

CLASSIFICATION OF MEAT WITH BOAR TAIN USING AN ELECTRONIC NOSE

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ABSTRACT

Five different meat parts (loin, neck, shoulder, outer and inner thigh) originating from two entire male pigs which were previously confirmed to exhibit boar taint, were measured with an electronic nose (EN) and tested by a trained human sensory panel. The intensity of boar taint perception assessed by a sensory panel was the highest for neck and the lowest for loin. Classification based on electronic nose sensory data showed correct classification in 94.8% of the samples. The ratio of correctly classified samples in cross-validation was 83.3%. Discriminant analysis was also performed using nine sensors that were chosen by stepwise optimization method. In this case, ratio of hits in cross-validation increased to 86.5%. High determination coefficient ($R^2 = 0.915$) was obtained between reference values of boar taint (obtained by sensory panel) and predicted values calculated from EN data.

Key words: pigs meat / boar taint / electronic nose / sensory panel / discriminant analysis

1 INTRODUCTION

Meat from young boars (uncastrated male pigs) can present a distinctive unpleasant odor, known as boar taint, which is detected during cooking and eating. It represents a potential problem for the industry since such unpleasant experience can discourage the consumer to repurchase pork or pork products. According to the European law (Regulation EC No. 854/2004) meat with evident boar taint has to be declared as unsuitable for human consumption.

Two compounds deposited in the fat tissue of pig are held responsible for boar taint. The first one, androstenone is a testicular steroid with a characteristic urinary odor (Patterson, 1968), the second one is skatole which has an intense fecal odor and is a result of bacterial degradation of tryptophan in the gut (Vold, 1970; Walstra and Maarse, 1970).

There are several analytical methods available to measure the quantity of boar taint compounds as reviewed by Haugen *et al.* (2012). These methods are not

applicable on the slaughter line because they involve complicated sample preparation and are labor and time demanding.

Presently, the human (nose) test is mainly used for boar taint detection in the daily routine of abattoir practice which consists of heating a piece of meat and assessing the absence or presence of boar taint by smelling. However this method is subjective. It is well known that 99% of the consumers can perceive the smell of skatole and consider it as unpleasant. On the other hand, a considerable part of the human population is insensible to androstenone (Kline *et al.*, 2007). By means of trained panel the threshold values of androstenone and skatole have been set to is 1.0 and 0.2 $\mu\text{g/g}$ fat, respectively (Aldal *et al.*, 2005). There is a need for methods which could be used at the slaughter line for routine detection and sorting out of tainted carcasses. Chemical gas sensor arrays, the so-called electronic noses (EN) are considered to have such potential. Relatively low number of publications dealt with the EN based determination of boar taint. A study of Bourrounet *et al.* (1995) tested a sensor array of

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five metal oxide sensors (MOS). An EN instrument built up from semi conductive polymer sensors along with human panel test was used in a study of Annor-Frempong *et al.* (1998). Hansen *et al.* (2005) calibrated a MOS-based instrument with GC-MS (gas chromatography coupled with mass spectrometry) method. All the mentioned studies demonstrated a potential of EN methods. Using a commercially available ion mobility spectroscopy based EN instrument, androstenone and skatole samples were discriminated accurately with sample separation limit of 0.50 µg/g and 0.21 µg/g, respectively (Vestergaard *et al.*, 2006). Using an Alpha-MOS EN system detection limits of 0.5 and 0.2 ppm were established (for androstenone and skatole, respectively; Merk, 2007). The aim of the present study was to test the applicability of EN instrument αFox 4000 (ALPHA MOS, Toulouse, France) with 18 metal oxide sensors for a discrimination of boar tainted samples of different meat parts.

2 MATERIALS AND METHODS

2.1 SAMPLES AND PREPARATION

Pork chops originating from two entire male pigs with previously determined boar taint odor were used. The samples were taken from five different carcass parts, loin (1), neck (2), shoulder (3), outer (4) and inner (5) thigh.

Meat samples of alike geometrical form and weighing app. 2 g were mixed and heated for one hour at 75 °C in nylon bags. For EN measurements the gravy and the solid parts were separated, and the gravy was diluted with distilled water to double volume. Finally, 20 parallels composed of 1 ml of dilution and 1 g of homogenized meat were prepared for each sample type. The vials were closed with silica septa and stored at -20 °C until the EN analysis. Meat samples of app. 100 g were stored at -20 °C until the sensory panel test.

2.2 SELECTION, TRAINING OF PANELISTS, AND SENSORY ANALYSIS PROCEDURE

University students (n = 17) were invited to serve as panelists. They were first trained for androstenone sensitivity using a triangle test according to Lunde *et al.* (2009). The panel members were also familiarized with the odor of skatole by smelling the content of bottle containing 10 g of skatole diluted in 100 ml ethanol. In the second step, boar taint intensity of meat samples was assessed by panelists with previously proven androstenone sensitivity (n = 11). Freshly cooked meat samples

were homogenized and placed on the coded and covered plates. Panelists evaluated meat samples by opening the plates and immediate sniffing. They rated boar taint intensity of the samples using a 9 cm undivided line scale. The samples were served in the randomized order.

