing prolonged physical activity in hot weather. The need for these different components (carbohydrate and electrolytes) will depend on the specific exercise task (e.g., intensity and duration) and weather conditions (ACSM, 2007).
There are three types of sports drink all of which contain various levels of fluid, electrolytes and carbohydrate. Drinks with an osmolality of 300 +/-10 mOsm/L are called isotonic and are said to be in balance with the body's fluid. Isotonic sports drinks quickly replace fluids lost by sweating and supply a boost in carbohydrates. Isotonic beverages are the drink of choice for most athletes - middle and long distance running or team sports. Hypotonic fluids quickly replace fluids lost by sweating and are suitable for athletes who need fluid replenishment without the boost of carbohydrate (e.g. jockeys and gymnasts). Hypertonic fluids are used to supplement daily carbohydrate intake after exercise to top up muscle glycogen stores (Vranešić et al., 2003; Legović et al., 2007).
Flavouring of drinks has also been considered to contribute to voluntary fluid intake, with studies reporting greater fluid intake during post-exercise recovery with sweetened drinks as opposed to plain

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water (Burke and Deakin, 2010). Taste and flavour of beverages may also influence the rate of gastric emptying. Flavours and aromas, which are perceived as being unpleasant, may slow gastric emptying and may even cause nausea (Brouns, 2002). Additionaly, Ali et al. (2011) examined sensory perceptions of different formulations of sports drinks when consumed before, at various points during, and following exercise and one of the main findings was that sensory ratings differed considerably during exercise relative to non-exercise conditions and also changed during the course of exercise itself.

Therefore, the aim of this study was to evaluate the application of a commercially available electronic tongue (αAstree, Alpha M.O.S.) as a rapid technique for recognition of different isotonic sports drinks and sports drinks samples during six months of storage as well as for determination of sensory taste attributes and physicochemical properties. Although electronic tongue systems were often used for analysis of different food products and beverages (Lvova et al., 2002; Moreno et al., 2006; Rudnitskaya et al., 2007; Chen et al., 2008; He at al., 2009; Peres et al., 2009; Álvaro et al., 2010), such a system was applied for the first time for isotonic sports drinks evaluation in this study.

Materials and methods

Materials

Different samples of isotonic sports drinks, mostly presented on Croatian market, were analysed during this investigation. Samples were labelled as A (aroma lemon-grapefruit, first producer), B (aroma orange, first producer), C (aroma lemon, second producer), D (aroma forest fruit, second producer), and E (aroma lemon-grapefruit, third producer). Additionally, sample A was monitored and analysed during its six month long shelf life and the samples were labelled as A-0 (fresh samples, obtained directly from the producer), A-2 (samples stored for 2 months), A-3 (samples stored for 3 months), A-5 (samples stored for 5 months) and A-6 (samples stored for 6 months). Samples were stored at room temperature (20-22 ˚C). Each sports drink container was opened right before analysis. Hydrochloric acid (w = 37 %, ISO – for Analysis grade) for electronic tongue measurements was purchased from Carlo Erba Reagents.

The αAstree electronic tongue measurements

The commercial electronic tongue *αAstree* (Alpha M.O.S.) was employed in assessing isotonic sports drinks samples, consisting of 7 potentiometric sensors designated as JB, BA, BB, HA, ZZ, CA and GA by the manufacturer (Alpha M.O.S.), an Ag/AgCl reference electrode (Metrohm, Ltd.), a mechanical stirrer (Metrohm, Ltd.), a 16-position Sample Changer and a 759 Swing Head for sampling (Metrohm, Ltd.), an interface electronic module for signal amplification and analog to digital conversion (Alpha M.O.S.). The electronic tongue was connected to a personal computer with the Astree II software (Alpha M.O.S., Version 3.0.1., 2003) installed. The software automatically gathers and stores the outputs of the sensors. The sensors used in this study are chemically sensitive field-effect transistors (chemFET). The sensors were specially designed by the manufacturer for food and beverage analysis (Alpha M.O.S., 2003). All samples were analyzed in triplicate by the electronic tongue and each analysis cycle lasted for 300 seconds. After every sample measurement a reference sample was analyzed consisting of hydrochloric acid diluted in deionized water (0.01 mol/L) to monitor and correct the drift of sensors in time. The sensors were rinsed with deionized water after every analysis cycle. Prior to each sample measurement the sensor array was conditioned in an isotonic drink sample to obtain stable sensor responses.

