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Review Article

Benefits of the Applications of Advanced Method in Food Inspection

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Abstract

The Electronic noses are devices able to characterize and differentiate the aroma profiles of the various foods, especially the meat and the meat products. During the recent years advanced method, the e-noses have been widely used in the food analysis and proved to provide a fast, simple, non-expensive and non-destructive method of the food assessment and quality control. The aim of this study is to summarize the most important features of this analytic tool and to present basic fields and the typical areas of the e-nose use as well as most commonly used sensor types and patterns for the e-nose design. Prospects for the future development of this technique are presented. The Methods and the researches may be a guideline for the practical e-nose use.

Key Words: electronic nose; sensors; gas chromatography; odor

Introduction

The most important factors affecting freshness and quality of the poultry and the fish are the color, the texture and the flavor. The Meat flavor quality is determined by composition of VOC as its critical factor. They should be qualified by electronic nose (e-nose) in the same way as human senses, because these modalities are the basis for human perception of freshness and quality. The odor of the meat is formed by a complex mixture of the different volatile organic compounds, originating from various reactions. It is often stated that the fresh meat is almost unscented and the only odor that can be detected by the consumer is described as bloody. During storage or thermal processes, the precursors of the aroma constituents undergo oxidation and decomposition reactions leading to a number of products which can then react further providing the organic compounds of low molecular mass and usually these secondary products are responsible for the odor development (1,2,3,4,5,6 and 7). The characteristic aroma of the meat usually originates from the thermal processes like the cooking, the roasting or the frying. The Chemical reactions occurring during the heat-treatment involve degradation of the amino acids, the peptides, the sugars, the ribonucleotides, the lipids and the vitamins. The key process in the aroma formation is Maillard reaction that occurs between reducing sugars and amino acids derivatives. The characteristic compounds for the cooked meat are the aldehydes, the ketones, the alcohols, the hydrocarbons, the pyrazine derivatives and the Sulphur compounds. A specific effect is the warmed-over flavor (WOF), which develops during the storage in the meat after the cooking. It comes from the lipid oxidation induced by the iron released from the myoglobin and hemoglobin during the cooking. The unpleasant odor is described as the metallic, the musty and the pungent and the secondary oxidation products responsible for it are hexanal, 2,3-octanediol, pentanal, 2-pentylfurane and 2-octenal (8,9,10,11,12,13 and 14) Another process connected to the odor development apart from the heat treatment of the meat is spoilage. During the storage the bacterial activity leads to the production of the volatile organic compounds of the unpleasant odor, most of which are easily identifiable (methanol, ethanol, dimethyl sulfide, methyl thioacetate, toluene, nonane, 2,3-butanediol and others). The Alcohols, the hydrocarbons, the aliphatic the ketones, the volatile acids and the benzenic compounds are the compounds typical for the physicochemical changes generated as a result of fat decomposition and lipid oxidation. The aroma profile of the meat can be influenced by different factors like the fat content, the animal diet, the breed, the pH, the storage condition or the heat treatment method. This subject is still not fully explored despite of many discussions. Assessment of the meat freshness can be done by analysis of mixture of volatile organic compounds. Classical methods of analysis of the meat aroma profile involve the gas chromatography (GC) and the olfactometry (O). A fusion of these two techniques, GC-O, combines the ability of the chromatographic unit to separate different compounds and the capability of the olfactometric system to characterize them (24,25,26,27,28,29,30,31 and 32). Apart from the chemical methods, the sensory descriptive analysis is still of great significance. The aroma profile is difficult to analyses and characterize in the laboratory since the human sense of smell does not distinguish individual components but rather identifies the specific mixture of volatiles as a whole. The Classical methods of chemical analysis based on gas chromatography result in the identification and the quantification of the particular compounds which can be considered the most important odor indicators. Often the single compounds present in meaningful quantity in the aroma profile are not noticeable by the human sense of the smell. The practice shows that there is not always a simple correlation between the concentration of particular compounds and the odor perception. Electronic noses are analytical instruments designed to mimic the work of the human sense of the smell. In this technique the analytic process does not concentrate on the identification and quantification of the components of the mixture of volatile compounds but rather on the quantitative description of the complete aroma profile, including the relationships between its components. In many researches the time change of the profile or the profile change in relation to standard profile is important. In such cases volatile profile is a fingerprint typical for certain test. The most important issues are presented below (33,34,35,36,37,38,39,40 and 41). The standard e-nose equipment is based on a series of gas sensors able to collect the chemical signal coming from the headspace and to transmit it to the electronic devices. Different types of sensors can be used for different applications, among them the most popular are electrochemical sensors like metal oxide semiconductors (MOS) or the conducting polymers (CP) and the piezoelectric sensors like quartz microbalances (QCM). The Optical, calorimetric and biosensors can be also incorporated into the e-nose system. Those innovative types of advanced method e-noses based on gas chromatography (GC) or gas chromatography with mass spectrometry (GC/MS) have been introduced recently and their high utility has been demonstrated. In this type of detection each peak from a mass spectrum or a chromatogram acts as a “sensor” providing also information about the chemical structure of the corresponding compound. Usually, it is a standard to couple e-nose with multivariate software equipped with the software tools for the chemometric interpretation of the sensor signals (42,43,44,45,46,47,48,49,50 and 51). The data collected from the sensors are analyzed using various statistical tools in order to create a numerical model of the aroma profile of the sample. When having a quantitative description of the aroma profile of samples one can then compare the unknown samples with the reference materials or study the influence of different factors on the odor. The most effective statistical methods used in these types of investigation include principal component analysis (PCA), partial least squares regression (PLSR), linear and canonical discriminant analysis (LDA and CDA) or the artificial neural networks (ANN). Although advanced method the e-noses are rather an unreliable tool for the determination of specific chemical compounds constituting the aroma profile, the advantages of this method over the traditional ones are conspicuous. The analyses are fast, simple and low-cost, what makes the e-nose a gratifying analytical method for quality-control applications. However, this technique requires specific and time-consuming training for staff. This review paper aims to present diversity of types of advanced method the e-noses used for the evaluation of the meat and the meat products. Prospects for the future development of this technique are presented. The Methods and the researches which discussed may be a guideline for the practical e-nose application (62,63,64,65,66,67,68,69 and 70).

