# Explaining and predicting fitness for consumption of meat from entire male pigs


## M. Kornelis and C.P.A. van Wagenberg

**LEI Wageningen UR, Wageningen, the Netherlands**

**Marcel.Kornelis@wur.nl, Tel.: +31-70-3358194**

**Coen.vanwagenberg@wur.nl, Tel.:+31-317-484558**




***Paper prepared for presentation at the 148th seminar of the EAAE, "Does Europe need a Food Policy?", Brussels, Belgium, 30 November – 1 December, 2015***

# Explaining and predicting the fitness for consumption of meat from entire male pigs


## Abstract

In the food industry, it is common practice to consider product quality as the physical and/or sensory aspects of foods, such as size, weight, appeal or taste. However, it has also been recognized that consumer perceptions of product quality, which can be looked upon as the "fitness for consumption", ultimately determines the profitability of foods producing companies. For companies, it is therefore of central interest to link their quality systems to the perceptions of consumers. In this study we developed a model for the pig-meat industry to assess the quality of meat from entire male pigs using consumer quality scores and a within-company quality system. The empirical database included androstenone, skatole and indole concentrations, sensory assessment scores for boar taint measured in the slaughter line, sensory assessment scores of an analytical panel, and more than two hundred consumer quality scores of fifty-five entire male pigs. It was found that the combination of inline human nose selection for boar taint and analytical panel information about taste lead to a better explanation and prediction of the fitness for consumption than the use of a model with only odour or taste variables as predictors. So, both odour and taste aspects matter.


## 1. Introduction

Within companies, product quality is commonly measured through a composite of instrument and/or expert ratings (Mitra & Golder, 2006; Lichtenstein & Burton, 1989). Among the food industries, these measurements may consider the physical and/or sensory aspects of foods, such as size, weight, appeal or taste. Since the consumer perceptions of product quality, which can be looked upon as the "fitness for consumption" (Steenkamp 1990), drive consumer preferences and purchase decisions, they ultimately determine the profitability of the foods producing companies. Therefore, it is of central interest for companies to link their quality systems to the perceptions of consumers. Relevant research in this area includes the seminal work of Grunert et al. (1996) and of Steenkamp & Van Trijp (1996), who consider the consumer as the golden standard for quality. That is, food products should be developed and offered in such a way that it reflect the quality demand of consumers.

The European pig-meat industry, which is the context of the current study, are no exception in this respect. Their focus on product quality has currently become of key interest, because of the shift towards the raise of entire male pigs instead of castrates from 2018 onwards, as proposed in the European Declaration on Alternatives to Surgical Castration of Male Pigs (European Commission, 2010). Entire male pigs may produce a cut-off flavour, known as boar taint. The presence of boar taint is commonly expected to decrease the fitness for consumption among consumers. This makes odour a key performance measure for decision makers in the pig-meat industry.

Although a substantial body of empirical research on the detection of intrinsic quality cues that can be linked to the occurrence of boar taint, there is a surprisingly limited number of studies that consider the external validity of these company specific quality measures. This study aims to quantify the most promising quality system that can link within company decision rules to consumption fitness by investigating the predictability of various compositions of ratings for the overall consumer quality perception. To do so, laboratory analyses for androstenone, skatole and indole, sensory assessment with the human nose in the slaughter line, sensory assessment by analytical panel members, and a consumption fitness experiment of more than two hundred German and Dutch consumers were performed on a sample of fifty-five entire male pigs.

The remainder is as follows: first, the consumption of fitness experiment, the working of lab-tests, analytical panel test, and inline human nose tests are described. Then, we continue with a description of the application. Afterwards, we present the study design, the advocated methodology, and the found empirical results. Finally, we draw conclusions and describe avenues for potential future research.

## 2. Linking within-company quality measures to consumer quality perception

In a marketing strategy, consumers are considered the golden standard, and a company has to decide what the target consumer-quality scores of its products will be. One may, for example, wish to position a product as a premium, and therefore target a high quality perception score, say a seven or higher on a nine-points scale, where nine and zero are the highest and lowest quality scores, respectively. Or, in another strategy, one may wish to offer the complete range of acceptable products, and only exclude the unacceptable ones from the offerings. In this case, the target quality score is in the lower range of a nine-point scale. Preventing consumers from encountering boar-tainted meat belongs to this second marketing strategy.

