MIDDLE POMERANIAN SCIENTIFIC SOCIETY OF THE ENVIRONMENT PROTECTION
ŚRODKOWO-POMORSKIE TOWARZYSTWO NAUKOWE OCHRONY ŚRODOWISKA
Annual Set The Environment Protection
Rocznik Ochrona Środowiska
Volume/Tom 18. Year/Rok 2016 ISSN 1506-218X 964-973

Application of Gas Sensor Array to Preliminary Food Quality Assessment

Łukasz Guz, Henryk Sobczuk*, Henryk Wasąg*, Ewa Guz***
**Lublin University of Technology*
***Medical University of Lublin*

1. Introduction

Traditionally, human olfaction technique was used to discriminate the smell quality of different products (Loutfi et al. 2015). In some cases the dynamic olfactometry can be used for evaluation of food quality as well as nuisance of odour from food industry (Sówka et al. 2011). Very good results can be obtained by application of gas chromatography-olfactometry (GC-O) in analysis and quality assessment (Plutowska & Wardencki 2008; Wardencki et al. 2013).

Another complementary device for analysis could be gas sensor array (e-nose). Gas sensor arrays are used for smell profiles analysis since many years. The possibility of implementation of mobile devices for monitoring odour profiles around the environmental odour sources is promising. Using such a method the online monitoring of air nuisance could be available and can give the information about necessity of apply the measures to mitigate detrimental impact of air pollution. However, the sensor arrays are often used to food quality assessment (Ampuero & Bosset 2003; Peris & Escuder-Gilabert 2009). Stabilized and repetitive laboratory conditions enable to assess with high accuracy the quality parameters of food products (Falasconi et al. 2012; Loutfi et al. 2015). Sensors array are used for example to classification of products based on their smell (Chen et al. 2013; García-González et al. 2014). There was also attempts to application of gas sensors array to examine geographical origin (Pillonel et al. 2003), ripening stage (Trihaas & Nielsen 2005) or shelf life (Benedetti et al. 2005).

The issue of cheese classification and assessment of quality is theme of many articles (Cevoli et al. 2011). Different grades and brands of cheeses, such as cheddar (O'Riordan & Delahunty 2003), emmental (Ampuero & Bosset 2003, Pillonel et al. 2003), pecorino (Cevioli et al. 2011), crescenza (Benedetti et al. 2005), danish blue cheese (Trihaas et al. 2005), swiss cheese (Jou & Harper 1998) and many others (Gursoy 2009) were examined using electronic nose.

New technologies, particularly related with biosensors and immunosensors can contribute to further advancement in food quality assessment. In biosensors, an appropriate transduction element is covered with a biologically active layer (Kress-Rogers 1997). The special biological coating significantly enhances the selectivity and sensitivity of sensors. Therefore, biosensors can be applied for detection of specific compounds constituting metabolic products of various strains microorganism living on the food products. Generally biosensors can be divided into two groups: biocatalytic and bioaffinity-based sensors. The biocatalityc sensors are coated with enzymes, the main purpose of which is to catalyse biochemical reactions. In the case of bioaffinity-based sensors, a bioactive coating is made from specific binding compounds, especially from proteins, lectins, receptors, nucleid acid, membranes, amines, lipids or whole cells. The biosensors can be called immunosensors if antibodies or antibody fragments are used as biological active layer (Luppa et al. 2001; Lee et al. 2010). At present, the widespread use of biosensors is hindered by very limited commercial offer. Only specialized laboratories can afford to scrutinize the wide spectrum of biological active layer on biosensors (Baldwin et al. 2011).

Smell profiles derived from multisensory device are complicated and difficult to interpret because of their multidimensionality and must be analyzed by means of analytical instrument of pattern recognition in such large data sets. A Principal Component Analysis (PCA), Partial Least Squares, Discriminant Functional Analysis or Artificial Neural Networks (ANN) are often used to analysis of data (Ping & Jun 1996; Brezmes et al. 1997; Ushada & Murase 2006). In many cases the ANN is more effective to analysis a nonlinear data sets than other statistical methods (Paliwal et al. 2003).