2.3 ELECTRONIC NOSE MEASUREMENT

An αFox 4000 (ALPHA MOS, Toulouse, France) type EN with 18 metal oxide sensors (MOS) was used. The adsorption of volatile compounds onto the MOS surface generates a change in the electrical resistance which varies with the type of compound and its concentration in the headspace (HS). According to the applied static HS technique, samples were placed in hermetically sealed vials of 10 ml. After the equilibrium has been established between the matrix and gaseous phase, an ALPHA MOS HS 100 auto sampler was used for sampling the HS. Synthetic air was used as a permanent air-flow. The acquisition time and time between subsequent analyses were 120 and 1080 s, respectively. Twenty parallel measurements were performed for each sample (n = 5). The following parameters were used to ensure acceptable signal intensity values: sample temperature 80 °C, equilibration time 180 s with agitation, injection volume 3000 µl, injection speed 500 µl/s and the flow rate 150 ml/min.

2.4 DATA EVALUATION

The multisensor arrays of EN were interfaced with computer which collected the sensor signals via RS-232 ports. The raw EN sensor values were saved in the form of relative resistance changes ($\Delta R/R_0$). The classification of meat samples was performed by multivariate general linear hypothesis (MGLH) stepwise procedure and discriminant analysis (DA) using the SPSS 16 software. Results were verified by cross-validation (CV). Percentage of correctly classified samples (CV%) was used as indicator of accuracy of the method. Calibration method to predict human sensory score was developed by partial least squares (PLS) regression using AlphaSoft V.12 software.

3 RESULTS AND DISCUSSION

3.1 HUMAN SENSORY ANALYSIS

Among the seventeen panelists (12 women, 5 men) four were insensitive to androstenone. This 23.5% rate is in good accordance with the data published in the

Table 1: The average boar taint score values given by the human sensory panel

Samples	boar taint
Loin (1)	1.81
Neck (2)	3.25
Shoulder (3)	2.43
Outer thigh (4)	2.63
Inner thigh (5)	2.37

panel was found for the neck, and the lowest for the loin (Table 1), which agrees with fatness level of these pieces being the highest in neck and lowest in loin. Our result agrees with positive correlation ($r = 0.64$) between skatole and fat levels, reported by Rius and García-Regueiro (2001) and results of Pauly *et al.* (2010) who also found higher boar odor and flavor intensities in neck than LD chops. According to our knowledge no other published results regarding boar odor and boar flavor in different muscles exist in the literature.

3.2 ELECTRONIC NOSE MEASUREMENT

In the first step, DA was performed. All sensor signals were used for classification. The classification was based on the previously (Material and methods paragraph) mentioned $\Delta R/R_0$ and intensity values that were applied as input variables during DA. Four canonical discriminant functions were generated with the first two

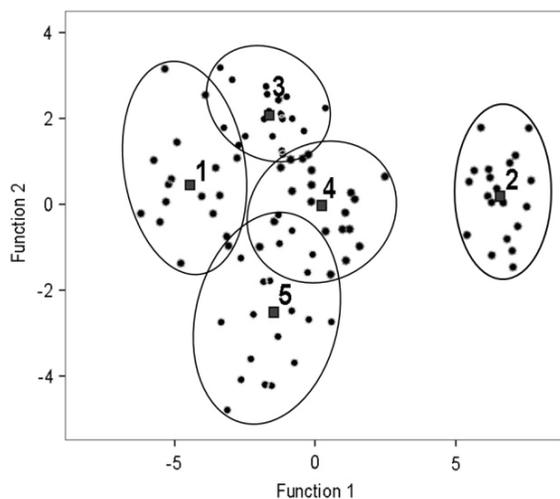


Figure 1: Discrimination of different meat samples using all EN sensors determined by the 1st and 2nd discriminant function (group 1: loin, group 2: neck, group 3: shoulder, group 4: outer thigh, group 5: inner thigh)

literature. Depending on the sex and geographical location, the percentage of people anosmic to androstenone is evaluated to be between 15 and 30% (Bonneau, 2004). The highest intensity of boar taint as assessed by sensory

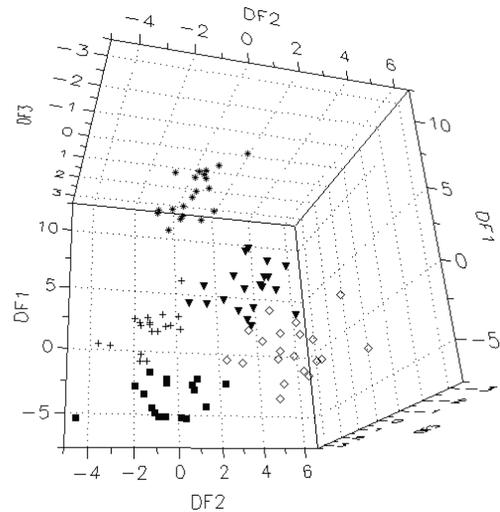


Figure 2: 3D graph of discrimination results for the five groups of meat samples when using all EN sensors (■: loin ▼: inner thigh ◇: outer thigh +: shoulder *: neck)

describing 97.2% of the total variance. Figure 1. represents the five sample-groups in a two-dimensional space determined by the first two functions. The most distinct group – presumably due to its highest fat content – was formed by the neck chop samples (2).

