Analysis of single-cultivar extra virgin olive oils by means of an Electronic Nose and HS-SPME/GC/MS methods

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Received 5 April 2005; received in revised form 7 April 2005; accepted 17 June 2005
Available online 10 August 2005

Abstract

The detection of aroma volatile compounds emitted by extra virgin olive oils (EVOOs) is of key importance in the quality control of this product. Physical–chemical techniques (GC, GC/MS, HPLC) and sensory analysis (panel test) are the classical methods used for this purpose, but they are expensive, time consuming, and do not allow on-line measurements.

In this paper a new device, an Electronic Nose, that is a sensor array based on pure and doped SnO2 sol–gel thin films used for the discrimination of different Mediterranean “single-cultivar” EVOOs, was presented. To confirm the sensor array responses, analytical technique like headspace-solid phase micro-extraction/gas chromatography/mass spectrometry (HS-SPME/GC/MS) analysis was applied to the analysis of volatiles compounds in EVOOs samples. Moreover sensory analysis on EVOOs was carried out.

The obtained GC/MS data were used to identify the particular compounds and characterize the chemical composition of the EVOOs samples. In addition a chemometric pattern recognition technique was used for multivariate data analysis. The variations in the GC/MS fingerprint of the different samples were analysed using principal component analysis (PCA). Statistical analyses were carried out on data obtained from Electronic Nose, GC/MS and sensory analysis.

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Keywords: Single-cultivar; Olive oils; Electronic Nose; Principal component analysis; SPME; GC/MS; Sensory analysis

1. Introduction

The Mediterranean diet is spreading worldwide thanks to its unquestionably beneficial nutritional properties. A primary ingredient of the Mediterranean diet is extra virgin olive oil, which is also one of the most important products of the Italian agricultural industry. Extra virgin olive oils (EVOOs), extracted from fresh and healthy olive fruits (Olea europea L.) and properly processed, are characterized by a delicate and unique flavour highly appreciated by consumers. Their peculiar taste and aroma are closely related both to some non-volatile compounds and to a number of volatile compounds.

Moreover, many types of EVOO are produced by mixing oils from different “cultivar”, that is, from different variety of tree species coming from different geographical origin area of cultivation. Each type of blend being characterized not only by a different smell, but also by a different taste and colour. The organoleptic properties of oils also depend on the particular blend. In order to satisfy consumer requirements, oil from a certain producer must be easily distinguishable and identified by presenting the same smell as well as the same taste and colour.

On the other hand, from the point of view of olives it is of great importance to evaluate and conserve their existing genetic diversity, still preserved in spite of the influence of the environments where they are cultivated. The origin and the geographical distribution of such high variability in
the cultivated olive are still under investigation. Most studies agree that after a spreading of new varieties of olive along the Mediterranean basins, most of the modern cultivars derive from the crossing of these ancient cultivars between themselves, or by their breeding with plants followed by local selection practices. The problem of olive germplasm classification is complicated by the richness of its genetic patrimony, but also by the absence of a reference standard and by the confusion over the cultivars names, with numerous cases of homonymy and synonymy.

The identification of local cultivars and their genetic and sanitary certification processes is key point in the improvement of olive oil production. In compliance with regional legislative decrees (in particular decree 289 of 1991) the certified olive plants are produced following a strict programme defined by IMBET Institute with SFR (Regional Plant Protection Service). Nurseries that produce certified plants, distinguished by a specific label, are provided with propagation material only from the mother tree blocks which are recognized and tested by the SFR.

In the Italian region, the presence of typical varieties, the peculiar microclimatic conditions and precise olive orchard management lead to the production of very valuable olive oil with a distinctive taste. Olive ripening is, also, one of the most important factors influencing olive oil quality and its stability during storage. Seasonality, water availability and temperatures clearly influencing the ripening process. In fact, the identification of a specific value of ripeness index, besides climatic factors, could be useful in order to determine the best harvest-time so that to obtain oils of a good standardised quality.

A sensory analysis is a scientific discipline which uses a panel of trained tasters. It is generally used to differentiate olive oil in terms of region of provenience, variety, ripeness and extraction techniques. In fact, new European legislation on olive oil is partially concerned with the sensory aspect of oil (European Unions’ Regulation No. 2568/91). Recently a new robust statistical approach to classify the oils: CO1/T20/Doc. No. 15 was applied [1,2]. The static headspace technique, which analyse the vapours (gas phase) in equilibrium with the oil (liquid phase), was used since it could reflect as close as possible the olive oil aroma perceived by sensory evaluation. In fact, volatile compounds have a key role in determining correlation between olive oil quality and sensory appreciation.