The aim of this article is a verification a fast and inexpensive food product quality assessment methods by mean of device with MOS gas sensors array.

2. Materials and methods

The 15 g of examined sample were placed on the bottom of 1 dm^3 conical flask (Fig. 1). The flow of synthetic air through the flask at volume 0.5 dm^3/min was caused by membrane micro-pump built-in measurement device. Before each measurement session the sensors array was heated for several hours and afterwards was purged with synthetic air. The time of every measurement was equal 20 minutes. Between the examined samples the sensor array was flushed by synthetic air for 2 minutes.

The five tightly packed full-fat cheese types of one producer were examined: edam, tsarist, podlaski, salami, gouda. Additionally it was tested chosen food products: bread, cucumber, tomato, black tea, mint tea, parsley, dill, bay leaf, allspice, cocoa, and coffee. First stage of measurement were done immediately after cheese unpacking (class of good cheese) and second after 72 hours storage in improper conditions in 20°C (class of bad cheese). The quality of food products were sensory and visually evaluated for the presence of unpleasant smell as well as presence of fungi spores.

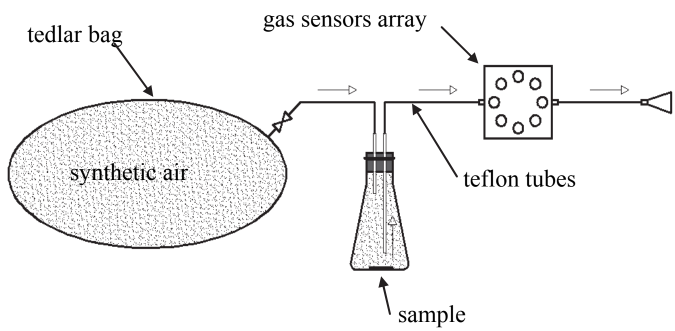

Fig. 1. Scheme of laboratory setup
Rys. 1. Schemat stanowiska badawczego

The sensors array consist of the eight MOS type gas sensors: TGS2600-B00, TGS2610-C00, TGS2611-C00, TGS2612-D00, TGS2611-E00, TGS2620-C00, TGS2602-B00 and TGS2610-D00 (TGS Figaro 2016). To temperature and relative humidity measurement the DS18B20 and HIH-4000 sensors are applied. The measuring devices is based on the construction described by Guz et al. (Guz et al. 2010; Guz et al. 2015).

The air flows through connector located in a central part of gas sensor chamber cover. The holes made in opposite side of small chamber allow to properly direct their flux over the sensors. Each sensor gives different signal response according to its sensitivity characteristics. In electrical circuit the simple resistor bridge consisting of two high precision resistor was used. The array response signal is measured with the ADuC741 24-bit analog to digital converter.

PCA analysis is used to transform complex and illegible data sets into new data set that reveal the information which were hidden by redundant data. PCA analysis reduces correlated dimensions, saving at the same time as much information as possible. Details about PCA analysis was presented in specialized books (Krzanowski 2000).

3. Results and discussion

Raw unscaled resistance (kΩ) from the particular sensors array are shown on the polar chart in Fig. 2 for the chosen groceries. The response of array was determined from the last minute of measurement (20^{th} min.). The sensors' response was stable and had not noticeable signal drift. For all sensors the mean signal noise and mean range of detected resistance variability, equaled 0.037 kΩ and 19.26 kΩ, respectively. Basic statistics of unscaled response of particular sensors are presented in Tab. 1. The smell profiles (set of all sensors' response) of presented food samples are different and allow to distinguish some products, eg. bread. Nonetheless, such multi-dimensional charts are inconvenient for preliminary assessment, and advanced methods of analysis should be applied. Therefore, the PCA was selected for the analysis of smell profiles.