Figures 1 graphically depicts the relationship between the consumer quality perception (on a nine-point scale) and its prediction, which is based upon the composite of within-company quality measures. Figure 1 gives the situation in the absence of a prediction error. In this situation, the consumer quality perception is perfectly predicted, so the company can use the collected consumer score for its own decision rules (areas C and D are empty). Area A in Figure 1 represents the unacceptable region, whereas area B represents the acceptable area.

The absence of a prediction error may be a too restrictive model of reality. Figure 1 gives the situation when a prediction error is present. Areas C and D is this figure indicate potential false positives and negatives, respectively. False positives occur when a company excludes products from the market, which are actually acceptable in the perception of the consumers, and false negatives are unacceptable products which are actually offered to the consuming audience. In the situation of prediction errors, the company has to set two target quality scores instead of a single one. On the consumer quality scale (the horizontal axis in Figure 1) the target may again be based on the aforementioned marketing and hybrid approach. For the target value of the prediction scale (the vertical axis), one may decide to minimize the number of false positives (C), minimize the number of false negatives (D), or to find an optimum between the numbers of C and D in terms of sales losses and benefits.

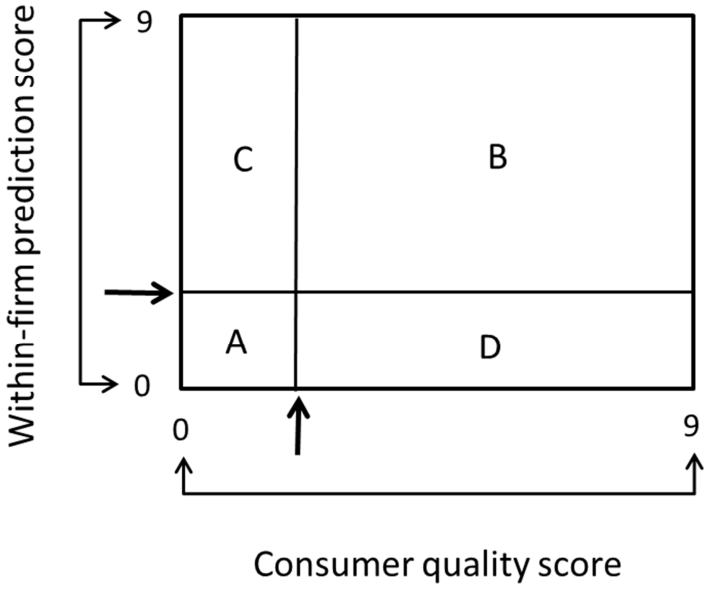


**Figure 1. The linkage between within-company and consumer quality perception: presence of prediction error**

## 3. Methodology

### 3.1. The consumer respondents

A total of 115 German respondents of eighteen years and older participated in the main study. ISI GmbH & Co. KG, a German research institute recruited respondents from a consumer panel, hereby ensuring that the participant was the regular cook in the household, the household consumed pig meat at least once a week, and the household normally purchased pig meat in a supermarket or from a butcher. A representative sample of 102 households in three areas of The Netherlands was recruited. The participants were regular pig meat eaters (at least once a week). Inclusion criteria were further that family members were willing to participate for 5 consecutive weeks. Loins, chops and bellies were selected of 55 entire male pigs, all slaughtered at a large pig slaughter company in the Netherlands. The households prepared and consumed the meat at home. Meat from each entire male pig was judged by 4 to 6 households. During the actual intake of the pig meat, the participants were asked to respond to nine importance statements about taste (three), texture (three), fat (one), and hedonic quality of the meat (two) about that pig meat on a nine-point scale with 'completely disagree' and 'completely agree', 'very untasty' and 'very tasty', or 'very unpleasant' and 'very pleasant' on the extremes. Each entire male pig has multiple scores on its loins, chops, and bellies, ranging from 16 scores to 30 scores per entire male pig[1]. Respondents were told that the research was about evaluation of pig meat, there was no mention of boar taint or animal welfare. Based on the nine importance statements, the underlying construct of meat quality was measured as the simple mean of these statements.

