Sensory evaluation of meat and meat products: fundamentals and applications

Daniel Mörllein

1 University of Göttingen, Department of Animal Sciences, D-37075 Göttingen, Germany

E-mail: daniel.moerlein@uni-goettingen.de

Abstract. Sensory analysis is widely applied to both fresh and processed meat. Herein, the frequently used sensory evaluation techniques are briefly characterised; some critical aspects, such as assessor selection, attribute generation, and context effects, are detailed. Without aiming to be exhaustive, some examples of previous research are showcased to demonstrate what types of research questions can be answered by utilising sensory evaluation.

1. Sensory evaluation techniques
It is fundamental to think about the scope of any sensory test, as there exist various approaches serving to answer distinct questions. Typically, sensory evaluation techniques are categorised in three fields:

- Discrimination testing (a.k.a. difference testing);
- Descriptive analysis;
- Consumer acceptance and preference testing.

1.1. Discrimination testing
Discrimination testing can help to achieve confidence as to whether or not sensory differences are perceivable to consumers or trained assessors. This type of testing is applied if little or no sensory difference between a set of samples is suspected. Difference tests can be conducted either generically or with prior specification of the attribute of interest. That is, one is interested in whether there is any perceivable difference or whether products differ, for example, in sweetness. Various standardised discrimination tests that differ in their complexity and their sensitivity/power are available such as the triangle or tetrad test (unspecific), 2-AFC and 3-AFC test (attribute specific).

1.2. Descriptive sensory analysis
Descriptive sensory analysis typically is used when one is interested both in the direction and in the magnitude of differences. That is, the aim is to identify the relevant sensory attributes of a given product or in which attributes the various products differ. Therefore, a trained panel consisting of selected assessors (typically 8-12 assessors) is used to develop a sensory lexicon for further quantitative assessment of products using that lexicon and (typically) line scales indicating the intensity of a given attribute.
1.3. Consumer acceptance testing

Consumer acceptance testing aims at identifying likes and dislikes for a given set of samples. Therefore, a large consumer sample (typically $n > 60$ consumers) is used and asked to indicate liking/disliking using hedonic scales. The most common hedonic scale is a 9 point anchored scale, i.e. with verbal labels for each category. If only two samples are studied, pairwise comparisons are applicable to illuminate consumer preferences; this is also possible whenever several samples are to be compared to a constant reference, as was done for boar tainted meat vs. castrate meat 1.

Frequently, it is important to understand which sensory attributes affect consumer acceptance. Therefore, to identify so called “drivers of liking”, liking data obtained through consumer testing is modelled via PLS-regressions or other multivariate approaches using sensory descriptive (profiling) data obtained from trained assessors.

2. Applications

Sensory analysis is widely applied to both fresh and processed meat. Without being exhaustive, some examples of sensory evaluation applied to meat are given as follows:

A recent study investigated the effect of differing marbling levels in beef strip loin steaks (all considered tender) on sensory evaluation by trained panellists and consumers’ acceptability. In the results, beef flavour scores increased with increasing fat level (2 to 26% fat), which was also the primary driver of acceptability 2. Hence, this study confirms the importance of flavour to beef palatability, regardless of tenderness.

Descriptive sensory analysis was used to investigate warmed-over flavour (WOF) development in cooked, chill-stored and reheated pork patties 3. Multivariate data analysis (Analysis of Variance–Partial Least Squares Regression, ANOVA–PLSR) was used to determine the association between the design variables (storage duration before reheating and pre-slaughter stress level of the pigs), and sensory and chemical data. As per the study, WOF was attributable to the development of lipid oxidation-derived off-flavour and odour notes, e.g. rancid-like flavour and linseed oil-like odour, in concurrence with a decrease in perceived meatiness, i.e., cooked pork meat-like flavour. The sensory variation related to pre-slaughter stress appeared to be distinct from WOF variation.

