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Oral presentation

The use of chemical sensor array technology, the electronic nose, for detection of boar taint

JE Haugen*

Address: Matforsk AS, Norwegian Food Research Institute, Osloveien 1, N-1430 Ås, Norway

* Corresponding author

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Introduction

Boar taint represents a complex issue related to a few key odour compounds present in pork meat. Studies have indicated that the substances skatole and androstenone contribute most to the sensory perception of boar odour and flavour, but also other substances have been suggested to play a role in the overall perception of boar taint. Analysis of off-odours and flavour in meat and meat products has traditionally been performed either by a trained sensory panel or by headspace gas chromatography mass spectrometry. In some cases, sensory assessment may fail in identifying boar taint represented by the chemical compounds androstenone and skatole. This may be due to anosmia, low odour thresholds to these compounds or misclassification due to other interfering off-odour compounds not related to boar taint (i.e. rancidity). The mentioned methods for detecting boar taint are time consuming and costly and it would therefore be useful to have objective rapid methods in order to sort out the boars on the slaughter line based on both chemical and sensory criteria. New methods should allow a high number of samples to be analysed within a short period of time with a sufficient reproducibility and accuracy.

Recently, there has been a rapid development of chemical sensor technology for analysis of volatile compounds. Chemical sensor arrays combined with multivariate data processing methods have demonstrated to have a potential for rapid non-destructive analysis of meat quality [1,2]. Non-specific gas-sensor arrays have the potential of detecting several compounds in the vapour phase related to boar taint. Accordingly, this could allow the measurement of the odour of the meat instead of analysing the specific compounds that might be responsible for boar taint. This technique cannot completely replace reference methods like the use of sensory panels, as the technique requires training and calibration against sensory analysis or some valid reference method.

Commercially available gas-sensor devices cover a variety of chemical sensing principles, system design and data analysis techniques. Gas-sensors are based on physical or chemical adsorption and desorption, optical adsorption or chemical reactions of an analyte in the gas phase that take place on the surface and/or in the bulk of the sensor material. These interactions cause characteristic physical changes of the sensor to be detected. A series of different transducing principles can be used in chemical gas sensors: heat generation, conductivity, electrical polarisation, electrochemical activity, ionisation, optical properties, dielectric properties and magnetic properties.

Gas-sensor technology has been suggested as a potential technology for future on-line use in sorting of boar-tainted carcasses on the slaughter-line. In recent years there have been reported several attempts to apply gas-sensor technology for the detection of boar-taint. The research in this field comprise limited feasibility studies analyzing pure lipid phases (oils and fats) spiked with pure androstenone and skatole and mixtures of both at different concentration levels and real backfat samples from boars with different levels of skatole and androstenone. A brief state of the art presentation of reported feasibility trials will be given and a discussion on the issues and challenges related to the development of a dedicated gas sensor technology for on-line detection of boar-taint at the slaughter line.

Discussion

Berdagué and Talou [3] analysed backfat samples from female, castrate, and entire male pigs with a prototype solid state based gas-sensor (MOS) array system after heating the samples. The measurements showed different gas-sensor signal profiles for the different sexes and they were able to discriminate the boar samples from the females and castrates. In another study with solid state based gas sensors [4], backfat from entire male pigs with 105 kg slaughter weight ranging from 0.1–15 μg/g androstenone was measured. 2–3 gram sample was heated at 150°C for 30 seconds in a 2.5 l flask and 50 ml gas volume was analysed. A correlation of $r = 0.9$ between the sensor readings and androstenone levels was obtained. By selecting two classes on the basis of androstenone content, <0.7 and >1.7 μg/g, they obtained 85 % classification rate. Annor-Frempong et al. [5] applied a commercial 12-conducting polymer sensor array on the measurement of pure lipid samples spiked with different levels of skatole and androstenone and entire male backfat samples. In addition the samples were assessed for extent of boar tainted odour by a trained sensory panel. Fat samples from Large White crossbred male pigs (68–105 kg slaughter weight) were used. The responses of the gas-sensor array showed a significant canonical correlation with the sensory panel ($r = 0.78$). In addition, the sensor system was able to discriminate pork samples with low (<0.2 skatol and < 0.5 androstenone), intermediate (<0.2 skatole and <1.0 androstenone) and high (>0.2 skatole and > 1.0 androstenone) levels of androstenone and skatole. In another study [6], using a commercial conducting organic polymer sensor array, it could also be shown that the sensor system could discriminate between belly fat from female, castrate and entire male pigs 70–110 kg in slaughter weight. The samples varied from 0.2–2.8 μg/g in androstenone and 0.03–0.7 μg/g in skatole content. 20 gram of fat was kept in 600 ml flasks and incubated for 7 minutes at 30°C before purging headspace gas into the sensor chamber. In this study, they were able to discriminate samples with different levels of boar taint with regard to low and high levels of respectively skatole and androstenone.