### 3.2. The human nose testers

The boar taint level of the 55 entire male pigs was measured with the human nose scoring system used in the pig slaughter company . Each entire male pig was assessed at the slaughter line by one employee of the slaughter company. Each assessor was tested to be sensitive for androstenone and skatole odour and received several weeks of training in a laboratory setting and at the slaughter line prior to being assigned as assessor for detection of boar taint at the slaughter line. At the slaughter line a metal plate heated with a gas burner, was pressed against subcutaneous fat in the dorsal neck region of an entire male pig. The assessor smelled the released odour and recorded 0 for no detectable boar taint, 1 for no boar taint but some off odour, 2 for more off odour but no boar taint, 3 for some boar taint odour and 4 for strong

[1] Detailed information about the number of household judgments for each selected entire male pig are available from the authors upon request.

boar taint odour (Mathur et al., 2012). No distinction is made between specific compounds of boar taint, such as androstenone and skatole.

### 3.3. The analytical panel

The analytical panel was developed at Essensor in Ede, the Netherlands. Twelve panellists were selected using a R-index difference test (Lee and van Hout, 2009) and practical criteria that they were available during the whole experiment period. Panellists were recruited from a group of consumers that were preselected based on their sense of smell according to ISO 8586. Panellists were to identify androstenone concentrations in water of 0.01, 0.1, 0.5 and 2.0 ppm and skatole concentrations in water of 0.001, 0.01, 0.1 and 0.5 ppm. Selected panellists had to at least give two out of three correct answers on the R-index difference test set reference compared to test product of the lowest androstenone and skatole concentrations. During the actual intake, the twelve panellists gave scores on a 100-scale regarding fat, bitter, and sour tastes, and a juicy, dry and watering feeling in the mouth. Every panel members judged all loins multiple times, and the overall judgement on the meat attributes was measured as the simple mean.

### 3.4. The lab tests

Neck fat samples were analysed at NutriControl (formerly Co-operative Central laboratory CCL) in Veghel, the Netherlands for the levels of androstenone and skatole. The method used to measure androstenone was determined using liquid chromatography–mass spectrometry (LC–MS) in accordance with Verheyden et al. (2007). Skatole and Indole were extracted from the fat sample using a mixture of methanol and hexane at 40 °C in an ultrasonic bath. It was separated by high-pressure liquid chromatography (HPLC) on a reversed phase column. Fluorescence was measured at 285 nm and 340 nm.

### 3.5. Statistical analysis

Linear regression models were used to predict the fitness of consumption, measured by the overall consumer quality rating $y_n$. As a benchmark for the models, we regressed the consumer quality scores on a model with only a constant $\mu$ as predictor, which represents the overall mean among the quality scores, the benchmark model. With respect to the inline human nose testers, the following model was used:

$$y_n = \mu + \beta_0 D_0 + \beta_1 D_1 + \beta_3 D_3 + \beta_4 D_4 + e_n, \text{ for } n = 1, \dots, 45, \quad (1)$$

where $\mu$ is a constant, $D_0, D_1, D_3,$ and $D_4$ are effect dummies representing a human nose score of 0, 1, 3, and 4, respectively, with $\beta_0, \beta_1, \beta_3,$ and $\beta_4$ their parameters, and $e_n$ is the residual term. It should be noted that in Eq. (1) human nose score 2 was excluded from the model, to avoid perfect multicollinearity with the constant term. Thus, the constant $\mu$ represents the human nose score of 2.

The second model considers the lab tests and is:

$$y_n = \mu + \theta_1 a_n + \theta_2 s_n + \theta_3 i_n + e_n, \quad (2)$$

where $\mu$ is a constant, $a_n, s_n,$ and $i_n$ are the concentrations of androstenone, skatole, and indole, respectively, and $\theta_1, \theta_2,$ and $\theta_3$ their parameters.

The analytical panel model has the following format:

$$y_n = \mu + \varphi_1 x_{1,n} + \varphi_2 x_{2,n} + \varphi_3 x_{3,n} + \varphi_4 x_{4,n} + \varphi_5 x_{5,n} + \varphi_6 x_{6,n} + e_n, \quad (3)$$

where $\mu$ is a constant, $x_{1,n}$ to $x_{6,n}$ are fat taste, bitter taste, sour taste, juicy in the mouth, dry in the mouth, and watering in the mouth, respectively, and $\varphi_1$ to $\varphi_6$ the parameters.

