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Detection of rancidity in freeze stored turkey meat using a commercial gas-sensor array system

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Abstract

Rancidity has been investigated with a commercial solid state based gas-sensor array system in freeze stored turkey stored at two different temperatures, −10 and −20 °C and different atmospheric conditions, respectively in presence of air and under vacuum. Samples were kept stored up to 9 months and analyzed at different times during storage. The gas-sensor readings showed high correlation with reference measurement data as TBARS, secondary volatile oxidation products, and rancidity related sensory attributes ($r > 0.9$, $p < 0.001$). It could be demonstrated that the gas-sensor based method had a similar ability as a trained sensory panel to detect lipid oxidation in freeze stored turkey meat. For samples stored in vacuum or at −10 °C a better discrimination was obtained with the gas-sensor array system. It was possible by means of selected sensor readings to obtain a complete discrimination between the samples stored in air at −10 and −20 °C, and vacuum and air stored samples from −20 °C, respectively. The performance of the gas-sensor array system with regard to the prediction of rancid odour and flavour was confirmed by GC/MS analysis showing that the major volatile compounds where also the lipid oxidation derived products representing the key rancid odour compounds. The results suggest that solid state based gas-sensor arrays could be an alternative rapid method to detect and quantify lipid oxidation in freeze stored poultry products.

Keywords: Gas-sensor array; Lipid oxidation; Turkey meat

1. Introduction

Storage conditions have a strong impact on the overall quality of meat products. In particular, lipid oxidation is one of the main factors limiting the quality and acceptability of lipid containing foods. This chemical alteration affects the flavour and odour quality of meat products in a negative way. The occurrence of rancidity in poultry meat is related to cold and frozen storage over longer period of time. Poultry meat, in particular, is prone to become rancid during storage due to occurrence of high abundance of pro-oxidants and the use of fish by-product containing feed with high abundance of polyunsaturated fatty acids, which makes this meat more vulnerable to lipid oxidation. In the food industry, there is an increasing demand for effective methods to determine and to detect lipid oxidation. During lipid oxidation a significant proportion of volatile secondary oxidation products, in particular aldehydes, are generated [1] and gas-sensor technology could therefore have a potential for determination of rancidity in stored poultry meat.

A few studies have been reported on the use of gas-sensor arrays for determination of lipid oxidation in foods, in particular on edible and fish oils [2–4]. These studies point at the potential gas-sensor array technology could have in determining the rancidity of pure lipids. However, very few papers have been published so far on the use chemical sensor arrays for the detection of lipid oxidation in meat products. In particular, the metal-oxide-semiconductor field-effect transistor (MOSFET) sensors with a thin catalytic metal gate have proved high sensitivity to typical volatile lipid oxidation products like aldehydes and ketones [4].

The purpose of this study was to evaluate the potential of a commercial hybrid MOSFET and MOS based gas-sensor array system for indirect determination of lipid oxidation in freeze stored turkey meat. Since the classical reference methods for determining oxidation of foods are in general time consuming, it is of interest to evaluate whether gas-sensor technology may be a rapid technique that can replace the traditional chemical and

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sensory methods. In addition, it was also of interest to assess to what extent this technique might have the ability to predict lipid oxidation at an early stage of the oxidation process.

2. Materials and methods

2.1. Samples

Turkey thighs without skin were collected at a commercial slaughterhouse and stored 1 day before mincing and packing. The meat was grounded through a plate (4 mm). One half was packed in plastic bags under vacuum, and the other half in plastic bags with air. The bags with air also had small holes so that oxygen could penetrate into the package. The meat packages contained 300 g minced turkey thighs and the meat layer was about 1 cm thick. A simple experimental design was chosen, so that the lipid oxidation should be relatively easy to follow; two different storage temperatures were used, −10 and −20 °C. Samples were taken out every second week over a period of 6 months and every fourth week the next 3 months, and stored at −80 °C until analysis. The total sample set consisted of 55 samples stored at respectively −10 and −20 °C, i.e. 17 samples in air, 10 samples in vacuum and 1 fresh unstored sample. The samples stored in air were repacked under vacuum before the second storage at −80 °C prior to analysis. The frozen samples were thawed at 4 °C over night prior to analysis.