A very recent study researched the use of alternative proteins for livestock feeding to elucidate consequences for resulting meat quality including sensory traits 4. Pork quality characteristics related to the dietary substitution of soybean meal with the micro-alga Spirulina (Arthrospira platensis) or black soldier fly (Hermetia illucens) partly-defatted larval meal were investigated, which included sensory profiling by trained assessors. The results showed that meat quality is not compromised by including these alternative protein sources in pig diets. Other fields of research involving sensory evaluation of fresh meat involve effects of breed, diet, husbandry systems, pre- and post-slaughter handling, packaging and ageing – to name a few.

Sensory evaluation techniques are also frequently applied to meat products. For example, quantitative descriptive analysis (= sensory profiling) was used to characterise traditional sausages produced in the Massif central region in France 5. Sensory data were correlated with information regarding the production obtained from the producers via a questionnaire. Thus the relationship of recipe/manufacturing and resulting sensory properties of the final products was established; discriminant analysis revealed it was possible to classify the sausages correctly into specific manufacturing practice groups based on the sensory data. Hence, this approach can be used for quality labelling such as protected designation of origin/ protected geographical indication (PGI/PDO).

Other applications include the reduction of salt, fat and sugar in meat products, modification of the fatty acid composition by adding plant oils, the use of new ingredients for meat processing (healthy meat products such as hydrolysed by-products or fibres with potential health benefits 6) and the use of boar tainted meat 7–9.
3. Assessor selection and performance

3.1. Descriptive analyses
For the objective assessment of fresh meat, guidelines for selection and training of assessors are publicly available. For example, exercises are outlined to screen assessors’ ability to detect difference in juiciness, tenderness or flavour of meat. For the evaluation of boar taint, it is critical to select appropriate assessors for sensory evaluations. It is well known that people differ tremendously in their olfactory acuity for androstenone, a key compound of boar taint, which in turn affects their perception of boar taint in meat; this also holds for consumers and their hedonic judgment of boar meat. Standardised smell tests can be applied to characterise both trained assessors and consumers. Therefore, it is suggested assessors are chosen according to their olfactory acuity for the key boar taint compounds, androstenone and skatole.

For research, their performance should be described as one would describe, e.g., the limit of detection of a gas chromatography protocol used. For critical applications, such as the detection of boar taint at slaughter (for sorting carcasses), performance criteria such as being under the receiver-operating characteristic (ROC) curve or intra-class correlations of a panel or evaluation method should be indicated.

3.2. Hedonic analyses
For the hedonic assessment of meat and meat products, consumer panellists must be recruited. Depending on the aim of the project, demographic and socio-economic criteria (e.g. age, gender, household size, income, area of residence), usage (e.g., heavy vs. light users) and attitudes are considered. Typically, one aims to address consumers of the products to be tested. Since consumers’ hedonic ratings vary to a greater extent than trained panellists’ ratings, large sample sizes are needed to show significance of product effects.

It is important to keep in mind that panellists trained for descriptive sensory analysis must under no circumstances evaluate products hedonically – this is one central paradigm of sensory analysis. However, this mistake is frequently to be found in practice and in academia.

4. Sample preparation and presentation
Depending on the aim of the project, a protocol for the sensory study needs to be chosen. This includes aspects such as product sampling, sample preparation and sample presentation. For fresh meat evaluation, frequent cooking procedures include braising, broiling, electric charbroiling, roasting, grilling, outdoor grilling and sous-vide cooking. Detailed descriptions are, for instance, provided in the American Meat Science Association (AMSA) guidelines. For example, sous-vide cooking is used to identify small flavour differences by avoiding additional aroma development from Maillard reaction. The amount of sample presented to panellists for one test can differ substantially (e.g. from presenting a whole steak to small cubes of meat. The size should be big enough so that panellists can evaluate the given sample. Additionally, sensory fatigue and satiety need to be taken into account. The presentation order should, whenever possible, be balanced or at least randomised to avoid first position effects and carry-over effects. Especially for consumer studies, a systematic bias of scores for the first sample is frequently observed.

