ISSN: 1692-7257 - Volumen 2 - Número 8 - Año 2006

ELECTRONIC OLFACTION SYSTEM TO QUALITY CONTROL OF BAKERY PRODUCT

SISTEMA DE OLFATO ELECTRONICO PARA EL CONTROL DE CALIDAD DE LOS PRODUCTOS DE HORNEO

PhD. Cristhian Manuel Durán A., PhD. Jesús Brezmes Llecha

Universidad de Pamplona
Ciudadela Universitaria. Pamplona, Norte de Santander, Colombia.
Tel.: 57-7-5685303, Fax: 57-7-5685303 Ext. 156
E-mail: {cristhian.duran, jesus.brezmes}@urv.net

Abstract: This paper describes an Electronic Nose (EN) based on a Headspace Sampler and an array of gas sensors developed with the aim to guarantee the quality of products of industrial bakery. The experimental application for the EN is the identification and classification of different fungi species. The different species have been identified with processing algorithms, basically PCA and the Fuzzy Artmap Neuronal Network. This device consists of an array of chemical sensors (gas sensors), software developed in Matlab 6.1 and the associated hardware which allows a fast data acquisition, and effective patterns recognition. This system is easy to use and appropriate for applications in the food industry.

Keywords: Electronic Nose, Pattern recognition, Fungi detection, Chemical sensors.

1. INTRODUCTION

An Electronic Nose (EN) is an instrument, which comprises an array of electronic chemical sensors with partial specificity and an appropiate pattern recognition system, capable of recognising simple or complex odours [1]. Gas sensors tend to have very broad sensibility, responding to many different substances.

Food companies can use the Electronic Nose as a quality control tool (e.g., to check raw materials, to check product deterioration during shelf life studies, to monitor product during transport to retailers, to ensure that packaging odours do not contaminate products, etc) and as a tool for process control (e.g., to monitor food odors during critical stages of production to ensure that optimum processing conditions are being maintained). In recent years, the use of arrays of gas sensors in these devices for the detection and classification of odors has created the field of Electronic Noses (EN). The EN recognizes global information (fingerprint) of the volatile compounds in contrast to classical techniques such as gas chromatography in which the single components are identified. They consist of a sampling system, electronic circuitry, an array of sensors and data analysis (pattern recognition) software.

2. EXPERIMENTAL

For the development of the EN, an already made Electronic Nose at the laboratory was used with the goal to make preliminary tests with fungi and to

evaluate the quality of responses of its Metal Oxide Sensors (MOS). The goal was to develop a more portable system, suitable to be used in nutritional product analysis, investigations and others applications.

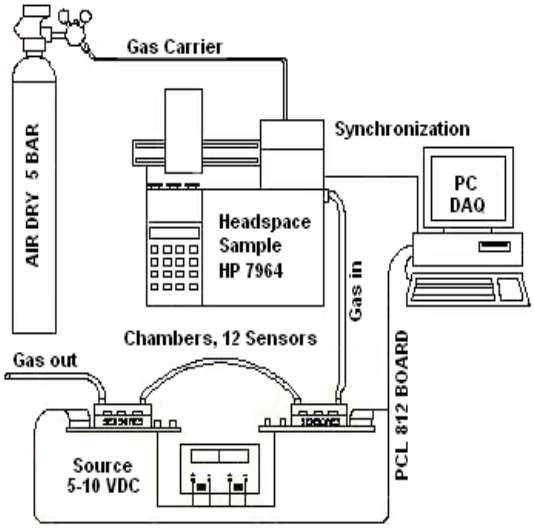

Fig.1. Scheme of the Electronic Nose developed in the Gas Sensor Lab

2.1. The laboratory E-nose

The initial prototype of electronic nose consists of: (see scheme in Fig.1).

Table.1. Sensor array description

Sensor	Target Vapours
TGS 800	Air contaminants
TGS 813	Combustible gas
TGS 822	Alcohol, toluene, *o*-xylene, etc.
TGS 825	Hydrogen sulphide
TGS 826	Ammonia
TGS 831	R-21, R-22
TGS 832	R-134a, R-22
TGS 842	Methane, butane, propane
TGS 880	Volatile Species from food
TGS 822	Alcohol vapours from food
FIS SP-31-00	Organics Solvents
FIS SP-32-00	Alcohol

- Hewlett Packard 7694 Headspace Sampler. This device is useful to prepare the sample and has a high reproducibility [2]. It is made up of a movable deposit where the vials take the scent, an oven where the sample is pre-conditioned and a manual flow meter to regulate the carrier gas flow (synthetic air dry).
- Two chambers of methacrylate, containing 12 gas sensors (FIS SP and TGS Models), in 2 arrays of 6 sensors each one. Table.1 describes each sensor used.
- Data acquisition board (PCL 812) Via PC.