The Applications of the e-nose in the meat analysis

The Spoilage monitoring Traditional methods of the meat spoilage

The monitoring is based on measurements of chemical or biological spoilage indicators. Standard tests include total bacterial count (TBC), rancidity measurements with thiobarbituric acid reactive substances assay (TBARS), determination of the VOCs by GC-MS and total volatile basic nitrogen (TVBN) measurements. The Colour evaluation and sensory descriptive analysis can be also useful in the detection of spoiled samples. However, all these methods are rather costly, time consuming and require specialized staff, what makes them difficult for on-line applications (71,72,73,74,75,76,77,78,79 and 80). As the spoilage process is strongly connected with odor changes, the most of studies investigate the possibilities of employing e-nose to this purpose. A standard procedure in this type of study involves choosing the storage conditions (the type of the packaging and the temperature), usually mimicking storage in typical household or industrial conditions and analyzing samples after different periods of time. A special attention must be paid to ensure careful preparation of the samples in order to preserve the headspace composition during storage and analysis. The sensor types used for this purpose include mainly metal oxide semiconductors or conducting polymers. During last years a few applications using colorimetric sensors could be noticed (81,82,83,84,85,86,87,88 and 89). The statistical tools employed for data analysis involve multivariate statistics and artificial neuron networks. The obtained results are then confronted with data from reference methods based on the microbiological evaluation, sensory descriptive analysis or chemical determination of spoilage indicators. A number of fully successful attempts to employ advanced method e-noses for the meat spoilage monitoring prove the utility of this analytic tool. Therefore e-nose found application as a laboratory tool, yet no in industrial practice. The prospects of method development involve further investigation of the value of information coming from particular sensors and constructing new portable instruments with reduced number of sensors in order to minimize costs and simplify the analysis (90,91,92,93,94,95,96,97,98 and 99).

