CA15215

Innovative approaches in pork production with entire males"

Fact sheet: Pork production with entire males

Background: Surgical castration of male piglets has been a traditional practice for ages in most countries mainly to prevent boar tainted pork, and to eliminate male specific behavior. As the surgery is generally carried out without using any pain relief, this represents a welfare relevant problem, which has been facing increasing criticism. According to EU Directive 2001/93/EEC, the castration without anaesthetic is allowed for piglets that are less than one week old. For older animals surgical castration must be performed by a veterinarian using anaesthesia and additional prolonged analgesia (https://www.fve.org/cms/wp-content/uploads/fve_09_040_castration_pigs_2009.pdf). Moreover, wound healing in piglets subjected to surgical castration at 4 days of age seems to be faster and with fewer complications than in animals castrated between 7 and 28 days of age (Heinritzi et al., 2006). At surgery male piglets are restrained, the scrotum is incised with a sharp scalpel, the testes are extracted and the spermatic cord cut with a scalpel, an antiseptic is applied to the open wound and the piglet is rapidly returned to its pen. The overall procedure takes 1 - 2 minutes (http://www.alcasde.eu/e-Learning/pig_castration/page_16.htm). Castration is painful, regardless of the surgical procedure as cutting and/or tearing of tissue (scrotum and spermatic cords) are known to induce acute pain and stress (Prunier et al., 2006; von Borell et al., 2009). After castration, suckling behaviour is reduced for around two hours and the open wound risks to get infected (http://www.alcasde.eu/e-Learning/pig_castration/page_16.htm). There is also some evidence of health impairment in castrated compared to entire male pigs leading to a higher mortality rate during the nursing period (6.3 vs 3.6%) especially if the birth weight is low (12.2 vs 6.2%) (Morales et al., 2017).

Advantage of pork production with entire male piglets: To omit castration and to produce pork with entire males has welfare (no pain and stress associated with the castration), economic (better feed conversion and no labour associated with castration) and environmental (boars have better N-retention than castrates) advantages (for review see Kress et al, 2019, Pauly et al., 2012). Due to increasing concentrations of androgens and estrogens during pubertal development, the sex hormone-dependent growth potential increases, favoring the accretion of lean meat at the expense of fat in the carcass (Table 1). The voluntary feed intake is reduced by gonadal steroids resulting in greater feed efficiency but may on the other hand impair growth rate of entire males compared to castrates in some genotypes (Claus & Weiler, 1994). In the final report of the European commission about best practices on the production, the processing and the marketing of meat from uncastrated pigs the value of better feed conversion was estimated to €7.11 per pig.

Table 1. Advantages of entire males in comparison to surgical castrates in various traits:

Parameter	Boar vs Barrow	Literature
Protein deposition (g/d)	+11 %	Quiniou et al., 2010
Feed/gain (kg/kg)	-10 %	
Average daily feed intake (kg/d)	-11 %	
Subcutanous fat (%)	-16 %	Pauly et al., 2009
N-excretion (kg/animal)	-20 %	Dämmgen et al., 2013