2.2. Sample preparation

It was done using the headspace sampler: The temperature of the Oven was 70°C-80°C, Vial heating time 50 min, Vial pressurization time 1 min, loop fill time 1 min, loop equilibration time 0.05 min, Injection time 10 min. The carrier gas was regulated at flow rate 25-50 ml/min.

In two test with the Headspace, a group of 27 and later 19 vials of 20 ml closed samples were filled with 7 fungi, 1 cultivation mid (substance to cultivate fungi) and ethanol (for the calibration of sensors). In the table.2 we can see the fungi species with the number of vials used by each specie.

Table.2. Fungi groups for each round

#Fungi	Name	1st Round	2nd Round
1	Eurotium Repens	3	2
2	Aspergillius flavus	2	2
3	Eurotium Rubrum	3	2
4	Aspergillius Niger	3	2
5	Penicillium Corylophilum	3	2
6	Eurotium Herbariorum	3	2
7	Eurotium Amstelodani	3	2

2.3. Measurement and data acquisition

The third and fourth column contains the number of vials used in the two tests for each specie. In order to obtain an appropriate number of measures a PC was used, with the DOS operating system and software written in house. The acquisition time for each sample was 10 minutes. In the first tests, a group of 20 vials with fungi, 4 vials ethanol and 3 vials of cultivation, the data aquisition was made with 12 sensors.

A total of 27 measures were acquired, to check the operation of the system and especially the response of the sensors. The responses were highly sensitive in the presence of volatiles, but had a poor resolution. The second test was made with another group of 14 fungis, 3 ethanol and 2 vials of

cultivation with the same number of sensors, 19 measures were acquired, the same sensitivity was obtained and the operation of the system was satisfying.

In Fig.2 the change of the sensor resistance Rs is observed, which is variable due to the presence of the odors emitted by fungi, and where Ro is the baseline reading, the reference gas being the ambient room air [1], [3]. The signals were obtained measuring Aspergillius Niger.

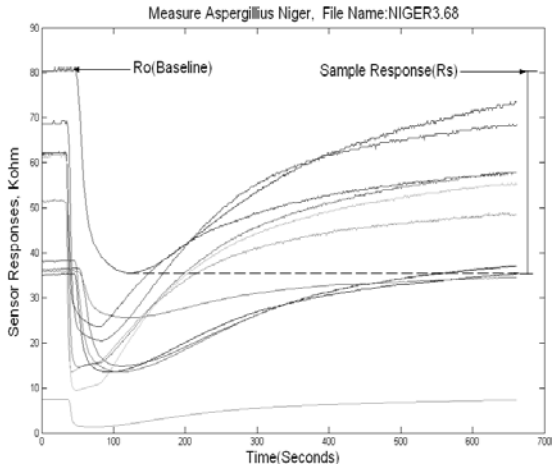

Fig.2. Gas sensor response as a function time

2.4. Data pre-processing

A pre-processing algorithm written in Matlab 6.1 was used to extract features from the data in terms of the static change in sensor resistance. In order to optimise the performance of that specific type of odour sensor the parameter used in this case was:

$$x_{ij} = (y_{ij} - y_i) \qquad (1)$$

Where y_i or baseline signal is the steady-state response or the conductance (resistance inverse) of the sensors i in air, and y_{ij} is the conductance of the sensor i in the presence of odour j [3].

2.5. Data processing

The pattern recognition (PARC) applied two tecniques often used in applications with electronic noses, based on Multivariate analysis (PCA) and Neuronal networks (Fuzzy Artmap).

Principal Component Analysis (PCA): Is an effective linear unsupervised method to project data from several sensors to a two-dimensional plane [4], [5], [6].

Fuzzy Artmap: Algorithm of artificial intelligence with supervised learning [7], [8]. In the training phase the network needs a set of measures (array of data). Each measurement must contain a vector of inputs (Parameters measured in each experience) and a vector of output data that codifies categories that have to be assigned. In the evaluation phase the input vector is provided and the network classifies this measurement following the criteria that has learnt in the training phase.

3. RESULTS

A set of Matlab 6.1 functions (toolbox) or algorithms has been developed and applied to analyze the data.

