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An electronic tongue for beer differentiation

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Abstract

In this work an electronic tongue, based on a potentiometric solid-state multi-sensor array, with 36 polymeric membranes, was built for developing an analytical tool to apply in process monitoring and quality control. As a first approach, this tool was applied together with a supervised pattern recognition tool to semi-quantitatively differentiate beers with different alcoholic levels.

The multi-sensor array device was built with membranes prepared using PVC, as polymeric matrix, and different combinations of 6 plasticizer compounds and 6 membrane additives. The multi-sensor system includes a reference electrode Ag/AgCl with double junction, being connected to a multiplexer Agilent Data Acquisition/Switch Unit model 34970A. Measurements were performed in a double wall glass cell thermostatized at 25 ºC. All samples were degassed and analysed during a 10-15 minutes period.

The ability of the multi-sensor device to recognise different alcohol levels was initially evaluated using ethanol standard solutions (concentrations varying from 0.1% to 10.0%). The results obtained showed that the response of some of the polymeric membranes varied linearly when the ethanol content increased. Considering these satisfactory results, the device was applied for semi-quantitative alcohol level beer recognition.

Forty-two beers, with ethanol levels varying between 0% to 8%, from different countries, of different brands and colors and prepared from different grains, were purchased in Portuguese commercial markets. The ethanol content of each beer was confirmed by HPLC analysis using a Varian HPLC system with a refraction index detector, equipped with a Supelcogel C-610H column (30cm x 7.8mm ID).

The multi-sensor signal pattern recorded for the beers analysed, together with linear discriminant analysis (LDA) was used to distinguish between 4 groups of beers with different alcoholic levels (A: lower than 1%, B: between 4% and 5%, C: between 5% and 6% and D: between 6% and 8%). A stepwise LDA analysis was performed and it was verified that only the signals of 18 polymeric membranes were included in the final model ($p<0.001$ for Wilks' Lambda test). Three significant discriminant functions were established ($p<0.001$) accounting for 100% of the total variance. The approach had a satisfactory ethanol level recognition performance, as it allowed 95.2% and 73.8% correct classification for original grouped cases and "leaving one-out" cross-validation procedure, respectively.

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An electronic tongue for beer differentiation

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ELECTRONIC TONGUE

New methodology
Faster
Low cost
Reliable

OBJECTIVES

Differentiate four BEER groups with ethanol contents:

- Group 1 - lower than 1% (7 beers)
- Group 2 - between 4% and 5% (22 beers)
- Group 3 - between 5% and 6% (9 beers)
- Group 4 - between 6% and 8% (4 beers)

SAMPLES

42 beers from different countries
Ethanol level confirmed by HPLC analysis

LINEAR DISCRIMINANT ANALYSIS

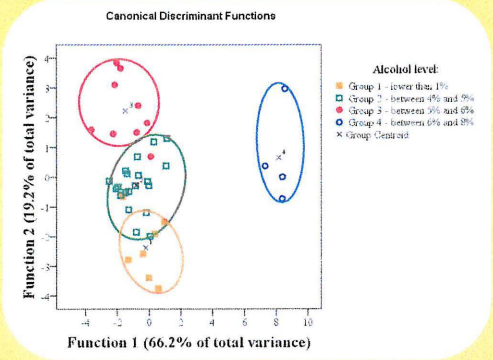
supervised pattern recognition tool
Stepwise technique using the e-tongue signal patterns
Leaving-one-out cross-validation procedure
Statistical analysis at a 5% significance level

SAMPLE ANALYSIS

16 beverages analysed twice
No dilution
Degassed beers

RESULTS

Classification model with 4 polymeric membranes signals:
A4, D5, E1 and F5



95.2% correct classification - **original grouped cases**
73.8% correct classification - **cross-validation procedure**

CONCLUSIONS

Satisfactory overall correct classification

APPLICATIONS

INDUSTRIAL MICROBIOTEC

Bioprocess monitoring
Multicomponent analysis
Evaluation of growth media

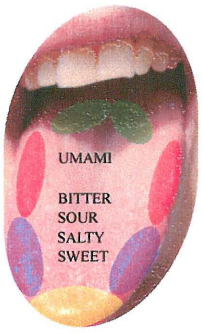
Additives and plasticizers used for polymeric membranes preparation

Membrane Additive substance	Plasticizer substance
[1] Octadecylamine	[A] Bis(2-ethylhexyl)phthalate
[2] Bis(2-ethylhexyl)phosphate	[B] Bis(1-butylpentyl) adipate
[3] Oleyl alcohol	[C] Tris(2-ethylhexyl)phosphate
[4] Methyltrioctylammonium chloride	[D] Dibutyl sebacate
[5] Tridodecylmethylammonium chloride	[E] 2-Nitrophenyl-octylether
[6] Oleic acid	[F] Dioctyl phenylphosphonate

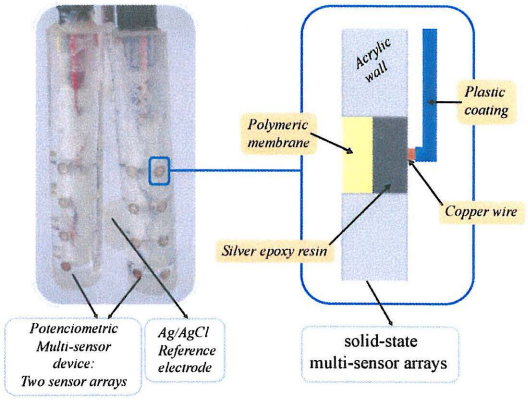
Each membrane: 31.9-32.3% of PVC
64.7-65.2% of one of the plasticizers
2.8-3.2% of one of the membrane additives

SENSORS

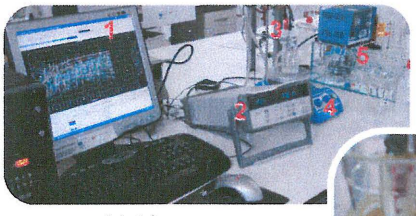
36 lipo/polymeric membranes
Non-specific
Low selectivity
Cross-sensitivity



Human tongue



E-tongue device



Multi-sensor system:

1- PC for data acquisition;
2- DataLogger Agilent;
3- E-tongue device in a double glass cell thermostatized
4- Magnetic stirrer;
5- Thermostatic bath.

E-tongue device in a double glass cell thermostatized

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