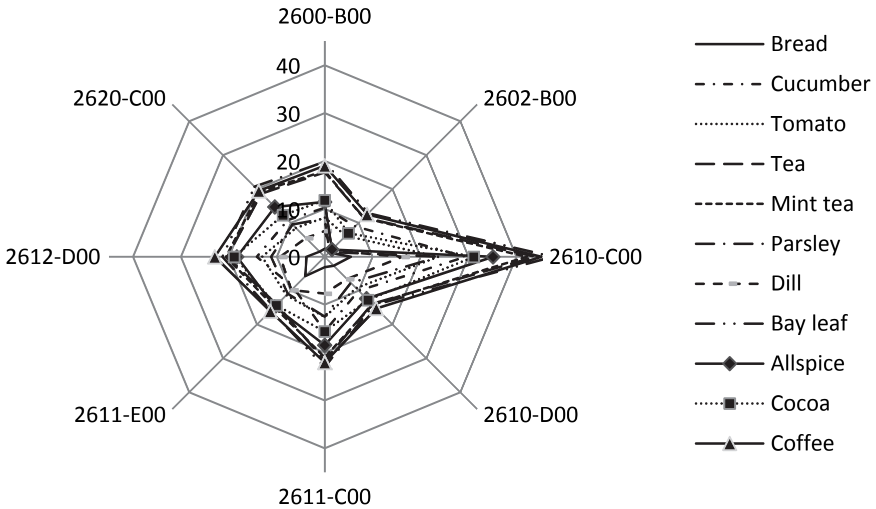

Fig. 2. Polar plot of sensor static response for the chosen groceries
Rys. 2. Wykres polarny statycznej odpowiedzi czujników na wybrane artykuły

The PCA analysis result of the chosen products, including fresh and stale cheese were shown in Fig. 3, on the two-dimensional charts. The first two principal eigenvalue captures 97.4% of the variability in the data. Particular products was located in definite areas of two dimensional principal component space. Between points represented cheese the other data points appeared, what can be serious impediment for recognition algorithm. Due to this reason it is impossible to derive general algorithm which would enable the quality assessment of all products.

Table 1. Basic statistics of unscaled sensors' response (kΩ) from last minute of measurements: range for all samples, mean signal noise
Tabela 1. Podstawowa statystyka nieskalowanych odczytów z czujników (kΩ) z ostatniej min. pomiaru: zakres dla wszystkich produktów, średni poziom szumów

Parameter	2600 -B00	2602 -B00	2610 -C00	2610 -D00	2611 -C00	2611 -E00	2612 -D00	2620 -C00
range (max-min)	18.17	11.61	42.17	12.60	20.89	10.33	19.12	19.17
mean signal noise	0.021	0.078	0.054	0.027	0.024	0.027	0.040	0.022

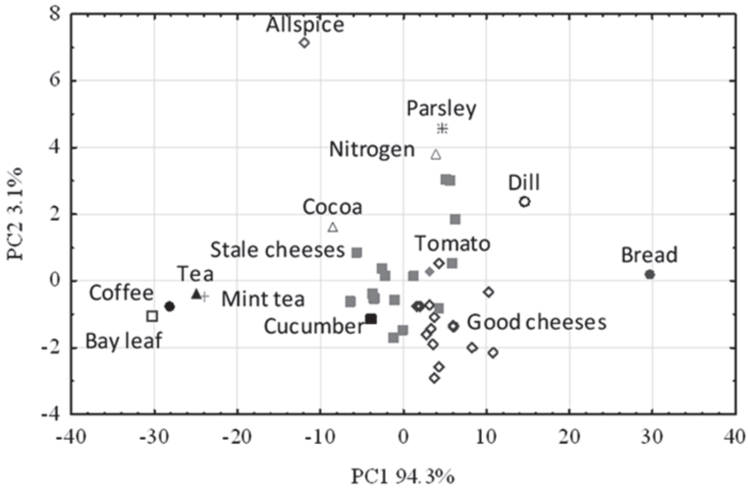

Fig. 3. PCA analysis plots of chosen articles
Rys. 3. Wykres analizy PCA dla wybranych artykułów