Disadvantage of pork production with entire male piglets: The risk of boar taint is the main quality problem in pork production with entire males. Boar taint is an offensive odour and flavour observed in the meat from some entire male pigs. Two main compounds, androstenone and skatole, are known to be responsible for boar taint. Androstenone is a testicular steroid with a urine like smell. It has biological significance as a male pheromone and is a precursor of the pheromone active androstenoles. Androstenone is formed in parallel to the synthesis of anabolic testicular steroids in the Leydig cells and distributed via the blood stream to the salivary glands where it accumulates due to specific binding protein (pheromaxein). Skatole is a microbial product of tryptophan degradation in the hindgut and has fecal odour. It is formed in males and females, but is found in higher concentrations in the adipose tissue of boars.
Excessive accumulation of skatole in adipose tissue can occur due to an increased rate of its biosynthesis, reduced rate of its catabolism in the liver or both. The reduced rate of the hepatic skatole degradation can be caused by the reduced expression and/or activity of skatole-metabolizing enzymes that are regulated by androstenone, testosterone or 17- β-estradiol (Doran et al., 2002, Zamaratskaia et al., 2007; Wierciska et al., 2012; Kojima and Degawa, 2013). It is also known that genetics, diet and environmental/management factors influence the level of the boar taint compounds.
Both, skatole and androstenone have lipophilic properties and thus can accumulate in the adipose tissue of growing boars around the most common slaughter ages/weights due to the progressing pubertal development. Consumer dissatisfaction gradually increases with high concentrations of one or both compounds and depends on olfactory acuity (Font-i.Furnols, 2012; Mörlein et al., 2019). A peculiarity related to androstenone is that about one third of the consumers are anosmic (inability to perceive odor) to androstenone, and a similar proportion of consumers is highly sensitive and rejects pork with even very low (< 0.5 ppm) androstenone concentrations. Such a high variability in perception has not been reported for skatole. Skatole tainted carcasses are rejected by most of the consumers at levels above 0.25 ppm (see: Font I Furnols 2012; Lunde et al., 2012).
It is important to note that there are several other issues of entire male production, which are associated to the quality of meat and fat. The quality issues are negatively affecting either meat intended for fresh consumption or (even more notably) reduce processing aptitude of such meat (Bonneau et al., 2018; Čandek-Potokar et al., 2015). especially in the case of dry cured products. In relation to shear force measurements, it has been confirmed by meta-analytic studies that entire males exhibit tougher meat compared to other sex categories (Pauly et al., 2012; Batorek et al., 2012). Increased toughness may be ascribed to the factors like lower intramuscular fat content, reduced water holding capacity and increased protein oxidation (Škrlep et al., 2019). As for meat products, reduced adiposity of entire males was associated to excessive desiccation (causing lower processing yields and harder texture) in addition to higher salt uptake during processing of dry-cured hams (Škrlep et al., 2016). The fat of EM is more polyunsaturated (Pauly et al., 2012), making its texture softer and being more easily separated from other tissues, especially in very lean individuals, lowering the quality of the cuts and makes it difficult for packing. In addition, the EM fat gets rancid faster (Babol & Squires, 1995). In minced meat products like dry-fermented sausages, unsaturated fat may cause additional problems related to proper drying, texture and surface oiliness.

Methods of boar taint detection and incidence of boar tainted carcasses in entire males

There are mainly two methods reported for determining the presence of boar taint in the fat of pig carcass. The first one is chemical analysis of androsteone and skatole concentrations. If this approach is used the critical point are the thresholds for acceptance, as the incidence of tainted carcasses may be high and exceed even 50% if the low thresholds are used, which were suggested in the nineties and used in some European countries at that time (Walstra et al., 1999). As new methods for measurements of boar taint compounds at the slaughterline become available, new thresholds have to be critically evaluadted as discussed below.The second method used for detection of boar taint is the Human Nose scoring at slaughter line by trained experts. In case of the human nose the incidence of tainted carcasses usually does not exceed 5% on average (Mathur et al., 2012). As consumer

dissatisfaction depends on both, the concentraions of compounds and the olfactory acuity as described above, sorting limits depend on the extent of acceptable dissatisfaction (Mörlein et al., 2019). Even if there is a huge variation in consumer response the expected risk of dislike and the number of discarded carcasses can be estimated as a function of sorting limits. Allowing the industry to set appropriate sorting limits the risk of dissatisfied consumers must be balanced with the proportion of discarded entire male carcasses (Christensen et al., 2019). The high variability in the occurrence of tainted carcasses can be explained, at least partially, by factors discussed below. During the fattening periods also some specific welfare problems may occur (Rydmer et al., 2012, Weiler et al., 2016; Reiter et al., 2017). Unwanted pregnancies may be observed in mixed groups, especially if the animals reach slaughter weight at an older age as e.g. under organic farming conditions. Boars are more active and more aggressive, which may cause welfare problems due to fighting especially if the group and the social ranking are not stable over the whole grower finisher period. An increase in sexual behavior during the fattening period leads to a higher risk of leg problems due to mounting or being mounted. In addition, a high frequency of penile injuries has been reported, which may be severe in an order of 10% of the boars and has to be regarded as a welfare problem.