By combining the potential explanatory information of these three models, we constructed a fourth model which includes all predictors of the previous three models:

$$y_n = \mu + \sum_{i=0}^{4} \beta_i D_i + \theta_1 a_n + \theta_2 s_n + \theta_3 i_n + \sum_{j=1}^{6} \varphi_j x_{j,n} + e_n \quad (4)$$

An effective sample size of forty-five entire male pigs was used to estimate the parameters of these models. Forecasts of the estimated models are then derived, and they are compared with the remaining ten entire male pigs of the hold-out sample.

## 5. Results

The benchmark model gave a significant overall mean value of 5.87 (at the .05% level), a Bayesian Information Criterion (BIC) of 2.05, and a Root Mean Squared Error of prediction (RMSE) of .69. The four alternative models to predict the consumer quality score are displayed in Table 1.The first regression model considers the potential use of dummy-coded human nose scores as predictors. This model (model 1 in Table 1), shows that only human nose score 4 has a negative impact on the quality ratings, whereas the other three scores have a positive effect on the consumer ratings. This suggest that boar taint score 4 may play a key role in the detection of boar taint. Although, the root mean squared error of prediction is lower than the model with only a constant term (.65<.69), none of the dummy variables were significant. The second model considers the results of chemical lab tests on androstenone, skatole, and indole. The RMSE of the second model (model 2) is again lower than the constant only model (.62<.69), but also here the three predictors are non-significant. The

model with analytical panel scores on fat, bitter, sour, juicy, and dry tastes (model 3) do not attribute to a better prediction of consumer quality measures, as all predictors are insignificant and the RMSE is even larger than a the parsimonious constant-only model (.70>.69). Finally, the fourth model, that includes all predictors revealed no significant predictors, and has even the largest RMSE of all models (Model 4). However, when we exclude the most insignificant predictors (based on their t-values), we obtain a much more parsimonious model with inline human nose score 4 and panel information about a sour taste as two significant predictors (model 5). As can be seen, both predictors have a negative impact on consumer quality judgments.

**Table 1: Prediction models**

| **Predictors** | **Model 1** | **Model 2** | **Model 3** | **Model 4** | **Model 5** |
|---|---|---|---|---|---|
| Constant | 5.77[a] | 5.96[a] | 11.3[a] | 13.04[a] | 6.93[a] |
| Human nose | | | | | |
| D0 | .22 | | | .017 | |
| D1 | .33 | | | .44 | |
| D3 | .24 | | | .33 | |
| D4 | -.30 | | | -.28 | -.45[a] |
| Lab tests | | | | | |
| androstenone | | .045 | | .074 | |
| skatole | | $-4.8\times10^{-5}$ | | -.00014 | |
| indole | | -.002 | | -.0017 | |
| Panel tests | | | | | |
| Fat | | | .014 | .0039 | |
| Bitter | | | .018 | .12 | |
| Sour | | | -.034 | -.04 | -.04[b] |
| Juicy | | | -.049 | -.09 | |
| Dry | | | -.055 | -.082 | |
| Watering | | | -.010 | .0023 | |
| Model performance | | | | | |
| R-squared | .12 | .08 | .13 | .32 | .16 |
| BIC | 2.26 | 2.22 | 2.42 | 2.77 | 2.05 |
| Kendall's W | .67 | .62 | .71 | .75 | .67 |
| Model performance holdout sample | | | | | |
| RMSE | .65 | .62 | .70 | .73 | .66 |
| Kendall's W | .61 | .79 | .58 | .59 | .60 |

Where: [a] denotes significance at a .05% level, [b] denotes significance at a .10% level.

## 6. Managerial implications

To illustrate the potential usefulness of the derived prediction model for managerial decision making, we consider the consumer quality scores and the within-company prediction scores using the odour and taste model 5. We display the 45 entire male pigs of the estimation sample associated to these two scores in Figure 2. Within-company decision makers can now

make two decisions based on the consumer scores and the model outcomes. The first one is the decision what the acceptable critical value is for the consumer market, and the second is the decision on the within-company critical value regarding the prediction of the consumer quality evaluations. These decisions may be based on cost-benefits trade-offs, which are beyond the scope of the current study. For illustrative purposes, however, we consider a possible case, in which a company chooses the midpoint of the nine-points quality scale (which is the score of five) as the target value for the consumer market. Following such a decision rule, the company aims to offer only entire male pigs with a quality score of five and higher to the market. The second decision considers the within-company prediction score. In this illustration, we chose a within-company value of 5.55. Applying both decision rules on the 45 entire male pigs of the estimation sample shows the number of rejected (one entire male pig), accepted (33), falsely accepted (four), and falsely rejected (seven) entire male pigs, which are represented by the areas A to D in Figure 2, respectively.