Reference determination of isotonic sports drinks samples sensory attributes and physicochemical properties

In all of the samples, sensory parameters were evaluated by sensory panel group of ten members in a sensory laboratory performed according to all of the requirements for the sensory evaluation (ISO, 2007). Specific sensory attributes that were studied (taste attributes), included: sweet taste intensity, sour taste intensity, bitter taste intensity and chemical senses intensity. The intensity of each sensory attribute was rated from 0 = "none" to 10 = "high". Electrical conductivity of isotonic sports drinks samples was measured by conductivity meter (Conductivity meter SG3, Mettler-Toledo Inc., USA), and results were expressed in miliSiemens per centimetre (mS/cm). For rapid determination of the sugar content in isotonic sports drinks samples, the refractometric value was determined with the assumption that soluble carbohydrates represent the largest part of the solids in the analysed samples. Refractometric value was determined refractometrically (Pocket Refractometer, ATAGO, Japan) and results were expressed in Brix percentages (% Brix). pH values of the samples were determined by a pH meter (InoLab 720, WTW Wissenschaftlich-Technische Werkstätten GmbH, Germany). All samples were analyzed in triplicate.

Data analysis

The sensor outputs stored by the Astree II software were exported to Microsoft Excel (Microsoft Excel 2002, SP-2) where operations of centering (Daszykowski et al., 2007) and drift correction (Hruškar et al., 2010) were performed. The centered and corrected data were transferred to Statistica 10 (Statsoft, Inc., 2011) where Principal Component Analysis (PCA) and Partial Least Squares Regression Analysis (PLS) were performed.

Results and Discussion

Classification of different isotonic sports drinks samples by the electronic tongue

The electronic tongue measurements of five different isotonic sports drinks (A-E), processed by PCA, are presented in Fig. 1. The results present the separation of isotonic drinks samples on the first two principal components (totally 83.76 % of the variance explained). On the first principal component (PC1 – 57.74 %) the samples are grouped into three distinct groups; samples A and E belong to one group, B samples are the second group, and C and D samples being the third group. A and E samples, which are in the first group, were of lemon-grapefruit aroma but produced by to different producers. Sample B, which is separated from the other samples, was of orange aroma. Samples C and D which are grouped in the third group were of different aromas (C – forest fruit aroma and D – lemon aroma) but produced by the same producer. Results of PCA analysis showed that, already on the first principal component, samples of different isotonic sports drinks can be classified by aroma.

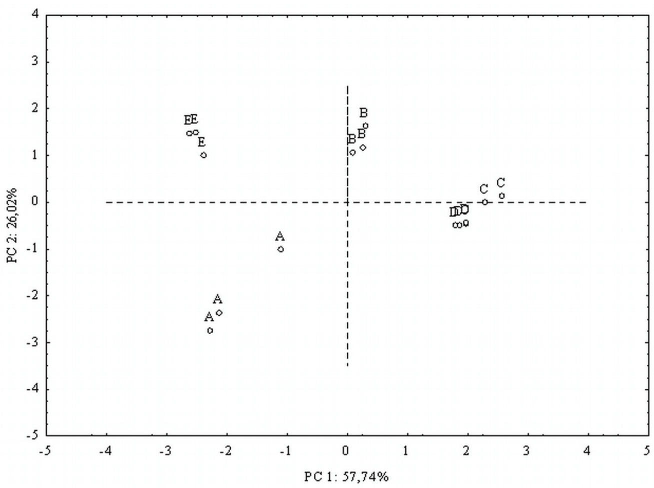

Fig. 1. PCA plot of different samples of isotonic sports drinks (A: aroma lemon-grapefruit, first producer; B: aroma orange, first producer; C: aroma lemon, second producer; D: aroma forest fruit, second producer; E: aroma lemon-grapefruit, third producer), number of replicas n=3

In order to accomplish the characterisation of the samples and to evaluate the performance of the electronic tongue system, in all of the samples sensory taste parameters, electrical conductivity, refractometric value and pH value were determined. Using PLS models, data acquired by the electronic tongue were combined with the actual results of sensory evaluation and also measurements of physicochemical properties. The plots of the sensory and physicochemical properties observed and predicted values are shown on Fig. 2. The best performance of the developed PLS models had the model for the determination of bitter taste intensity (r=0.9896), followed by the model for the determination of sour taste intensity (r=0.9712), sweet taste intensity (r=0.9590), pH value (r=0.9320), chemical senses intensity (r=0.9169), refractometric value (r=0.8864) and electrical conductivity (r=0.8750). All of the developed PLS models showed high correlations between the actual observed values and values predicted by the electronic tongue, indicating that electronic tongue can be used for rapid evaluation of sensory taste attributes and also electrical conductivity, refractometric values and pH values of different isotonic sports drinks.

