Food Quality and Preference 71 (2019) 209–216

Contents lists available at ScienceDirect

Food Quality and Preference

journal homepage: www.elsevier.com/locate/foodqual

# Estimating the risk of dislike: An industry tool for setting sorting limits for boar taint compounds

Rune H. Christensen[a], Dennis B. Nielsen[b], Margit D. Aaslyng[b,*]

[a] Christensen Statistics, Bringetoften 7, DK-3500 Værløse, Denmark
[b] Danish Meat Research Institute, Technological Institute, Gregersensvej 9, DK-2630 Taastrup, Denmark

ARTICLE INFO

*Keywords:*
Boar taint
Mixed-effects logistic regression
Sorting limits
Risk analysis

ABSTRACT

Producing entire male pigs entails a risk of boar taint in the meat due to increased levels of the compounds skatole and androstenone in the carcass. Allowing meat from entire male pigs to be marketed and sold together with meat from castrates and female pigs increases the risk of consumers being dissatisfied due to boar tainted samples. To reduce this risk, it is necessary to set sorting limits for androstenone and skatole preventing meat from the most boar-tainted entire males from reaching the market. This paper presents a model framework in which the risk of consumer expressions of dislike is modelled as a function of the concentrations of skatole and androstenone. A bivariate log-normal model of skatole and androstenone concentrations is estimated from a representative sample of entire male pigs, and, by combining these two models, the expected risk of dislike and the number of discarded carcasses is estimated as a function of sorting limits. If the risk of dislike of meat from entire male pigs equals the risk of dislike of meat from castrates, up to 80% of the carcasses should be discarded. However, there is a huge variation in consumer response. This new analytical approach allows the industry to set appropriate sorting limits by balancing the risk of dissatisfied consumers with the proportion of discarded entire male carcasses.

## 1. Introduction

Producing entire male pigs entails a risk of boar taint being present in some carcasses (Aaslyng, Broge, Brockhoff, & Christensen, 2016; Bee, Chevillon, & Bonneau, 2015; Font-i-Furnols, 2012). Meat with boar taint is declared 'unfit for human consumption due to organoleptic anomalies, in particular a pronounced sexual odour' according to EU legislation (Regulation (EC) No. 854/2004, 2004), and a sorting procedure at the slaughterhouse is therefore necessary. There is a general consensus that two compounds are primarily responsible for boar taint: skatole (3-Methyl-Indole) and androstenone (5α-Androst-16-en-3-one) (Patterson, 1968; Vold, 1970).

Allowing meat from entire male pigs to be marketed and sold to consumers together with meat from castrates and female pigs increases the risk of consumers being dissatisfied. To reduce this risk, it is necessary to set sorting limits for androstenone and skatole to prevent meat from the most boar-tainted entire males from reaching the fresh meat market. In Denmark, skatole in the neck fat of entire males has been analysed for many years, and a sorting limit of 0.25 μg/g is used. However, androstenone is also a boar taint compound, and analysing for the presence of this compound and including it in a sorting strategy will also be relevant in the future. Slaughter plants in Germany, the Netherlands, Belgium and France use a human nose score in their sorting procedure at the slaughterhouse, although it is difficult to establish a precise and reproducible sorting limit using this method (Bee et al., 2015).

Average consumer response is often referred to when setting a limit for acceptability (Bonneau & Chevillon, 2012; Font i Furnols, Gispert, Diestre, & Oliver, 2003), yet this assumes that an average consumer represents consumers in general, and this will seldom be the case. Sensitivity to and appreciation of the boar taint compounds, especially androstenone, differ between consumers (Meier-Dinkel, Trautmann, et al., 2013), and reactions to boar-tainted meat can therefore also be expected to differ between consumers. Furthermore, among consumers who are equally sensitive to skatole and androstenone, huge variations exist in their reactions to boar-tainted meat, and this must be taken into account when consumer studies are used to predict consumer response to meat with different levels of skatole and androstenone (Aaslyng et al., 2016; Aluwe et al., 2017). In addition, it might be the most critical consumers who either complain about the pork or stop buying it altogether, and their reaction might therefore be the most interesting. At the same time, a low sorting percentage is an advantage for the

* Corresponding author.
*E-mail address:* mdag@teknologisk.dk (M.D. Aaslyng).

https://doi.org/10.1016/j.foodqual.2018.07.008
Received 8 May 2018; Received in revised form 29 June 2018; Accepted 10 July 2018
Available online 11 July 2018
0950-3293/ 

industry, since it ensures an economical production process. Setting sorting limits is therefore a question of balancing the risk of dissatisfaction with the proportion of discarded entire male carcasses.

Against this background, it is necessary to understand the effects of the sorting limits for skatole and androstenone on:

1. the risk of consumer dissatisfaction, and
2. the proportion of discarded entire male carcasses

These are the key topics addressed in the present paper. To understand the effects of the sorting limits, we will consider representative samples of entire males and consumers to ensure that the modelling results have external validity and can therefore be used to establish the sorting limits.