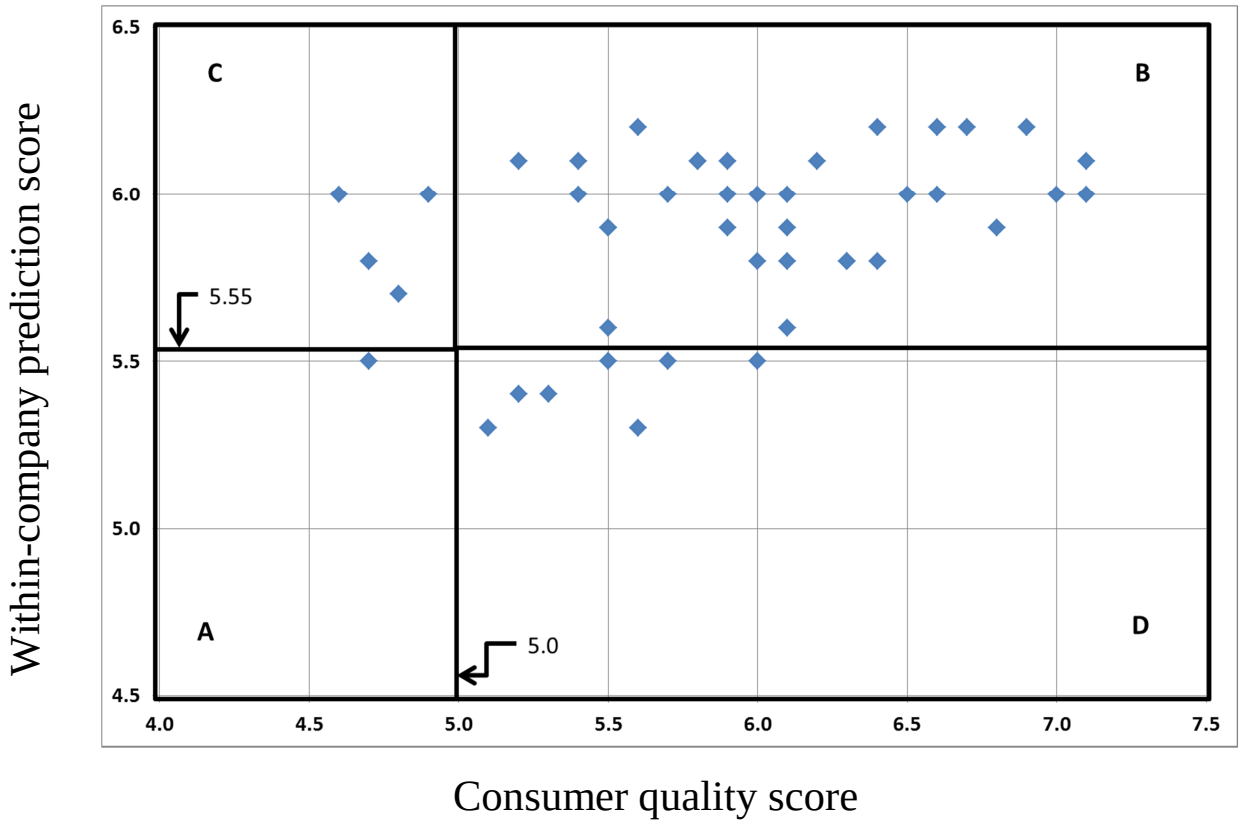


**Figure 2. Illustration of possible cut-off values**

In addition, one can derive, how the above decision values would translate back to the company's operational level in terms of odour and taste scores. Since, the advocated prediction model has the following function form:

$$y_n = 6.93 - .45D4_n - .04sourtaste_n, \quad (5)$$

where $D4_n$ is a dummy variable with the value of 1 if the inline human nose score is 4, and 0 otherwise. The sour-taste variable can have values between 0 and 100, and the rest has been defined as before. Using a within-company critical value of 5.55, one can consider many different situations where the combination of the scores lead to acceptance or rejection of the meat. Table 2 presents four potential cases. As can deduced from Table 2, an inline human nose score of 4 does not automatically have to lead to a rejection of the meat in this model. Depending on the sour taste of the meat with a human nose score of 4 could still be acceptable for the market, as comparing case 1 and 2 shows. Also, meat with a score lower than 4, could be unacceptable if the taste becomes to sour, as can be seen by comparing case 3 and 4.