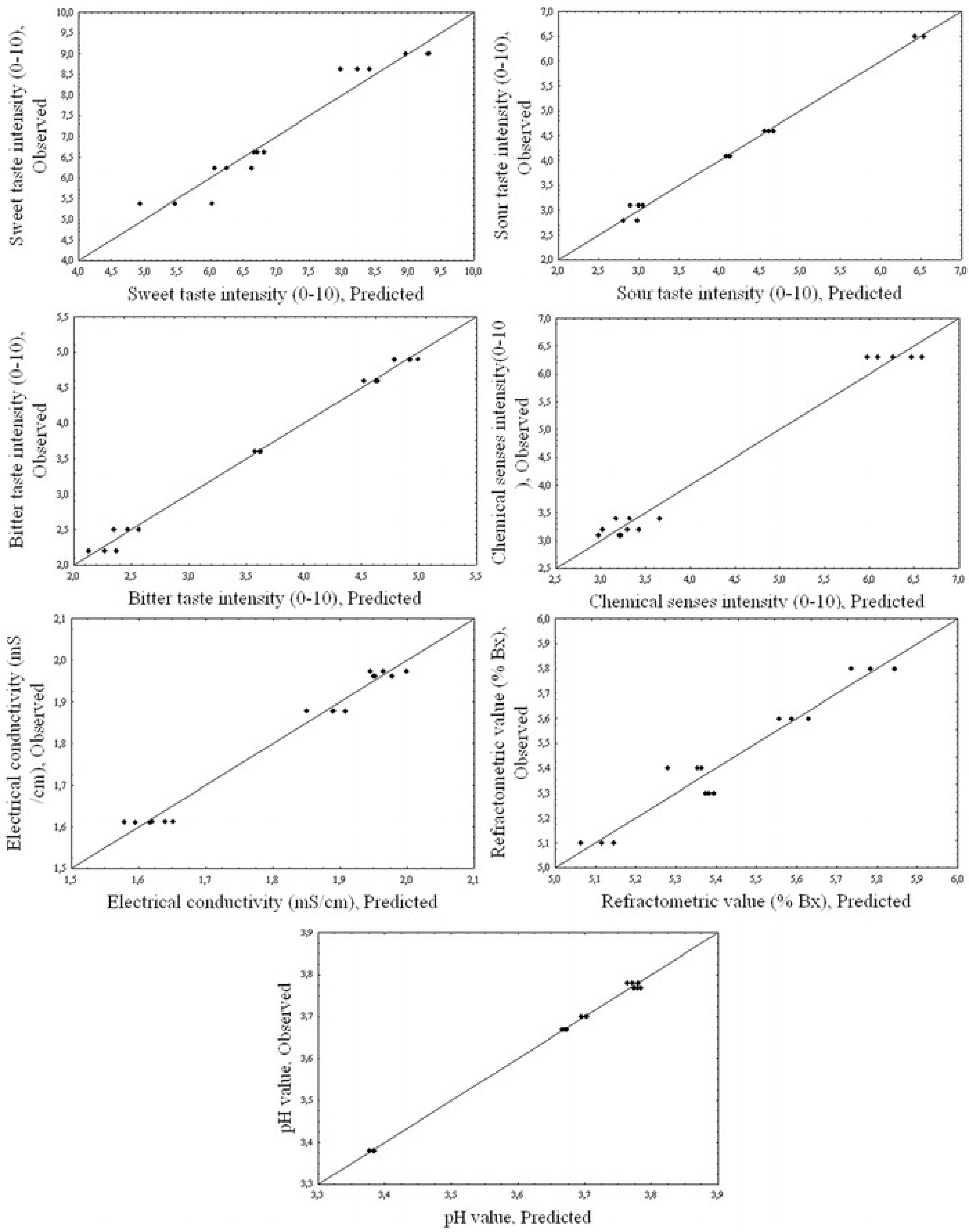

Fig. 2. PLS regression between the potentiometric sensor array (predicted values) and sensory taste attributes and physicochemical parameters of different isotonic sports drinks