Management alternatives to reduce problems in pork production with entire males: There is a number of strategies to reduce the incidence of boar taint and associated problems. In some countries, entire males are slaughtered at a lower slaughter weight. As the level of androstenone and skatole have been found to be inheritable, the use of breeds or individual genotypes with a lower level of boar taint at the common slaughter weights in breeding programmes is promising. Even if it is not clear which specific genes are responsible for boar taint, eliminating the need for castration via genetic and genomic selection may be a solution in the long term. However, the interactions of all factors must be understood before introducing changes into selective breeding (Larzul et al., 2018; Schiavo et al., 2018; van Son et al., 2018). Another potential alternative is the use of skatole reducing feeds. However, this does not solve the issue of androstenone as this component is less susceptible to dietary manipulations (Engesser, 2015; Zamaratskaia and Rasmussen, 2018; and see list of feed ingredients with boar taint reducing capacities http://www.ca-ipema.eu/papers). Together with management strategies which reduce the stress during the fattening, transport and at slaughter (Wesoly et al., 2015), the incidence of tainted carcasses can be reduced considerably.

References:

Babol, J., Squires, J. Quality of meat from entire male pigs. Food Research International, **1995**, 28, 201-212.

Batorek, N, Čandek-Potokar, M., Bonneau, M., Van Milgen, J. Meta-analysis of the effect of immunocastration on production performance, reproductive organs and boar taint compounds in pigs. Animal, **2012**, 6, 1330-1338

Bonneau, M.; Čandek-Potokar, M.; Škrlep, M.; Font-i-Furnols, M.; Aluwé, M.; Fontanesi, L. Potential sensitivity of pork production situations aiming at high-quality products to the use of entire male pigs as an alternative to surgical castrates. *Animal* **2018***, 12,* 1287-1295, doi: 10.1017/S1751731117003044

Čandek-Potokar M, Škrlep M, Batorek Lukač N. Raising entire males or immunocastrates – outlook on meat quality. Procedia Food Science **2015**, 5, 30-33

Christensen RH, Nielsen DB, Aaslyng MD (2019) Estimating the risk of dislike: An industry tool for setting sorting limits for boar taint compounds. Food Quality and preference 71(2019): 209-2016.

Claus, R., Weiler, U. 1994 Endocrine regulation of growth and metabolism in the pig: a review. Livestock production science, 1994, 37(3) 245-260

Dämmgen, U., Berk, A., Otten, C., Brade, W., Hutchings, N. J., Haenel, H.-D., Rösemann, C., Dänicke, S., Schwerin, M. Anticipated changes in the emissions of green-house gases and ammonia from pork produc-tion due to shifts from fattening of barrows towards fattening of boar Landbauforsch· Appl Agric Forestry Res · 1 **2013** (63)47-6 DOI:10.3220/LBF_2013_47-60

Doran, E.; Whittington, F.W.; Wood, J.D.; McGivan, J.D. Cytochrome P450IIE1 (CYP2E1) is induced by skatole and this induction is blocked by androstenone in isolated pig hepatocytes. *Chem. Biol. Interact.* **2002***, 140,* 81-92, doi: 10.1016/S0009-2797(02)00015-7

Engesser, D.J. Alternatives for boar taint reduction and elimination besides surgical castration and destroying testicular tissue. **2015** Inaugural-Dissertation to obtain the degree of a Doctor medicinae veterinariae (Dr. med. vet.) from the Faculty of Veterinary Medicine University of Leipzig Germany http://ul.qucosa.de/api/qucosa%3A13364/attachment/ATT-0/

Font-i-Furnols, M. Consumer studies on sensory acceptability of boar taint: a review. *Meat Sci.* **2012***, 92, 319-329*. doi: 10.1016/j.meatsci.2012.05.009.

Heinritzi, K., Ritzmann, M., Otten, W. Alternatives for castration of suckling piglets, determination of catecholamines and woundhealing after castration of suckling piglets at different points of time (Alternativen zur Kastration von Saugferkeln, Bestimmung von

Katecholaminen sowie Wundheilung nach Kastration von Saugferkeln zu unterschiedlichen Zeitpunkten). Deutsche Tierärztliche Wochenschrift **2006,** 113, 94–97

Kojima, M.; Degawa, M. Serum androgen level is determined by autosomal dominant inheritance and regulates sex-related CYP genes in pigs. *Biochem. Biophys. Res. Co.* **2013***, 430,* 833–838, doi.org/10.1016/j.bbrc.2012.11.060

Larzul, C.; Fontanesi, L.; Tholen, E.; van Son, M. Genetic approaches for rearing entire males. *Adv. Anim. Biosci.* **2018***, Volume 9, Special Issue s1,* s01.