The additional PCA analysis was done only for cheese without miscellaneous articles and the results are shown on Fig. 4. In the chart it can be noticed that class of fresh cheese denoted as (1) and stale cheese (2) partially overlap. From the presented graph it can be ascertained that there are no distinct differences between cheese samples: fresh edam (E1), gouda (G1), podlaski (P1) and stale tsarist (C2). This indicate that even if it was taken few types of one product – cheese in this case – it is still troublesome to make quality assessment with applied sensors. From all measured samples, 23% of samples were classified incorrectly. The results is unacceptable, if consuming spoiled products can cause a food poisoning or more serious health problems.

It seems to be the best solution to derive evaluation algorithm for one specified type of food product. On the Fig. 5 the selected sort of products, good and stale were circled. If each product species is considered separately the classes of fresh and stale product are well distinguished. Coefficient of correct classification has increased to 100%.

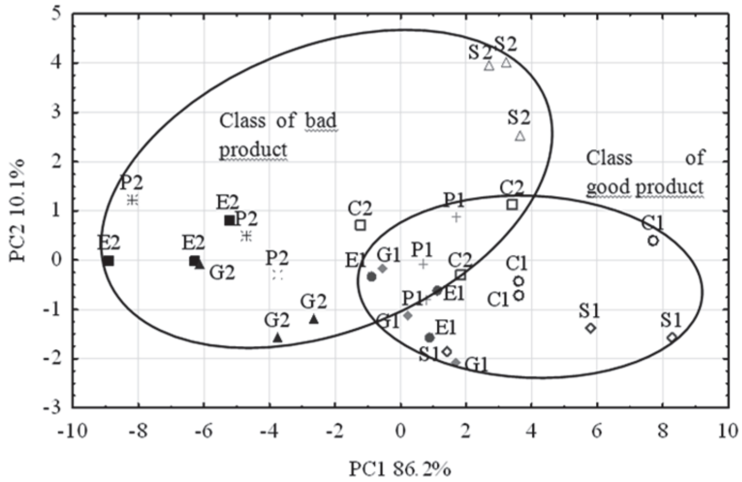

Fig. 4. PCA plots for fresh (1) and stale (2) of chosen types of products in overall: E – edam, G – gouda, P – podlaski, S – salami, C – tsaris
Rys. 4. Wykresy analizy PCA dla świeżych (1) oraz nieświeżych (2) wybranych typów produktów ogólnie: E – edamski, G – gouda, P – podlaski, S – salami, C – carski

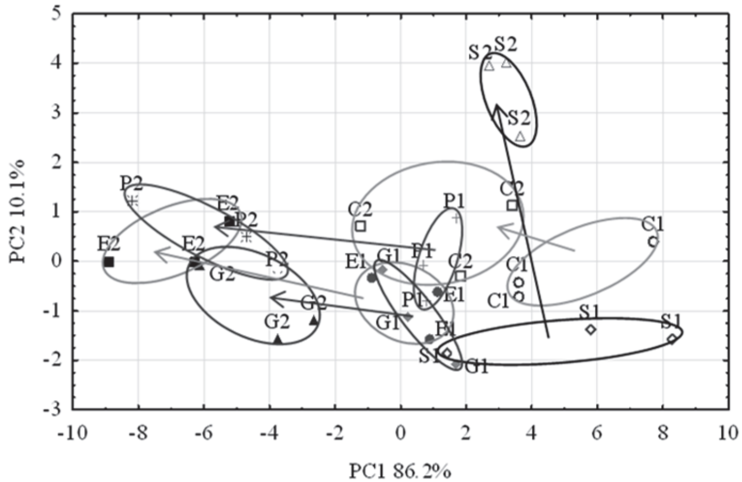

Fig. 5. PCA plots for fresh (1) and stale (2) marked separately: E – edamski, G – gouda, P – podlaski, S – salami, C – carski
Rys. 5. Wykresy analizy PCA dla świeżych (1) oraz nieświeżych (2) zaznaczonych oddzielnie: E – edamski, G – gouda, P – podlaski, S – salami, C – carski

4. Conclusions

By means of MOS gas sensors array, PCA analysis and artificial neural networks it is possible to assess food quality. The assessment is accurate and reliable only if used algorithm is derived for one specified type of product produced in identical technological process.