According to the results (data not shown), 94.8% of originally grouped cases were correctly classified. The ratio of correctly classified samples during cross-validation was 83.3%.

All the misclassified samples belonged to the groups of thigh (outer – inner) which can be related to their similar fat content.

Based on the first three functions from DA (cumulative variance 98.9%) a 3D distribution of samples is presented in Fig. 2.

Additionally, 9 sensors (LY2/LG, LY2/G, LY2/AA, LY2/gCT, P10/2, P40/1, T70/2, P30/1, P40/2) were chosen by the stepwise optimization method, and only these were involved in the discriminant analysis. The ratio of correctly classified cases was 91.7%, but the cross-validation score (i.e. the number of correctly classified samples) was higher with the stepwise method, than that of using all the sensors, (86.5% vs. 83.3%). No miss-classification occurred within the group of neck chop samples. However, four samples of group 3 were placed into group 4, and three of group 4 samples were placed into group 3 (Table 2.).

Table 2: Successfully classified samples during cross-validation

Cross-validation	Loin (1)	Neck (2)	Shoulder (3)	Outer thigh (4)	Inner thigh (5)	Total
Loin (1)	15	0	2	0	0	17
Neck (2)	0	20	0	0	0	20
Shoulder (3)	0	0	15	4	0	19
Outer thigh (4)	0	0	3	16	1	20
Inner thigh (5)	1	0	0	2	17	20

3.3 CORRELATION BETWEEN SENSORY PANEL AND ELECTRONIC NOSE

Finally, PLS regression was used for quantitative evaluation of EN data in relation to sensory panel scores. Sensory panel values were averaged for each of five groups, and these average scores for boar taint were correlated with signals from all sensors. Results were evaluated by means of determination coefficient (R^2). Figure 3 shows the association between reference values of boar taint obtained by human nose and predicted values calculated by EN data. The R^2 was 0.92 which denotes high accuracy, and proves the efficiency of the applied procedure.

4 CONCLUSIONS

Based on the results of sensory panel it can be concluded that the intensity of boar taint perception increases with increasing level of fat content. Our study also

proved, that the electronic nose is able to discriminate with high accuracy different meat parts presenting different levels of boar taint. The EN responses were successfully calibrated against sensory panel scores.

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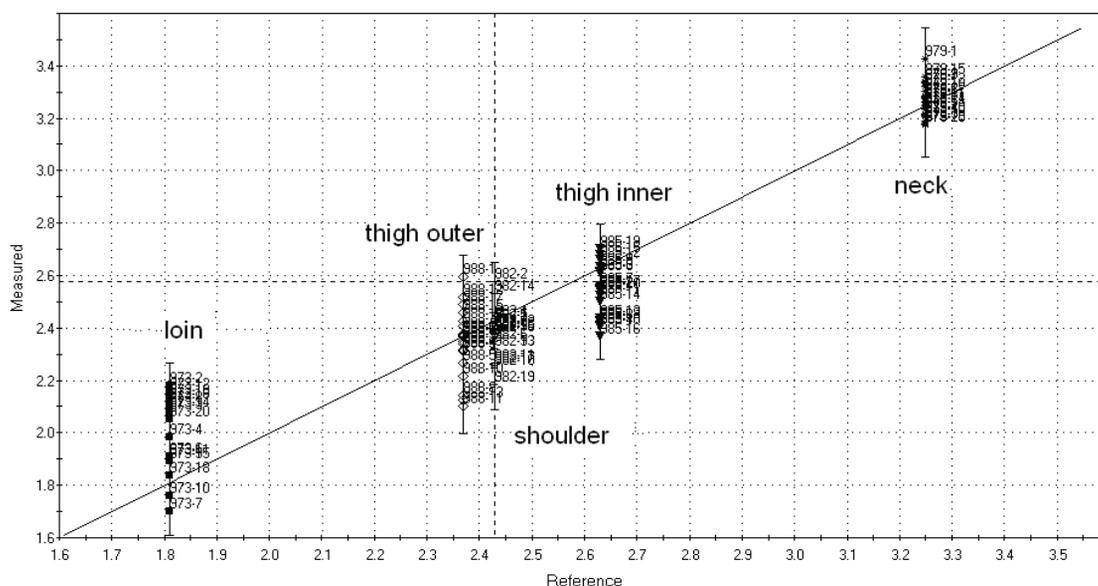


Figure 3: Association between predicted (PLS) and reference (sensory panel) values of boar taint, based on EN data and human nose scores obtained for the different meat parts

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