2.2. Reference methods

The following analysis methods were included: thiobarbituric reactive substances (TBARS), Sensory analysis and dynamic headspace gas-chromatography mass-spectrometry (GC–MS). The thiobarbituric acid reactive substances (TBARS) test is a traditional method used to measure rancidity in foods and measures oxidation products of polyunsaturated lipids. TBARS values were determined in duplicate by the method of Sørensen and Jørgensen [5]. After extraction of 10 g meat and reaction with TBA, absorbance was measured at 532 nm against a blank containing 5 mL distilled water and 5 mL TBA reagent. Results expressed as mg malondialdehyde per kg meat were calculated from the 1,1,3,3-tetrahydroxypropane (TEP) based standard curve.

For the sensory analysis, a professional panel consisting of 11 trained female assessors was used. The assessors have been selected on the basis of standardised performance tests with regard to sensitivity and reproducibility [6]. Quantitative descriptive analysis (QDA) was performed according to international standard methods [7]. The samples were vacuum-packed in plastic bags, before heating in a water-bath at 80 °C for 30 min. Each assessor was served 20 g meat directly from the plastic bag. Samples were served once and the serving order was randomised. The odour and flavour attributes were evaluated according to a continuous scale ranging from the lowest intensity of each attribute (value 1.0) to the highest intensity (value 9.0). The assessed rancid odour and flavour were defined by terms like grass, hay, stearine, paint, and soap. In addition, also other odour and flavour were assessed as intensity, metallic, turkey, acidic, sour, off and stale.

Gas chromatography analysis was carried out on samples in order to identify and quantify volatile organic compounds and sampling was performed by applying dynamic headspace according to [8]. Fifteen grams of homogenised sample was distributed evenly in a 250 mL Erlenmeyer flasks. The samples were heated to 70 °C in a water-bath and purged with 100 mL/min nitrogen through a Drechsel-head for 30 min. Volatile compounds were adsorbed on Tenax GR (mesh size 60/80). Water was removed from the tubes by nitrogen flushing (50 mL/min) for 5 min in the opposite direction of sampling. Trapped compounds were desorbed at 250 °C for 5 min in a Perkin-Elmer Automatic Thermal Desorption System ATD400 and transferred to an Agilent 6890 GC System with an Agilent 5973 Mass selective detector, which is a quadropole, operated in electron impact (EI) mode at 70 eV. Scan range was from 33 to 300 amu. The compounds were separated on a DB-WAXetr column from J&W Scientific/Agilent (0.25 mm i.d., 0.5 μm film, 30 m). Helium (99.9999%) was used as carrier gas. The temperature program started at 30 °C for 10 min, increased 1°C/min to 40 °C, 3°C/min to 70 °C, 6.5°C/min to 160 °C, 20°C/min to 230 °C with a final hold time of 4 min. Integration of peaks and tentative identification of compounds were performed with HP Chemstation (G1701CA version C.00.00, Agilent Technologies), Wiley 130 K Mass Spectral and NIST98 Mass Spectral. Comparison of retention times and mass spectra of the sample peaks with those of pure standards confirmed identities of several of the components. System performance was checked with blanks and standard samples before, during and after the sample series. The concentration of the volatile compounds was calculated in ng/g sample based on an internal standard (heptanoic acid ethyl ester). All samples were analysed in duplicate.

2.3. Gas-sensor measurements

The gas-sensor array instrument used was an AppliedSensor AB, model 3320, consisting of 10 MOSFET, 12 MOS sensors and an IR-based CO_2-senor. Charcoal filtered humidified ambient air was used as reference gas and 1% ethanol in distilled water was used as calibration gas.

For the gas-sensor analysis, 6 g of sample were transferred to 30 ml glass vials with teflon/silicon septa and screw cap. The vials were flushed by a stream of nitrogen before they were capped to prevent oxidation during incubation. The temperature of the samples was conditioned to room temperature at 22 °C, before they were placed in the autosampler of the electronic nose. Thereafter the samples were incubated at 60 °C for 20 min each before headspace gas was pumped into the sensor chamber for 10 s at a flow-rate of 150 mL/min. Recovery time for the sensors was 240 s (flushing with reference air). Samples were analysed in random order and calibration samples were measured after every tenth sample in order to monitor possible sensor drift.

2.4. Data analysis

For the data analysis, principal component analysis (PCA) and Partial Least Squares regression (PLSR), with full cross