Bibliography

Ampuero, S. & Bosset, J.O. (2003). The electronic nose applied to dairy products: a review. *Sensors and Actuators B: Chemical, 94(1)*, 1-12.

Baldwin, E.A., Bai, J., Plotto, A. & Dea, S. (2011). Electronic Noses and Tongues: Applications for the Food and Pharmaceutical Industries. *Sensors, 11*, 4744-4766.

Benedetti, S., Sinelli, N., Buratti, S. & Riva, M. (2005). Shelf Life of Crescenza Cheese as Measured by Electronic Nose. *Journal of Dairy Science, 88(9)*, 3044-3051.

Brezmes, J., Ferreras, B., Llobet, E., Vilanova, X. & Correig, X. (1997). Neural network based electronic nose for the classification of aromatic species. *Analytica Chimica Acta, 348*, 503-509.

Cevoli, C., Cerretani, L., Gori, A., Caboni, M.F., Gallina Toschi, T. & Fabbri, A. (2011). Classification of Pecorino cheeses using electronic nose combined with artificial neural network and comparison with GC–MS analysis of volatile compounds. *Food Chemistry, 129(3)*, 1315-1319.

Chen, Q., Liu, A., Zhao, J. & Ouyang, Q. (2013). Classification of tea category using a portable electronic nose based on an odor imaging sensor array. *Journal of Pharmaceutical and Biomedical Analysis*, *84*, 77-83.

Contarini, G., Povolo, M., Toppino, P.M., Radovic, B., Lipp, M. & Anklam, E. (2001). Comparison of three different techniques for the discrimination of cheese: Application to the ewe's cheese. *Milchwissenschaft, 56*, 136-140.

Falasconi, M., Concina, I., Gobbi, E., Sberveglieri, V., Pulvirenti, A. &Sberveglieri, G. (2012). Electronic Nose for Microbiological Quality Control of Food Products. *International Journal of Electrochemistry, 2012*, 1-12.

García-González, D.L., Tena, N., Aparicio-Ruiz, R. & Aparicio, R. (2014). Sensor responses to fat food aroma: A comprehensive study of dry-cured ham typicality. *Talanta, 120*, 342-348.

Gursoy, O., Somervuo, P. & Alatossava, T. (2009). Preliminary study of ion mobility based electronic nose MGD-1 for discrimination of hard cheeses. *Journal of Food Engineering*, *92(2)*, 202-207.

Guz, Ł., Łagód, G., Jaromin-Gleń, K., Suchorab, Z., Sobczuk, H. & Bieganowski, A. (2015). Application of Gas Sensor Arrays in Assessment of Wastewater Purification Effects. *Sensors, 15*, 1-12.

Guz, Ł., Sobczuk, H. & Suchorab, Z. (2010). Odor measurement using portable device with semiconductor gas sensors array (in Polish). *Przemysł Chemiczny, 89*, 378-381.

Jou, K.D. & Harper, W.J. (1998). Pattern recognition of Swiss cheese aroma compounds by SPME/GC and an electronic nose. *Milchwissenschaft, 53(5)*, 259-263.

Kress-Rogers, E. (1997). Biosensors and electronic noses for practical applications. In: E. Kress-Rogers (Ed.), *Handbook of biosensors and electronic noses: medicine, food, and the environment* (pp. 3-39). New York, NY, CRC Press.

Krzanowski, W.J. (2000). *Principles of Multivariate Analysis: A User's Perspective*. New York, NY: Oxford University Press.

Lee, S.H. & Park, T.H. (2010). Recent Advances in the Development of Bioelectronic Nose. *Biotechnology and Bioprocess Engineering, 15*, 22-29.