**Table 2. Applying the modal rule for five possible cases**

| Case | IHNS | Sour taste score | Prediction [a] | Outcome [b] |
|---|---|---|---|---|
| 1 | 4 | 24 | 5.52 | Reject |
| 2 | 4 | 15 | 5.88 | Accept |
| 3 | 0,1,2, or 3 | 10 | 6.53 | Accept |
| 4 | 0,1,2, or 3 | 40 | 5.33 | Reject |

[a] Prediction is based on $y_n = 6.93 - .45D4_n - .04sourtaste_n$

[b] Critical value of the modal rule is 5.55 for the within-company prediction.

**7. Conclusion and discussion**

In this study, the relationship between the pig-meat quality perceptions of consumers and possible within-company quality ratings was investigated. Using an empirical database, including more than two hundred consumer quality ratings of fifty-five entire male pigs, it was found that the combination of extreme aberrant odour, as reflected by an inline human nose score of '4' in the current empirical database, and a sour taste, as indicated by a sensory panel, led to the best understanding of consumer quality perceptions, as they can explain a substantial, albeit small part of the variation among consumer quality ratings. Chemical

analyses for androstenone, skatole and indole did not contribute to a better understanding of consumer quality scores.

More research on the relationship between consumer quality ratings and implementable company decision rules may be essential for a long-term market success, because, a better understanding of the fitness for consumption may decrease the number of false rejections and acceptations. A potential avenue for future research may be the incorporation of more consumer characteristics. Indeed, as much of the variation among consumer quality perceptions can be explained by differences among consumers themselves, this may lead to a more segmented market approach. Rather than focusing on a single quality perception level, a company may then opt to consider multiple quality targets. This may not only benefit the consuming audience more accurately, but also improve the trade-off between false rejections and acceptations.

The empirical results indicate that the sole use of chemical analyses for androstenone, skatole, and indole, did not lead to a promising explanation of the consumer quality differences in a market, because none of these three predictors were found to be significant. This suggests the fitness for consumption cannot be restricted to only these three product attributes. In addition, it is of interest to see, that in the current study, judgments regarding odour and taste outperform lab tests in explaining consumer variation. This suggest that human judgment could be key for a quality system in which the consumer is regarded as the golden standard, as they can capture more about consumer perceptions than chemical laboratory analyses.

Although the empirical database contained judgments of more than two hundred households, the external validity may be hampered by the number of entire male pigs, viz. fifty-five. Indeed, this number is very small as compared to the total number of carcasses that are produced for consumer markets on a daily basis. Increasing the empirical knowledge base in this respect may be another welcome area for future research.

The prosed framework in this study, in which the within-company predictions and the consumer quality scores are linked through linear regression models to identify true and false rejections and acceptations is not restricted to only the pig-meat industry. The proposed methodology is flexible enough to capture the link between the instrument and expert quality ratings to the consumer perceptions in other food industries as well.

**References**

Aluwé M., S. Millet, G. Nijs, F.A.M. Tuyttens, K. Verheyden, H.F. De Brabander, D.L. De Brabander, M.J. Van Oeckel (2009). Absence of an effect of dietary fibre or clinoptilolite on boar taint in entire male pigs fed practical diets. Meat Science 82, pp. 346–352.

European Commission (2010). European Declaration on alternatives to surgical castration of pigs. Directorate General Health and Consumers, European Commission, Brussels. Retreived 2 July 2013, from http://ec.europa.eu/food/animal/welfare/farm/initiatives_en.htm.

Lee, H.S. and D. van Hout (2009). Quantification of sensory and food quality: the R-index analysis. Journal of Food Science 74(6), pp. R57–R64.

Mathur PK, Ten Napel J, Bloemhof S, Heres L, Knol EF and Mulder HA (2012). A human nose scoring system for boar taint and its relationship with androstenone and skatole. Meat Science 91, pp. 414-422.

Verheyden, K., Noppe, H., Aluwé, M., Millet, S., Vanden Bussche, J., & De Brabander, H. F. (2007). Development and validation of a method for simultaneous analysis of the boar taint compounds indole, skatole and androstenone in pig fat using liquid chromatography-multiple mass spectrometry. Journal of Chromatography A 1174, pp. 132–137.