5. Sensory descriptors
The AMSA provides guidelines for cooking, sensory evaluation and instrumental tenderness measurements of meats including a generic scheme for descriptive meat analysis. Whenever possible, such a generic scheme should be replaced with a species-specific flavour lexicon, whereby each flavour attribute can be referenced and scaled. If this is not practical or not necessary based on the experiment objectives, one or two flavour notes, such as beef flavour identity (=the amount of beef flavour), could be used instead. The development and application of a set of sensory descriptors was demonstrated earlier to derive a sensory landscape of 15 meat species, so this could well serve as a
basis. If texture of the meat is of special interest, a detailed vocabulary can be found elsewhere \cite{17}. For the case of boar taint, specific descriptors such as sweaty, urine, manure and mothball have been identified and are being frequently used \cite{9,18}.

6. Consumer ballots
Typically, consumer ballots comprise first order questions (“How do you like/dislike this product overall?”) and second order questions (“How do you like the tenderness of this steak?”) for further diagnostics. In addition, just about right (JAR) scales can be applied to identify how consumers perceive certain attributes and how that affects their hedonic evaluation. To do so, usually a 5 point category scale is used, and consumers indicate whether a specific attribute’s intensity is too low, too high or just right. Penalty analysis is used to assess the impact of a product being not JAR by calculating the overall liking drop. For further product diagnostics, check-all-that-applies (CATA) has been increasingly applied in research to speed-up product optimisation processes. Therein, consumers indicate their overall liking and record their perception of various attributes. Penalty analysis on CATA items proved to be a simple and useful approach to identify drivers of liking and directions for improving the products \cite{19}.

7. Non-inferiority testing
When reformulating products, replacing unwanted ingredients or changing processing technology, it is often rather desirable that consumer liking stays the same as before. For such research questions, non-inferiority testing \cite{20} is suggested rather than looking at significant differences. Non-inferiority testing is suitable whenever a formulation is to be identified that is as similarly acceptable as the current standard. For example, a consumer study identified the maximum allowable proportion of tainted boar meat for Frankfurter type sausages without significantly impairing consumer acceptance \cite{7}.

8. Context
Frequently, the effect of labels (e.g., organic, country of origin, production system) on sensory consumer acceptance is studied. This is because meat and meat products typically are sold with such labels on the pack. Strikingly, such labels often improved the acceptance scores, even though the underlying meat was not scored significantly differently under blind conditions. In the case of boar taint, it was demonstrated that labelling the meat as originating from “young boars” did not decrease consumer acceptance \cite{14}. On the contrary it was demonstrated repeatedly that labelling products as “organic” or “free range” increases consumer acceptability scores \cite{21,22}.

Another aspect is consumption context. Occasionally, the product of interest is presented in a meal context to evaluate its perception in a more realistic situation than presenting the product alone. A comparative study on consumer acceptance of pork with differing levels of boar taint found, however, no difference regardless of whether the meat was presented with or without side dishes \cite{23}. The study also showed that sensory defects detected by trained panellists may not be noticed by untrained, and thus usually less sensitive, consumers.

Also, the testing surroundings itself provides context that can affect consumer ratings. Emerging immersive technologies (e.g. virtual reality, VR glasses or screens) are being researched as to whether they could help to increase the external validity of sensory consumer testing by providing the consumption context more realistically than classical sensory laboratory testing.