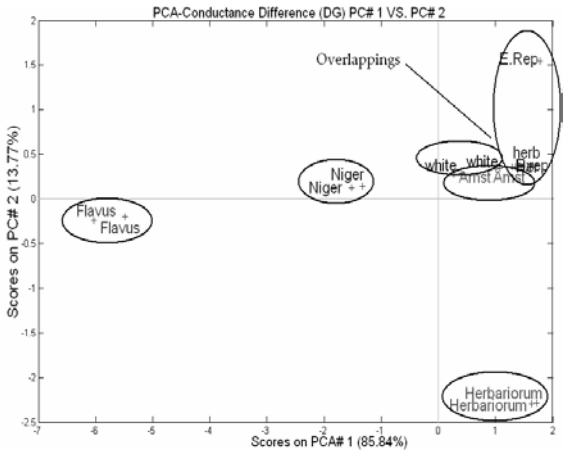

Fig.3. Result of the PCA of the gas sensor array for 19 gas samples

The results were the following:

1) With PCA Analysis and previous pre-processing (Autoscales), the obtained result can be seen in the Fig.3. The goal was to classify the 7 species of fungi corresponding to 19 measures; therefore the data was separated according to the variance captured by each PC (Principal Component). Most of the fungi could not be distinguished but 3 different kinds could be told apart; this verifies the performance of the EN in classifying between different kinds of organic components.

2) The Fuzzy Artmap verifies the previous result. This neural network was used to classify the samples of 9 species. A cross-validation technique

called leave one out of order one, was implemented to estimate the success rate in classification The success rate was 9 with an average of 47.368 %.

The following step was to design an electronic nose system using the experience obtained with the laboratory EN. The main components used to improve the system were: A board from National Instruments (6023E Model) [9], a chamber of methacrylate with an array of 12 gas sensors (The same as the laboratory's EN), an interface board (Electronic Control for Headspace sampler and the board data acquisition) Via PC, See Figs. 4 and 5. The processing and acquisition software was written in Matlab 6.1[10], having added Graphical User Interface (GUI).

Its compact design makes it more portable and facilitates the tests in the laboratory with less errors. It also improves the stability when el repartir with the headspace sampler.

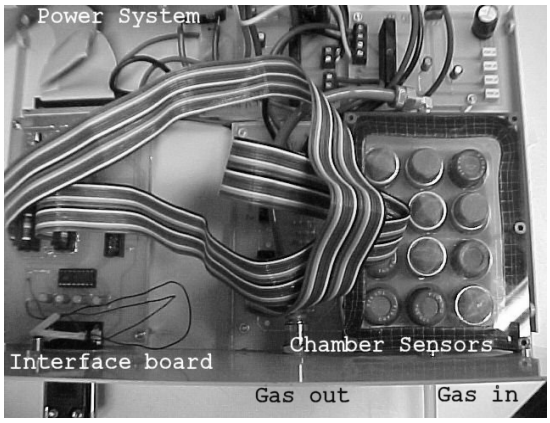

Fig.4. Photograph 1, components of the optimized Electronic Nose

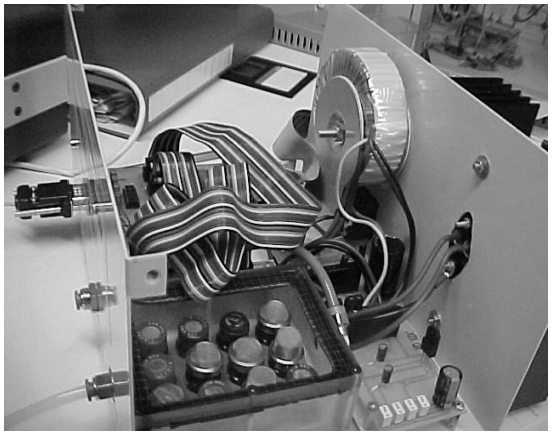

Fig.5. Photograph 2, components of the optimized Electronic Nose

The Fig.6 shows the software developed with a group of windows or GUIs, which make the synchronization tasks with the headspace sampler, data acquisition and processing much simpler. In contrast to the previous EN system, the fast processing is a great advantage and allows a suitable and significant time gain.