Loutfi, A., Coradeschi, S., Mani, G.K., Shankar, P., Bosco, J. & Rayappan, B. (2015). Electronic noses for food quality: A review. *Journal of Food Engineering, 144*, 103-111.

Luppa, P.B., Sokoll, L.J. & Chan, D.W. (2001). Immunosensors– principles and applications to clinical chemistry. *Clinica Chimica Acta, 314*, 1-26.

O'Riordan, P.J. & Delahunty, C.M. (2003). Characterisation of commercial Cheddar cheese flavour. 1: traditional and electronic nose approach to quality assessment and market classification. *International Dairy Journal, 13(5)*, 355-370.

Paliwal, J., Visen, N.S., Jayas, D.S. & White N.D. (2003). Comparison of a neural network and a non-parametric classifier for grain kernel identification. *Biosystems Engineering, 85*, 405-413.

Peris, M. & Escuder-Gilabert, L. (2009). A 21st century technique for food control: Electronic noses. *Analytica Chimica Acta, 638*, 1-15.

Pillonel, L., Ampuero, S., Tabacchi, R. & Bosset, J.O. (2003). Analytical methods for the determination of the geographic origin of Emmental cheese: Volatile compounds by GC/MS-FID and electronic nose. *European Food Research and Technology, 216*, 179-183.

Ping, W. & Jun, X. (1996). A novel recognition method for electronic nose using artificial neural network and fuzzy recognition. *Sensors and Actuators B: Chemical, 37*, 169-174.

Plutowska, B. & Wardencki, W. (2008). Application of gas chromatography–olfactometry (GC–O) in analysis and quality assessment of alcoholic beverages – A review. *Food Chemistry, 107(1)*, 449-463.

Sówka, I., Skretowicz, M., Szklarczyk, M. & Zwozdziak, J. (2011). Evaluation of nuisance of odour from food industry. *Environment Protection Engineering, 37(1)*, 5-12.

TGS Figaro sensors datasheet, 2016. Retrieved from http://www.figarosensor.com.

Trihaas, J. & Nielsen, P. (2005). Electronic nose technology in quality assessment: monitoring the ripening process of Danish blue cheese. *Journal of Food Science, 70*, 44-49.

Trihaas, J., Vognsen, L. & Nielsen, P.V. (2005). Electronic nose: New tool in modelling the ripening of Danish blue cheese. *International Dairy Journal, 15(6–9)*, 679-691.

Ushada, M. & Murase, H. (2006). Identification of a moss growth system using an artificial neural network model. *Biosystems Engineering*, 94, 179-189.

Wardencki, W., Chmiel, T. & Dymerski, T. (2013). Gas chromatography-olfactometry (GC-O), electronic noses (e-noses) and electronic tongues (e-tongues) for in vivo food flavour measurement. In D. Kilcast (Ed.) *Instrumental assessment of food sensory quality: A practical guide* (195-229). Cambridge, Woodhead Publishing.

Zastosowanie matrycy tlenkowych czujników gazu do oceny jakości produktów spożywczych

Streszczenie

W publikacji przedstawiono metodę badania jakości artykułów spożywczych za pomocą matrycy wieloczujnikowej opartej na rezystancyjnych czujnikach gazu. Urządzenie pomiarowe składające się z 8 czujników typu MOS określa profile zapachowe próbek. Przebadane zostało 5 gatunków żółtego sera w różnych stanach świeżości, poddane przechowywaniu w niewłaściwych warunkach. Do analiz wstępnych została wykorzystana statystyczna analiza głównych składowych (PCA). Analiza PCA wykazała skuteczność opisywanej metody oceny jakości jedynie w obrębie jednego gatunku danego produktu. Niemożliwe jest opracowanie ogólnego algorytmu określającego jakość dowolnej liczby gatunków danego produktu.

Słowa kluczowe:
matryca czujników gazu, profil zapachowy, ser, ocena jakości

Keywords:
gas sensor array, smell profile, cheese, quality assessment