9. Conclusion
If applied correctly, sensory science is a powerful tool, as it provides measures no other instrument (to date) can provide: a detailed description of how a food item is perceived by the human senses and/or how much this item is liked. It is, therefore, fundamental to think about the scope of any sensory test and to consider good sensory practice.
References
[1] Aluwé M, Aaslyng M, Backus G, Bonneau M, Chevillon P, Haugen JE et al. 2018 Consumer acceptance of minced meat patties from boars in four European countries Meat Sci. 137 235–43
[2] Corbin C H, Quinn T G O, Garmyn A J, Legako J F, Hunt M R, Dinh T T N et al. 2015 Sensory evaluation of tender beef strip loin steaks of varying marbling levels and quality treatments Meat Sci. 100 24–31
[3] Byrne D V., Bredie W L P, Bak L S, Bertelsen G, Martens H and Martens M 2001 Sensory and chemical analysis of cooked porcine meat patties in relation to warmed-over flavour and pre-slaughter stress Meat Sci. 59 229–49
[4] Altmann B A, Neumann C, Rothstein S, Liebert F and Mörlein D 2019 Do dietary soy alternatives lead to pork quality improvements or drawbacks? A look into micro-alga and insect protein in swine diets Meat Sci. 153 26–34
[5] Rason J, Dufour E and Lebecque A 2007 Diversity of the sensory characteristics of traditional dry sausages from the centre of France: Relation with regional manufacturing practice Food Qual. Prefer. 18 517–30
[6] Jakobsen L M A, Vuholm S, Aaslyng M D, Kristensen M, Sørensen K V, Raben A et al. 2014 Sensory characteristics and consumer liking of sausages with 10 % fat and added rye or wheat bran Food and Nutrition 2 534–46
[7] Mörlein I, Meier-Dinkel L, Gertheiss J, Schnäckel W and Mörlein D 2019 Sustainable use of tainted boar meat: Blending is a strategy for processed products Meat Sci. 152 65–72
[8] Meier-Dinkel L, Gertheiss J, Schnäckel W and Mörlein D 2016 Consumers’ perception and acceptance of boiled and fermented sausages from strongly boar tainted meat Meat Sci. 118 34–42
[9] Aaslyng M D and Koch A G 2018 The use of smoke as a strategy for masking boar taint in sausages and bacon Food Res. Int. 108 387–95
[10] AMSA Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat. American Meat Science Association, Champaign, Illinois USA. 2015 pp 1–104
[11] Trautmann J, Gertheiss J, Wicke M and Mörlein D 2014 How olfactory acuity affects the sensory assessment of boar fat: A proposal for quantification Meat Sci. 98 255–62
[12] Meier-Dinkel L, Sharifi AR, Tholen E, Frieden L, Bücking M, Wicke M et al. 2013 Sensory evaluation of boar loins: Trained assessors’ olfactory acuity affects the perception of boar taint compounds Meat Sci. 94 19–26
[13] Aluwé M, Tuyttens F A M, Bekaert K M, De Smet S, De Brabander D L and Millet S 2012 Evaluation of various boar taint detection methods Animal 6 1868–77
[14] Trautmann J, Meier-Dinkel L, Gertheiss J and Mörlein D 2016 Boar taint detection: A comparison of three sensory protocols Meat Sci. 111 92–100
[15] Adhikari K, Chambers IV E, Miller R, Vázquez-Araújo L, Bhumiratana N and Philip C 2011 Development of a lexicon for beef flavor in intact muscle J Sens. Stud. 26 413–20
[16] Rødbotten M, Kubberød E, Lea P and Ueland Ø 2004 A sensory map of the meat universe. Sensory profile of meat from 15 species Meat Sci. 68 137–44
[17] Cavitt L C, Xiong R and Owens C M 2005 Changes in Tenderness of Broiler Breast Fillets Journal of Muscle Foods 16 223–42
[18] Annor-Frempong I E, Nute G R, Whittington F W and Wood J D 1997 The problem of taint in pork: I. Detection thresholds and odour profiles of androstenone and skatole in a model system Meat Sci. 46 45–55
[19] Ares G, Dauber C, Fernández E, Giménez A and Varela P 2014 Penalty analysis based on CATA questions to identify drivers of liking and directions for product reformulation Food Qual. Prefer. 32 65–76
[20] Meyners M 2012 Equivalence tests - A review Food Qual. Prefer. 26 231–45
[21] Scholderer J, Nielsen N A, Bredahl L, Claudi-Magnussen C and Lindahl G 2004 Organic por: consumer quality perceptions 2004pure.au.dk/portal/files/32304683/pp0204.pdf.
[22] Morales R, Aguiar A P S, Subiabre I and Realini C E 2013 Beef acceptability and consumer expectations associated with production systems and marbling Food Qual. Prefer. 29 166–73
[23] Meier-Dinkel L, Strack M, Höinghaus K and Mörlein D 2016 Consumers dislike boar taint related off-flavours in pork chops regardless of a meal context Meat Sci. 122 119–24