It is not optimal to directly study the effects of skatole and androstenone on consumer dislike using a representative distribution of entire males, since most entire males will have skatole, in particular, but also androstenone concentrations in a narrow range (Moerlein et al., 2016). This makes it difficult statistically to extract the effects of skatole and androstenone; there is a high risk that these effects will be masked by the variation within and between consumers and pigs. Instead, the use of meat from entire males with, respectively, high and low concentrations of skatole and androstenone is preferable. However, this introduces the challenge that the distribution of skatole and androstenone in the sample of entire males is not representative of the population of entire males.

In situations where consumer differences are comparable in size to the systematic effects in the model including the effects of androstenone and skatole, there is an important distinction between the effects for a *typical* consumer and the effects *averaged* over the consumer population. Not only will the distinction make for a more nuanced discussion of the effects of skatole and androstenone on the risk of consumer dislike, but it will also show that the estimated risks are different.

We suggest an approach to study the effects of sorting limits for skatole and androstenone on the risk of consumer dissatisfaction and the proportion of discarded entire males using information from two sources: (1) a consumer study on pork chops using a representative consumer sample and a selected sample of boar-tainted meat and (2) a screening study of skatole and androstenone in a representative sample of entire males.

Overall, this approach will use no more consumers and pigs than are necessary and will also provide the best chance of determining the effects of skatole and androstenone on the risk of consumer dislike and ensuring the external validity and generalisability of the results for the general consumer and entire male populations.

The next section outlines the methodological approach and introduces the sections that follow before the paper ends with a discussion and conclusions.

## 2. Methodological approach

In this study, two sources of information were available:

1. a consumer study on pork chops in which 180 consumers evaluated pork chops from 55 entire males and 18 castrates and expressed liking on a 15 cm line scale.
2. skatole and androstenone concentrations in the neck fat in a representative sample of 871 entire male pigs from a Danish slaughterhouse.

We defined a threshold, $k$ on the 15 cm liking scale such that consumer evaluations of liking below $k = 4$ were taken as expressions of dislike or dissatisfaction, while consumer evaluations of liking above $k = 4$ were taken as expressions of liking or satisfaction. This choice of threshold ($k = 4$) represents approximately one forth of the liking scale with 17% of the liking ratings below $k = 4$. This choice is a balance between modelling clear expressions of low liking and leaving enough data in the dislike category for an informative analysis. Our model framework allows for other choices of threshold depending on industry needs, since the exact choice of threshold is not important for the calculations and the presentation. If the industry aims for a less restrictive definition of dislike, a threshold of $k = 5$ could be used as threshold between liking/disliking while for a more restrictive definition, say $k = 3$, could also be used. Choices of the threshold other than $k = 4$ would alter the output, but not the model framework.

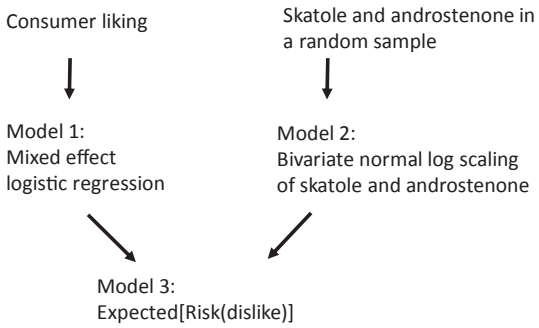


**Fig. 1.** Structure of approach to estimate the expected risk of consumer dislike of meat from entire male pigs for the purpose of setting sorting limits.

Fig. 1 illustrates the process in which the two sources of information from the consumer study and the entire male screening study are synthesised to provide an estimate of the risk of dislike with respect to representative consumer and entire male populations. This risk of dislike is then studied jointly with the proportion of discarded entire males as a function of sorting limits.

Based on the consumer study, the risk of consumer expressions of dislike (in this case defined as liking scores below 4) is modelled as a function of the concentrations of skatole and androstenone (Model 1, Fig. 1). Consumers in this study were a representative sample of pork consumers in Denmark as described in Section 3. However, the pigs were deliberately selected in as broad a range of concentrations of skatole and androstenone as possible, which involved selecting entire males with comparably high concentrations of the two compounds. In addition to this dataset, a representative sample of entire male pigs was analysed for the concentration of skatole and androstenone in the neckfat as described in Section 4. From this sample, a bivariate log-normal distribution of skatole and androstenone was estimated (Model 2, Fig. 1).

The model from the consumer study is therefore capable of expressing the relationship between the risk of dislike, as expressed by a representative consumer sample, and entire males with specific concentrations of skatole and androstenone. To model the risk of consumer dislike in the population of entire males as such, we combine the model of the risk of dislike with the estimated representative distribution of skatole and androstenone in the population of entire males (Model 3, Fig. 1).

The remaining sections of this paper describe the three parts of the model framework: 1) the consumer study: the mixed-effects logistic regression model describing the effects of concentrations of skatole and androstenone on the risk of consumer dislike, 2) the entire male screening study: the estimated bivariate distribution for skatole and androstenone and 3) the synthesis of the mixed-effects logistic regression model of dislike and the estimated bivariate distribution of skatole and androstenone, which provides the risk of dislike for a representative consumer and the population of entire males with and without sorting limits.

## 3. Consumer study

In the consumer study, 180 consumers recruited by a recruiting