The Differentiation between types of the meat

The Determination of the animal species from which the meat was produced is an important problem of the food analysis. From the consumer’s point of view, it is an essential issue not only because of quality of the product or the meat adulteration but also because of health, dietary and religious aspects. The classical methods of the meat species identification involve expensive and time-consuming molecular biology-based methods or spectroscopic measurements requiring specialized equipment and complex data analysis. It has been recently demonstrated that e-nose can be a reliable analytic tool for screening of the meat samples for animal species origin (100,101,102,103,104,105,106 and 107). A successful differentiation between the meat samples from sheep, cattle, poultry, and swine was performed using an electronic nose based on gas chromatography. A simple statistical data analysis using principal component analysis (PCA) could clearly separate groups of samples derived from different animals. Moreover, although advanced method the e-noses generally do not give information about chemical composition of the headspace, the chromatographic analysis performed by this type of e-nose allowed the tentative identification of compounds responsible for the aroma profile, using Kovat’s indices. The methodology presented in the study was extremely simple, fast and no-expensive, providing a useful tool for the food analysis. The ability of electronic nose to discriminate between types of the meat can be also applied in the detection of the meat adulteration with proteins from another, cheaper species. The Pork adulteration in minced mutton was studied with an e-nose containing 10 metal oxide sensors. Mutton samples were mixed with pork in different proportions and the headspace of each sample was tested with the e-nose. Various statistic tools were implemented to analyze the data obtained (PCA, DA, PLS, MLR and BPNN) and it was clearly demonstrated that the e-nose methodology coupled with multivariate analysis can easily predict the degree of adulteration of pork in minced mutton. There are also other possibilities to use e-nose technique for the meat type and quality differentiation for the meat adulteration detection and for quality control (108,109,110,111,112,113,114,115 and 116).

The Evaluation of the effect of dietary supplementation of the animals

The Animal nutrition has a potent influence on the meat quality. Different types of dietary regimes can be applied for specific purposes, among them supplementation of functional ingredients such as vitamin E, selenium, conjugated linoleic acids or omega-3 fatty acids gained a special interest over last years. The Evaluation of the relationship between animal diet and the meat attributes is an important feature. An investigation of animal diet influence on overall antioxidant power in the meat and its connection with the aroma profile. Crossbreed steers were either pasture or grain-fed and in both groups a part of animals obtained an additional vitamin E supplementation. An e-nose with 32 conducting polymer sensors was used to analyze the aroma profile of fresh beef samples from all the four groups. Antioxidant capacity tests were also performed. The relationship between the e-nose data and the antioxidant status related variables was analyzed while the linear discriminant analysis of e-nose measurements was employed to investigate the meat samples grouping as a function of feeding (52,53,54,55,56,57,58,59,60 and 61). The e-nose distinguished correctly grain and pasture produced meat as well as supplemented and nonsupplemented with vitamin E grain produced meat. These results show that the aroma profile of the meat is strongly related on the antioxidant status which affects the lipids oxidation influencing the consequent production of volatile short chained aldehydes. The e-nose proved therefore to be a useful tool to discriminate the aroma profile of the fresh meat samples with different antioxidant potential. The influence of animal dietary regimes on the lipid oxidation can manifest in the change of volatile compounds profile of the meat and this effect was also investigated with the use of e-nose. In described experiment, pigs were divided into four feeding groups with different diets: control diet, supplemental vitamin E and organic selenium diet, supplemental organic selenium diet and supplemental vitamin E diet. The samples were analyzed using electronic nose equipped with ultrafast gas chromatograph with flame-ionization detectors. The e-nose data were analyzed using the Aro Chem Base database and ANOVA. The measurements performed by the e-nose showed that the addition of antioxidants to the pigs feed prevented the formation of Sulphur compounds in the raw meat. The electronic nose successfully allowed to determine seventeen specific volatile compounds in the supplemented meat (15,16,17,18,19,20,21,22 and 23).