In a Norwegian study, the incidence of boar-taint in young boars, 34–45 kg in slaughter weight, was investigated [7]. A hybrid commercial solid state gas-sensor array system with MOSFET and MOS type sensors was used. 5 gram backfat samples varying from 0.06–0.8 μg/g in skatole and 0.02–3.3 μg/g in androstenone were incubated for 30 minutes at 65°C in 30 ml vials before the gas measurement. The sensor readings showed a significant correlation, $r = 0.7$, with androstenone levels and $r = 0.5$ with skatole. However, low correlation was obtained with the sensory scores of respectively boar odour and boar flavour. In a recent study a prototype of four different porphyrine coated quartz resonator sensors (QMB) have been used to detect androstenone in pork fat [8]. The sensor system was tested on pork fat samples spiked with various concentrations of androstenone ranging from 0.7 to 10 μg/g. Samples were prepared in sealed vials and incubated at 35°C for 30 minutes followed by extraction of sample headspace gas into the sensor chamber. The difference in sensor signals of the androstenone spiked fat and pure pork fat showed high non-linear correlation with androstenone concentrations for the single sensors. By using the sensor signal of all four sensors, they obtained a correlation of $r = 0.98$ with androstenone concentration. It was also demonstrated that the sensor system was able to discriminate the samples with different levels of androstenone. In another recent study by Vestergaard et al. [15] backfat samples from young boars [9] were analysed by using a commercial ion mobility spectrometer in combination with a MOS gas sensor (MGD-1, Environics Ltd., Finland). The male pig samples varied in androstenone and skatole levels (0.09–0.88 μg/g and 0.01–0.26 μg/g fat, respectively). Sensory perceptible boar taint (especially boar odour) was found to be more related to androstenone than to skatole. Multivariate models implementing some generally prescribed cut-off limits for androstenone (0.50 μg/g) and skatole (0.21 μg/g) indicated that the e-nose could be used for categorising samples with respect to these cut-off limits. E-nose data were good predictors of the chemical compounds androstenone ($r = 0.97$) and skatole ($r = 0.79$).

The high correlation found for androstenone with gas-sensor data may not necessarily imply that the sensors are sensitive enough to detect this compound specifically in the vapour phase of real fat samples, since there will also be other major volatile compounds present in the gas phase. The same will be the situation in the case of skatole. The high correlation found between androstenone and the gas sensor readings, rather indicates that there may be other major compounds present in the gas phase that may be highly correlated to androstenone. Accordingly, this could possibly be used as an indirect way of measuring androstenone levels and boar-taint. It has been demonstrated in other studies that androstenone is highly correlated to a few major volatile compounds [10,11]. It has been questioned whether other volatile compounds also may contribute to the sensory perception of boar-taint. It is therefore still a need for more detailed GC/MS analyses of fat from boars with varying levels of skatole and androstenone to obtain a deeper insight in the chemical composition of the volatile compounds related to boar taint. A complete characterisation of the profile of volatile compounds in boar fat would be very useful to reveal possible marker compounds correlated to boar taint. This could also be a fruitful basis for the development of a dedicated gas-sensor system for the detection of boar taint.

Sampling is a crucial issue related to gas-sensor technology. The substances to be measured in the vapour phase, skatole and androstenone, are lipophilic compounds with a relative high molecular weight compared to other odour active compounds. Due to their low volatility, boiling points above 250°C, and their presence at low concentration in pork fat tissue, only small fractions (0.1–1%) may be present in the vapour phase. Direct sampling at ambient temperatures will therefore not be sufficient to allow the detection of these compounds due to the limited sensitivity of gas-sensors. In order to enhance the sensitivity, other sampling approaches will be required. Heating of the pork fat or applying enrichment techniques (purge and trap) using adsorbents combined with heating of the fat would be a more appropriate way of gas sampling for the application of boar taint [12,13]. However, by heating of fat, also other volatile compounds present in the fat may be released, which may interfere with skatole and androstenone. In particular, volatile secondary lipid oxidation products may be generated at high levels in the vapour phase. This may partly be overcome by applying oxygen free conditions during heating and sampling.

Due to limited specificity of gas-sensors, recent research and development has combined separation techniques like gas chromatography with gas-sensing devices, using gas-sensors as GC detectors. These micro-machined GCs' allow the detection of single volatile compounds within 10–60 seconds. In particular, uncoated surface acoustic wave (SAW) sensors have been used for this purpose [14]. The use of this technology in combination with gas enrichment techniques could also have a potential for future on-line detection of boar taint.

Conclusion

The results from the reported feasibility studies show significant correlation between the sensor signals and levels of skatole and androstenone and sensory attributes related to boar odour and flavour. The results suggest that gas-sensor technology may have a potential for future rapid sorting of boars at the slaughter line. However, there is still a need for research and development in this field in order to end up with a successful application. The studies so far represent limited laboratory trials, and the existing gas-sensor systems do not fulfil the software and hardware specifications required for on-line implementation. In particular, this applies for the gas sampling, which is a key issue. Coming up with an automated on-line system based on gas-sensor technology would require the development of a tailor-made dedicated sensor system including optimized gas-sampling unit, sensor module, signal processing and alarm system. The system could be calibrated either with respect to the chemical substances related to boar odour/flavour or sensory perception. In the latter case, this would not necessarily imply the need for a skatole and androstenone specific sensor array, since also other possible compounds may be involved in the sensory perception of boar-taint, but rather a broad-selectivity sensor array that matches the sensory perception of boar taint.

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