A variety of new sensors devices as well as new techniques for existing stand-by off-line sensors are emerging to help the food manufacturer in the field of quality control. Numerous are the areas of interest like the detection of foreign objects in food, control in automation procedure and full inspection at the high speeds of today’s processing.

Electronic Nose instrumentation has advanced rapidly during the past 10 years with a lot of successful applications in food and drinks industry applications [3,4]. Indeed, reports have been written on the capability of Electronic Nose to detect the freshness of food such as meat [5] and milk [6].

This paper reports the use of a metal oxide sol–gel thin films based Electronic Nose, developed at the sensors laboratory of CNR-IMM Institute in Lecce, to analyse different “single-cultivar” EVOOs produced by Tuscan producers. To confirm the Electronic Nose response, analytical technique like Headspace-solid phase micro-extraction/gas chromatography/mass spectrometry (HS-SPME/GC/MS) analysis was applied to the analysis of volatiles compounds in EVOOs samples. Moreover sensory analysis on EVOOs was carried out.

The obtained GC/MS data were used to identify the particular compounds and characterize the chemical composition of the EVOOs samples. In addition a chemo metrics/pattern recognition technique was used for multivariate data analysis. In particular, statistical analyses were carried out on data obtained from Electronic Nose, GC/MS and sensory analysis.

2. Experimental

Twelve samples of different Tuscan single-cultivar EVOOs (Leccino, Maremmano, Olivestra di Montalcino, Gremino di Montecatini, Leccione, Madonna dell’Innumera, Lazzero di Prata, Americano, Scarlinese, Morcone, 2CRL, Tisignana) were analysed by means of three different techniques. In the case of the Electronic Nose analysis and HS-SPME/GC/MS analysis, the same samples, in the same vial, were used. For the sensory analysis samples coming from the same productive process were used.

2.1. Electronic Nose analysis

The multi-sensor array used for the reported research was composed by five different micro-sensors, which had different sensing layer. They were pure and Ni, Os, Pt, Pd-doped tin oxide sol–gel thin films. For the preparation of the pure SnO2 sols we started from anhydrous SnCl4 as precursor. For the preparation of the doping solution a prescribed amount of suitable solutions, with an atomic ratio X/N = 0.05 (X = Ni, Os, Pt, Pd, respectively), were added to the SnO2 sols. Details of the preparation of the solution are reported elsewhere [7]. The films were deposited, by means of spin coating, onto Al2O3 substrates pre-arranged for cutting and obtaining (3 mm × 3 mm) single samples. After the spinning the sensitive layers were thermally annealed at 500 °C. The alumina substrates were equipped, on the backside, with Ti/Pt meander as heating element. Moreover, on the front side, onto the sensing layer, interdigitated Ti/Au electrodes were deposited. Finally, the devices were mounted onto TO-8 socket.

During the operation, all the sensors were heated at the operating temperature, which in this case was about 250 °C, by supplying a given voltage to the heating element. The sensor responses towards the volatile compounds of the different olive oil samples were carried out by applying a constant voltage of 2 V between the electrodes and measuring the cur-
rent flowing through the sensors by means of an electrometer Keithley 6517A type equipped with a multiplexer module. Concerning the experimental set-up for the measurements, the baseline was acquired in a dry air–nitrogen atmosphere in a continuous total flow of 100 sccm (50 sccm air and 50 sccm nitrogen), while for the measurement 10 ml of sample in a 20 ml vial kept at a temperature of 30 °C, was stripped by means of a deviation of the only 50 sccm nitrogen flow for 20 min, maintaining the other 50 sccm of dry air constant. In this way, the volatile compounds were directly transferred by the carrier gas into the sensor chamber. All fluxes were controlled by means of mass flow meters and a mass flow controller (mod. MKS 647B).

All the process was controlled by a PC by means of National Instruments software. A scheme of the experimental set-up is reported elsewhere [2].

The responses of the sensors towards the EVOOs samples were analysed by means a PCA algorithm.

2.2. HS-SPME/GC/MS analysis

For this test the same 12 samples of EVOOs were used. The volatile compounds, of the samples headspace, were extracted and concentrated by using a SPME fibre (poly(dimethylsiloxane) (PDMS) 100 µm, red), separated with a HP 6890 GC System and identified with a HP 5973 Mass Selective Detector.