The Production process monitoring

There are rather few examples in literature of direct use of e-nose for production process monitoring. Usually these are older references such as e-nose usage to identify spoiled Iberian hams during the curing process. They discussed use of e-nose for recognition of different Iberian ham ripening times. The sensors with tin-oxide semiconductor thin films were used for the tests. Some of the sensors were doped with metal catalysts. The PCA was used for results analysis together with artificial neural network. Electronic nose can be applied to study dynamic processes occurring during production of sausages. An investigation of the seasoning processes for the dry-cured meats was performed with an electronic nose containing 12 metal oxide sensors. Fresh pork sausages were subjected to the manufacture's protocols and 5, 7, 10, 14 days seasoning. Research included monitoring of presence of ochratoxin A-producing and non-producing Penicillium strains during the seasoning process. The Food contamination with the ochratoxins is very dangerous for humans and is considered as possibly carcinogenic by The International Agency for Research on Cancer in 1993. The e-nose data were analyzed using DFA. Proposed research technique was successfully applied for the rapid prediction of ochratoxin A. These mentioned applications of the e-nose are satisfactory examples of successful use of e-nose based systems for quality control (119,118,119,120,121,122,123,124 and 125).

The Specific purposes:

The boar taint and the WOF evaluation the Boar taint and the WOF are the sensory defects in the meat flavor. The Boar taint is characteristic for pork derived from non-castrated male pigs. It is connected to the presence of the androstenone and the skatole but it was shown that the sensory evaluation of the 'boar taint' level does not always agree with the absolute concentrations of these two compounds. There is therefore a demand for developing a system able to efficiently discriminate between different intensities of this undesirable odor. Used e-nose and sensory panel to measure the intensity of the boar taint in the entire male pigs. An electronic nose based on ion mobility spectrometry was employed to mimic the responses given by the sensory panel. The data from e-nose analysis were calibrated using canonical correlation with the sensory measurement and a discriminant function for separating levels of boar taint in pork by e-nose was developed (126,127,128,129,130,131 and 132). The Sensorics research affirmed stronger correlation of the boar taint with the androsterone than with the skatole. The research showed that e-nose technique based on ion mobility spectrometry may have a potential for a rapid sorting of boar fat at the slaughter line. The warmed-over flavor develops in the meat which has been pre-cooked, chill stored and reheated. The sensory analysis of volatile compounds on the meatballs derived from pigs fed with standard diet supplemented with the addition of rapeseed and palm oil using solid state-based gas sensor array system (e-nose) and the gas chromatography/gas spectrometry together with measurements of thiobarbituric acid reactive substances (TBARS). The Obtained data were analyzed using partial least square regression modelling (PLSR). MOS sensor responses showed to be significantly related to WOF characteristics detected by both sensory and chemical analysis. This shows the potential of using gas sensor technology to monitor WOF in the pork. The simple and rapid method of prediction of WOF in cooked chicken by colorimetric sensor array. The Data from colorimetric sensor array was classified using principal component analysis and hierarchical cluster analysis. Research showed that colorimetric sensor array may be successfully used to predict WOF development in the cooked chicken meat (133,134,135,136,137 and 138).

Conclusions:

In the recent years it was demonstrated that electronic noses provide a fast, simple and non-destructive method of the meat analysis. advanced method E-noses were successfully employed mainly in the quality control of the meat being able to monitor spoilage or adulterations and the obtained results were in accordance with the sensory evaluation, offering a reliable tool for on-line analysis. The ability of e-nose to determine the antioxidant status of the meat samples was also proved. It can be stated that every factor that influences the aroma profile of the meat, could be potentially indirectly analyzed with the e-nose system and this field still seems to be insufficiently explored. Moreover, the development of new types of advanced method e-noses, based on gas chromatography, opens new perspectives for analysis of the aroma profile of the meat. Despite of many scientific works proving usefulness of e-nose based on different types of sensors or GC techniques for the meat quality appraisal or spoilage detection, use of e-nose in industry practice is insufficient. There was not found any description or report on large scale industrial application of e-nose. Almost every paper describes potentially large possibilities of use of e-nose in industrial practice, but none reports real-life implementation. This may be explained by sensor vulnerability (sensor time drift), relatively high e-nose costs and effort consuming staff training. The above does not mean that e-nose will not be used widely in future in industrial practice. There is still lack of effective application, although the potential of e-nose approach was proven.

Conflicts of Interest

The author declares no conflicts of interest

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