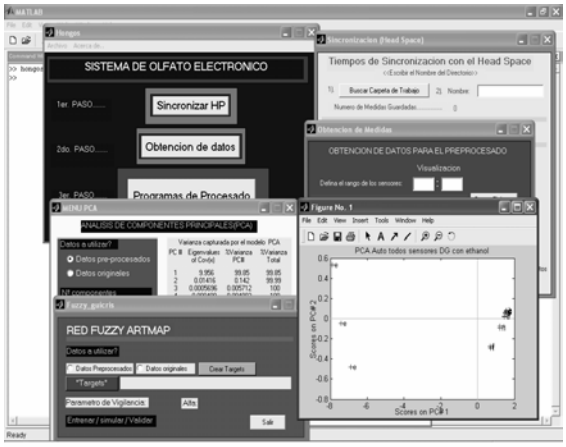

Fig.6. GUI's for data acquisition and processing

3.1. Final tests

In order to evaluate the behavior of the new system, several tests with 9 vials (3 Ethanol, 3 Ammonia and 3 Acetone) were executed.
The GUIs of synchronization, pre-processing and PARC techniques were used to improve the system. The system operated suitably. Fig.7 shows the response with a PCA.

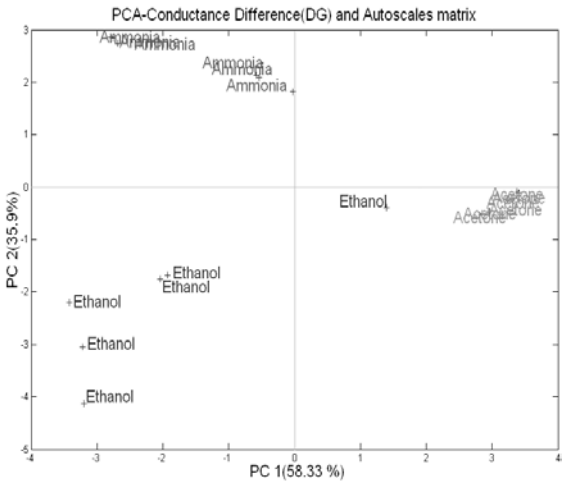

Fig.7. PCA plots drawn with 18 measures and 12 sensors

A separation of contaminants could be observed but with one error with a measurement of ethanol, which lays very close to the cluster of acetone. The captured variance was a 95 % in the 2 first PC (Principal Components).

With the fuzzy Artmap and the cross-validation technique (leave one out) the results of the PCA, have been verified, with a success rate in classification of 94.4 %.

Fig.8. Photograh of the electronic nose system

4. CONCLUSIONS

In this paper we have presented an EN system designed to classify between different fungi species, as shown in Fig.8. With preliminary laboratory tests the gas sensors achieve broad sensitivity and selectivity, responding to each one of the samples, while the Matlab toolbox permits to make pre-processing and data analysis with PARC methods, PCA and Fuzzy Artmap. These results show that is possible to use the Electronic Nose for food quality analysis. By means of adequate selection of materials, conditions of operation and better PARC, better results are expected with a new version of this device.

REFERENCES

J. Gardner and P. Bartlett, "A brief history of electronic noses", Sensors and Actuators B, Chem., pp. 211-220, 1994.

http://www.chem.agilent.com/.

J. Gardner, P. Bartlett, "Electronic Noses: Principles and Applications", Oxford University press, New York, pp.128-129, 1999.

H. Hong, C. Han, S. Kim, D. Hyun, K. Lee, Y. Sung, "Portable electronic nose system with gas sensor array and artificial neuronal network", Sensors and Actuators B 66, pp. 83-90, 2000.

M. Pardo, G. Faglia, G. Sberveglieri, "Electronic nose for coffee quality control", IEEE, Technology Conference, Hungary, pp: 123-127, 2001.

P. Boilot, E.L. Hines, M.A. Gongora, R.S. Folland, " Electronic Noses inter-comparison, data fusion and sensors selection in discrimination of standart fruit solutions", Sensors and Actuators B 88, pp:80-88, 2003.

E. Llobet, E.L. Hines, J. Gardner, P.N. Barlett, T.T. Mottram, "Fuzzy Artmap based electronic nose data analysis", Sensors and Actuators B 61, 183-90, 1999.

E. Llobet, J. Brezmes, R. Ionescu, X. Vilanova, S. Al-khalifa, J. Gardner, N. Bârsan, X. Correig, "Wavelet transform and Fuzzy Artmap based patterrn recognition for fast gas identification using a micro-hotplate gas sensor", Sensors and Actuators B, press, (2001).

The National Instruments, http://www.ni.com/

The Mathworks, Inc., Matlab (Version 6.1). http://www.mathworks.com