The volatile compounds of the sample were collected by a HS-SPME/GC/MS. EVOO sample (10 ml) was weighed and placed in 20 ml vial. The vial was sealed with PTFE/BYTL septum and equilibrated at 30 °C for 30 min with the presence of SPME fibre in the oil homogeneous headspace. After the equilibration time the fibre was injected into hot (150 °C) inlet GC port (in splitless mode). The volatile compounds were then separated with a capillary column HP-5MS (30 m × 0.25 mm i.d. × 0.25 mm film thickness). The separation was performed as follows: initial oven temperature 40 °C for 5 min, and subsequently programmed from 40 to 280 °C at a rate of 8 °C/min where it was held for 5 min. The compounds were analysed by MS. Mass spectra was obtained in the electron impact mode (EI 70 eV). The operating conditions were as follows: temperature interface 280 °C (transfer-line), temperature ion source 230 °C and temperature quadrupole 150 °C. The mass range varied from 30 to 350 amu, the solvent delay time was 4 min, the threshold 150 and scan speed 4.45 scan/s. Identification of the peaks was based on comparison of their mass spectra with the spectra of the NIST library.

2.3. Sensory analysis

In order to perform the sensory analysis the total of the same 12 samples used in the other analysis of single-cultivar EVOOs grown in Tuscan region were used. The sensory panel was selected and trained according to the COI regulation (International Olive Oil Council). The evaluation of the samples was performed under the conditions described in the COI regulation (COI, 1986) regarding sensory booths, time of day, oil temperature, samples' codification, amount of oil to test and the glass appropriate for this. The intensity scale ranged from 0 to 5. The obtained data for the 10 specific descriptors of the sensory profile were submitted to principal component analysis (over the median values for each sample).

3. Results and discussion

This work reports the discrimination among different single-cultivar EVOO samples through Electronic Nose analysis and the correlation with analytical analysis. First of all, PCA analysis shows the results obtained by means of sensor array data. Fig. 1 reports the three-dimensional score plot in which separation among clusters is not complete. As one can see, the variances explained by the first two principal components are 57% and 23% for the first and the second, respectively. Thus the analysis was extended until the third component (12% of the total variance) and reporting on the PCA–PC2 plane only the data points those are not clear visualised in the three-dimensional space.

By means of HS-SPME/GC/MS analysis only eighteen different chemical compounds were identified in the EVOOs aroma. The histogram in Fig. 2 summarises these results. While, in Fig. 3 the PCA results performed on these data are reported. From a qualitative point of view, from HS-SPME/GCMS analysis one can see that aldehydes, terpenes and alcohols are the main chemical families present in the analysed headspaces. Aldehydes, in particular hexanal and nonanal, coming from lipid oxidation, is the predominant chemical family present in the headspace. Depending on the specific concentration of these substances they can give the aroma of herb olive rising to rancidity in the case of very high concentrations [8,9]. Ethanol gives the smell of ripened olive while 2-pentene-1-ol gives the smell and taste of green olive [10]. Molecules present in less quantity such as α-pinene or α-farnesene were isolated. These molecules are active compounds giving the characteristic aroma of hot spicy [11].

Finally, Fig. 4 reports the biplot obtained from PCA in the case of the sensory analysis. From panel test point of view, the EVOO samples can be distinguished in sweets oils and spicy EVOOs. In which separation among clusters is not complete. As one can see, the variances explained by the first two principal components are 12% of the total variance and reporting on the PCA–PC1 axis, and the others on the positive ones.

If we try to give a complete interpretation of whole data, obtained from these three techniques of analysis, we can observe that in Fig. 1 samples 3 and 11 are not separated but if we observe the panel test analysis in Fig. 4 they are very similar. We can give the same interpretation in the case of the samples 5 and 12. Moreover, from the chemical point of view, those samples are quite similar as one can argue from graph in Fig. 3 deriving from HS-SPME/GCMS analysis. While for the samples 4, 8, 13 and 2 they seem to be not separated only for a three-dimensional effect of the representation of
Fig. 1. Three-dimensional PCA plot obtained from the data of the repeated exposure of the single-cultivar EVOOs to the sensor array working at the temperature of 200°C.