Application of the potentiometric electronic tongue to differentiate isotonic sports drinks samples during storage

Electronic tongue system showed high performance in evaluation of isotonic sports drinks samples and it was used to differentiate isotonic sports drinks samples during six months of storage, or during declared shelf life. Isotonic sports drink samples (labelled as A in the first part of the investigation), obtained directly from the producer, were stored for 0, 2, 3, 5, and 6 months, and analysed by electronic tongue system. Sensory taste parameters (sweet taste intensity, sour taste intensity, bitter taste intensity and chemical senses intensity) of samples were evaluated by sensory panel group and in all samples electrical conductivity, refractometric value and pH value were determined.

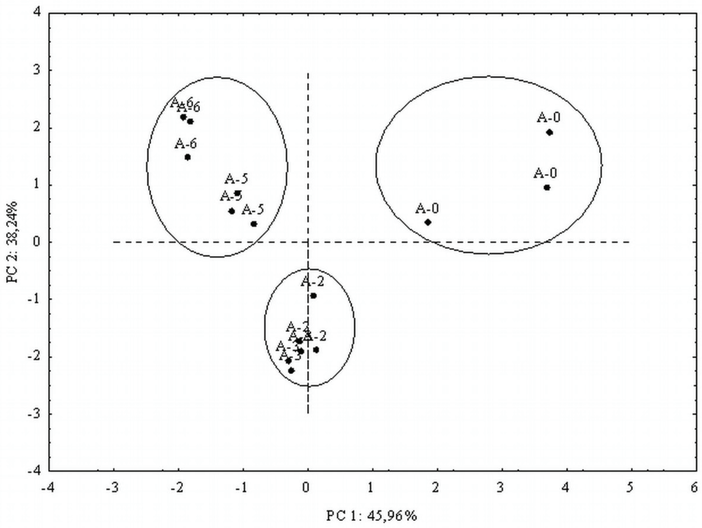

Fig. 3. PCA plot of isotonic sports drinks samples during six months of storage (A-0: fresh samples obtained directly from the producer; A-2: samples stored for 2 months; A-3: samples stored for 3 months; A-5: samples stored for 5 months; A-6: samples stored for 6 months), number of replicas n=3

Fig. 3 shows a two plane PCA plot of isotonic sports drink samples measurements performed by the electronic tongue. The first two planes (PC1 and PC2) represent very high 84.20 % of the total variance. As shown on PCA map, the samples grouped into three distinct clusters according to their freshness. The fresh samples (A-0) separated from the samples stored for 2 and 3 months (A-2 and A-3) and also from the samples stored for 5 and 6 months (A-5 and A-6) on the first principal component (PC1-45.96 % of the variance). On the second principal component (PC2-38.24 % of the variance) samples stored for 2 and 3 months were separated from the other analysed samples. The results of electronic tongue measurements showed that fresh isotonic sports drink differ in taste ingredients from the samples stored for two and three months and from the samples at the end of the shelf life. Results of referent sensory and physicochemical analyses were combined with the data acquired by the electronic tongue and created PLS models are shown on Fig. 4. High correlations were determined between the observed sensory taste attributes and values predicted by the electronic tongue, where the best performance had the model for the determination of sour taste intensity (r=0.9651), followed by the model for the determination of sweet taste intensity (r=0.9638), bitter taste intensity (r=0.9535), and chemical senses intensity (r=0.9508). PLS models of the observed and predicted refractometric and pH values also showed very high correlations (r=0.9816 and r=0.9663, respectively), while PLS model for observed and predicted values of electrical conductivity showed lower correlation (r=0.4529). Obtained results indicate that electronic tongue can be used for rapid evaluation of sensory taste attributes and also refractometric and pH values of isotonic sports drinks during storage.

Conclusions

Electronic tongue system showed high performance in differentiation of samples of isotonic sports drinks during six months of storage or during shelf life, indicating that differences in chemical composition of isotonic sports drinks, connected with the sensory taste attributes, occurred during storage and that electronic tongue is capable to detect those differences. High correlations between the observed and predicted values of sensory taste attributes and physicochemical parameters confirmed the performance of the electronic tongue and also indicate that electronic tongue system can be used for rapid evaluation of sensory taste attributes as well as electrical conductivity, refractometric value and pH value of isotonic sports drinks.