Fig. 2. Histogram of the 18 identified volatile compound of 12 EVOOs by means of HS-SPME/GC/MS analysis.
With the aim to obtain other significant information, we performed some statistical analysis. The first aim of these latter analysis, performed on the sensor response patterns, is to extract information on the volatile composition of the EVOO samples. Thus a linear regression was carried out assuming, as dependent variable, each volatile compound concentration obtained by GC analysis, and, as independent variables, the sensor responses. The reliability of the regressive model was checked by analysis of variance (ANOVA) by testing the hypothesis on simultaneous null values of the regression coefficients [12]. The null hypothesis is rejected if the computed statistic $F$-test (Fisher test) exceeds the critical tabulated $F$-value at the $\alpha$-percent level of significance. Otherwise, a good fit of the model to experimental data is indicated by value of the multiple coefficient of determination, $R^2$, close to 1.

The regression analysis assesses the sensor response pattern that is related with six volatile compounds (hexanal, 1-pentene-3-one, 2-pentene-1-ol, ethanol, (E)-3-ethyl-1,5-octadiene, (E)-3-ethylene-1,5-octadiene). The results are shown in Table 1.

Once the selection of the volatile compounds, which are related with the sensor responses, have been performed, the next step of data analysis was to select the needed set of independent variables to retain in the regression model by applying the backward selection approach. This technique was used to discriminate the semiconductor sensors which respond more significantly in presence of the respective volatile compound. The best subset of independent variables was chosen by comparing the adjusted coefficient $R^2$ from the
to all the others.

Finally, by means of the sensory analysis we deduced the sensorial impact information deriving from different EVOO aroma. Moreover, by means of statistical treatment of the data it was possible to argue other complementary information concerning the main chemical compounds interacting with the sensor array and concerning the predominance of some samples of the array with respect to all the others. In particular, the work is in progress in order to improve the discrimination capability of the Electronic Nose in the field of olive oils analysis. Because we obtained that SnO\textsubscript{2}/Pt based sensor responses showed a predominant role in the regression model, we are trying to adjust the sensor array by using sensors with different sensing material, that is SnO\textsubscript{2}/Pd. Thus, the Electronic Nose, when properly used, can be a comparative and complementary, not totally alternative, device to conventional techniques in specific application of food industry.

4. Conclusion

In this work 12 different single-cultivar Tuscan extra virgin olive oils were analysed by means of three different methods: Electronic Nose, HS-SPME/GC/MS and sensory analysis. By means of Electronic Nose it was possible to separate among clusters of different EVOOs. While, with the HS-SPME/GC/MS we obtained the chemical map of the different samples. Finally, by means of the sensory analysis we deduced the sensorial impact information deriving from different EVOO aroma. Moreover, by means of statistical treatment of the data it was possible to argue other complementary information concerning the main chemical compounds interacting with the sensor array and concerning the predominance of some samples of the array with respect to all the others.

### Table 1

The coefficient $R^2$, the adjusted coefficient $R^2$ and the value of F-statistic test of the regressive model

<table>
<thead>
<tr>
<th>Chemical compound</th>
<th>$R^2$</th>
<th>Adjusted $R^2$</th>
<th>F-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanol</td>
<td>0.7876</td>
<td>0.6112</td>
<td>4.4553*</td>
</tr>
<tr>
<td>2-Methyl-1-pentene</td>
<td>0.9228</td>
<td>0.8505</td>
<td>1.1867**</td>
</tr>
<tr>
<td>1-Pentene-3-one</td>
<td>0.8806</td>
<td>0.7811</td>
<td>8.5720**</td>
</tr>
<tr>
<td>Hexanal</td>
<td>0.9536</td>
<td>0.9149</td>
<td>28.4617**</td>
</tr>
<tr>
<td>2-Hexanone</td>
<td>0.7845</td>
<td>0.5499</td>
<td>3.6649</td>
</tr>
<tr>
<td>Cyclopentane, 2-propenyl (iso)</td>
<td>0.1804</td>
<td>-0.5026</td>
<td>0.2643</td>
</tr>
<tr>
<td>1-Hexene-1,5-octadiene</td>
<td>0.8205</td>
<td>0.6709</td>
<td>5.4679*</td>
</tr>
<tr>
<td>1-Ethyl-1,3,7-octatriene,3,7-dimethyl</td>
<td>0.8661</td>
<td>0.7545</td>
<td>7.7686*</td>
</tr>
<tr>
<td>Limonene</td>
<td>0.3722</td>
<td>0.5182</td>
<td>3.3655</td>
</tr>
<tr>
<td>1-Ethyl-1,3-hexadiene</td>
<td>0.2361</td>
<td>-0.4085</td>
<td>0.3711</td>
</tr>
<tr>
<td>3,5-Octadiene,3,7-dimethyl</td>
<td>0.2774</td>
<td>-0.4085</td>
<td>0.6412</td>
</tr>
<tr>
<td>Nonanal</td>
<td>0.4672</td>
<td>0.2032</td>
<td>1.0517</td>
</tr>
<tr>
<td>2-Pentene-1-olz</td>
<td>0.4193</td>
<td>-0.5600</td>
<td>0.2017</td>
</tr>
<tr>
<td>1-Methylcyclopenta-1-olz</td>
<td>0.6356</td>
<td>0.4016</td>
<td>2.4705</td>
</tr>
<tr>
<td>2-Methyl-1-ethylcyclopenta-1-olz</td>
<td>0.6486</td>
<td>0.3558</td>
<td>2.2202</td>
</tr>
</tbody>
</table>