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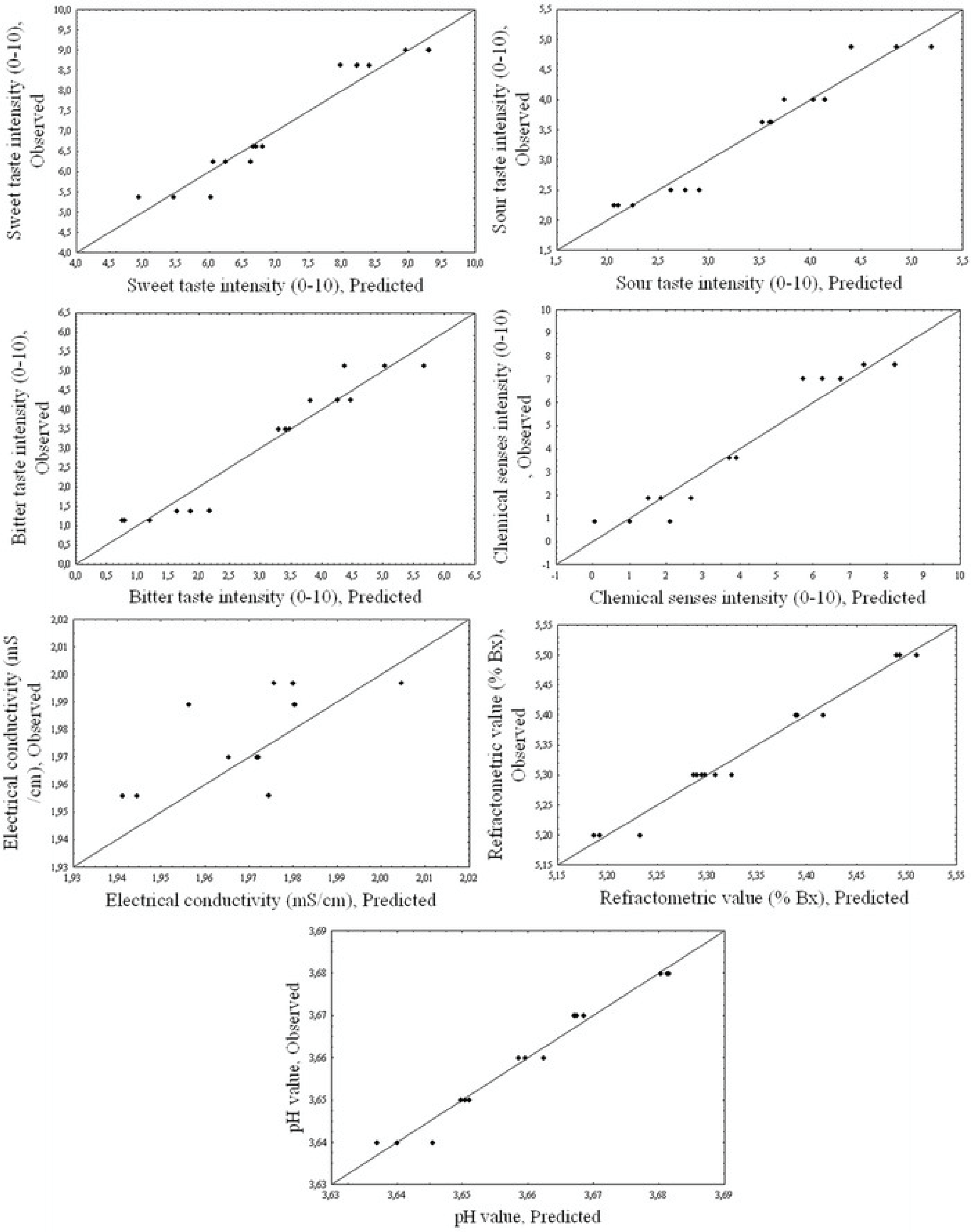

Fig. 4. PLS regression between the potentiometric sensor array (predicted values) and sensory taste attributes and physicochemical parameters of isotonic sports drinks samples during six months of storage

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