* P < 0.05.

** P < 0.001.

full regression model and the reduced regression model. The backward selection analysis performed on the resulting six chemical compounds and the sensor responses established that the SnO\textsubscript{2}/Pt sensor responses have a predominant role in the regression model, mainly in the regression with ethanol, 2-pentene-1-olz, (E)-3-ethyl-1,5-octadiene, (E)-3-ethylene-1,5-octadiene. On the other hand, SnO\textsubscript{2} and SnO\textsubscript{2}/Pd sensor responses are less statistically significant, as reported in Table 2.

Finally, we tried to relate the capability of the Electronic Nose to detect and classify olive oil aroma with the sensor profile using eight assessors. Moreover, the regressive analysis was performed on the sensory data for assessing relationships among sensor attributes (the independent variables) and the single chemical compounds (the dependent variables). A two-way analysis of variance was, previously, run on the sensory data in order to choose the more significant attributes, thus to lower the number of variables for the regression model (“pine-seed” and “almond” resulting the unselected variables).

The previously analytical analysis established a relationship between olive oil volatile compounds and sensory attribute perceived by the human olfactory sensing [10–13]. The regression analysis performed of the ANOVA selected sensory attributes with each volatile compounds shows that the $F$-value exceeds the critical $F$-value tabulated at the 5% level ($P<0.05$) only for the regression with hexanal and 2-hexenal. The sensory attributes more related with the two volatile compounds are ripe olive, green olive.

Two-way ANOVA analysis on sensory data allows to select the sensor attributes significant for the discrimination of oil samples. The non-significant attributes are “pine-seed” and “apple”. The median of each ANOVA-selected score attribute is employed in the regression model with the volatile compound concentration.

The obtained results show that hexanal and 2-hexanal are significantly related with the attributes. In particular, hexanal is related with the attributes ripe olive, green olive, and green wood while 2-hexanal is related with almond, green olive, green wood.

### Table 2

Comparison between $R^2$ of full model and $R^2$ of unsaturated model

<table>
<thead>
<tr>
<th>Chemical compound</th>
<th>$R^2$</th>
<th>Adjusted $R^2$</th>
<th>$R^2$</th>
<th>Adjusted $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanol</td>
<td>0.7876</td>
<td>0.6112</td>
<td>0.7860</td>
<td>0.681</td>
</tr>
<tr>
<td>1-Pentene-3-one</td>
<td>0.9228</td>
<td>0.8505</td>
<td>0.8808</td>
<td>0.8626</td>
</tr>
<tr>
<td>2-Pentene-1-olz</td>
<td>0.8806</td>
<td>0.5811</td>
<td>0.8788</td>
<td>0.8519</td>
</tr>
<tr>
<td>Hexanal</td>
<td>0.9536</td>
<td>0.9149</td>
<td>0.9536</td>
<td>0.9271</td>
</tr>
<tr>
<td>2-Hexanone</td>
<td>0.7845</td>
<td>0.5499</td>
<td>0.7708</td>
<td>0.7367</td>
</tr>
<tr>
<td>Cyclopentane, 2-propenyl (iso)</td>
<td>0.1804</td>
<td>-0.5026</td>
<td>0.1704</td>
<td>-0.5026</td>
</tr>
<tr>
<td>1-Hexene-1,5-octadiene</td>
<td>0.8205</td>
<td>0.6709</td>
<td>0.8085</td>
<td>0.7367</td>
</tr>
<tr>
<td>1-Ethyl-1,3,7-octatriene,3,7-dimethyl</td>
<td>0.8661</td>
<td>0.7545</td>
<td>0.8354</td>
<td>0.7700</td>
</tr>
</tbody>
</table>

Ethalin: SnO\textsubscript{2}/Pt+SnO\textsubscript{2}/Ni+SnO\textsubscript{2}/Os; 1-pentene-3-one: SnO\textsubscript{2}/Os+SnO\textsubscript{2}/Pt+SnO\textsubscript{2}/Ni+SnO\textsubscript{2}/Os; 2-pentene-1-olz: SnO\textsubscript{2}/Pt+SnO\textsubscript{2}/Ni+SnO\textsubscript{2}/Os+hexanal; 2-Methylcyclopenta-1-olz: SnO\textsubscript{2}/Pt+SnO\textsubscript{2}/Ni+SnO\textsubscript{2}/Os+2-pentene-1-olz; (E)-3-ethyl-1,5-octadiene: SnO\textsubscript{2}/Pt+SnO\textsubscript{2}/Ni+SnO\textsubscript{2}/Os+2-pentene-1-olz; (E)-3-ethylene-1,5-octadiene: SnO\textsubscript{2}/Pt+SnO\textsubscript{2}/Ni+SnO\textsubscript{2}/Os+2-pentene-1-olz; (E)-3-ethyl-1,5-octadiene: SnO\textsubscript{2}/Pt+SnO\textsubscript{2}/Ni+SnO\textsubscript{2}/Os+2-pentene-1-olz; (E)-3-ethylene-1,5-octadiene: SnO\textsubscript{2}/Pt+SnO\textsubscript{2}/Ni+SnO\textsubscript{2}/Os+2-pentene-1-olz.
Biographies

Daniello Dolci was born in 1973. He graduated as Environmental Analytical Chemist, Faculty of Chemistry at the University of Bologna in 2001. Afterwards, he worked in the Micro-electronic and Microsystems Institute (IMM) of the National Research Council (CNR) for 1 year and half. He developed instrumental system (mainly for GC and GC/E-nose) for the analysis of aromas and flavours. At present, he works in the pharmaceuticals industry. His scientific interest is to improve the process technology and to decrease the chemicals emissions in the environment.

Cosimo Distante was born in Francavilla Fontana (Brindisi province) Italy in 1970. He received a Laurea degree in computer science from the University of Bari in 1997, and a PhD degree in material engineering from the University of Lecce, Italy. He has been a visiting researcher at the Computer Science Department of the University of Massachusetts at Amherst during 1998–1999. In 2001, he joined the Institute for Microelectronics and Microsystems (IMM) of the Italian National Research Council (CNR) as a research scientist. He is mainly interested in the fields of pattern recognition, robot learning, computer vision and intelligent interfaces for networked transducers.

Mauro Epifani graduated in Physics in February, 2000, with a work on the sol-gel synthesis of nanostructured materials for gas-sensing and optical applications. At present he held a permanent position as a researcher at the Institute for Microelectronics and Microsystems of the Council National of Research (CNR-IMM) in Lecce (Italy). His research interests concern the sol-gel preparation of mesoporous oxide thin films and hybrid organic–inorganic materials, and the chemical synthesis of metal and semiconductor colloids.

Dr. Pietro Siciliano, physicist, senior researcher, received his degree in physics in 1985 from the University of Lecce. He took his PhD in Physics in 1989 at the University of Bari. During the first years of activities he was involved in research in the field of electrical characterization of semicon- ductors devices. He is currently a senior member of the National Council of Research in Lecce, where he has been working from many years in the field of preparation and characterization of thin films for gas sensor and multilayer systems, being in charge of the Sensors and Microsystems Group. He is author of about 200 scientific papers, on national and international journals, and a lot of communication, some invited, to International Conferences. He is responsible for several national and international projects at IMM-CNR in field of Sensors and Microsystems, mainly for environmental, automotive and agro-food applications. He has been organiser and Chairman of International Conferences and Director of International Schools on Sensors and Microsystems. He is member of the Steering Committee of AISEM, the Italian Association on Sensors and Microsystems. At the moment he is Director of IMM-CNR in the Department of Lecce.

Antonella M. Taurino received her degree in Physics from the University of Lecce in April 2000, with a thesis on Electronic Nose. In 2001, she took an advanced post degree specialization course in Electron Microscopy. In 2004, she got her PhD in Materials Engineering with a thesis on nanostructured based gas sensors devices. At present she works in the field of structural and electrical characterization of innovative nanostructured materials for gas sensors application.

Marzia Zuppa received her degree in physics in 2001 from University of Lecce. She is a PhD student in Energetic System and Environment at the Innovation Engineering Department of the University of Lecce. Her current research interest is in the field of signal processing for chemical sensor data of miniaturized devices for environment quality control.