Lunde, K.; Egelandsdal, B.; Skuterud, E.; Mainland, J.D.; Lea, T.; Hersleth, M.; Matsunami, H. Genetic Variation of an Odorant Receptor OR7D4 and Sensory Perception of Cooked Meat Containing Androstenone. *PLOS ONE* **2012***, 7,* e35259, doi: 10.1371/journal.pone.0035259

Mathur, P.K.; ten Napel, J.; Bloemhof, S.; Heres, L.; Knol, E.F.; Mulder, H.A. A human nose scoring system for boar taint and its relationship with androstenone and skatole. *Meat Sci.* **2012***, 91,* 414–422, doi: 10.1016/j.meatsci.2012.02.025

Morales, J., Dereu, A., Manso, A., de Frutos, L., Piñeiro, C., Manzanilla, E.G. and Wuyts, N. 2017 Surgical castration with pain relief affects the health and productive performance of pigs in the suckling period. Porcine Health Management **2017** 3:18 https://doi.org/10.1186/s40813-017-0066-1

Mörlein D , Aluwé M , Backus G , Bonneau M , Brockhoff P, Chevillon P, Christensen R, Font-i-Furnols M, Gertheiss J, Meier-Dinkel L, Mörlein J , Oertel E, Oliver MA , Tuyttens F , van den Broeke A , Aaslyng M (2019) Drivers of (dis)liking: Systematic pairwise preference tests to reveal the relationship between boar taint and consumer acceptance Poster presented at ICOMST 2019.

Pauly, K., Luginbühl, W., Ampuero, S., Beem G. Expected effects on carcass and pork quality when surgical castration is omitted. Meat Sci **2012**;92:858-62.

Pauly, C., Spring, P., O'Doherty, J., Ampuero Kragten, S., & Bee, G. Growth performance, carcass characteristics and meat quality of group-penned surgically castrated, immunocastrated (Improvac®) and entire male pigs and individually penned entire male pigs. Animal, **2009,** 3(7), 1057-1066. doi:10.1017/S1751731109004418

Pauly, C; Luginbühl, W.; Ampuero, S.; Bee, G. Expected effects on carcass and pork quality when surgical castration is omitted — Results of a meta-analysis study. *Meat Sci.* ***2012****, 92,* 858–862, doi: 10.1016/j.meatsci.2012.06.007.

Prunier, A.; Bonneau, M.; von Borell, E.H.; Cinotti, S.; Gunn, M.; Fredriksen, B.; Giersing, M.; Morton, D.B.; Tuyttens, F.A.M.; Velarde, A. A review of the welfare consequences of surgical castration in piglets and evaluation of non-surgical methods. *Anim. Welfare* **2006**, *15,* 277–289.

Quiniou, N, Courboulay, V, Salaün, Y, Chevillon, P 2010. Impact of the non castration of male pigs on growth performance and behaviour – comparison with barrows and gilts. Conference at the 61st Annual Meeting of the European Association for Animal Production, Heraklion, Crete Island, Greece, paper 8; 7pp.

Reiter, S.; Zöls, S.; Ritzmann, M.; Stefanski, V.; Weiler, U. Penile Injuries in Immunocastrated and Entire Male Pigs of One Fattening Farm. *Animals* ***2017****, 7,* doi: 10.3390/ani7090071.

Rydhmer, L.; Zamaratskaia, G.; Andersson, H.K.; Algers, B.; Guillemet, R.; Lundström, K. Aggressive and sexual behaviour of growing and finishing pigs reared in groups, without castration. *Acta Agr. Scand. A-An* **2006***, 56,* 109–119, doi: 10.1080/09064700601079527

Schiavo, G.; Bovo, S.; Cheloni, S.; Ribani, A.; Geraci, C.; Gallo, M.; Etherington, G.; Palma, F:D.; Fontanesi, L. Mining whole genome resequencing data to identify functional mutations in boar taint-candidate genes. Adv. Anim. Biosci. 2018, Volume 9, Special Issue s1, s04

Škrlep, M., Čandek-Potokar, M., Batorek Lukač, N., Prevolnik Povše, M., Pugliese, C., Labussière, E., Flores, M. Comparison of entire male and immunocastrated pigs for dry-cured ham production under two salting regimes. Meat Science, 2016, 111, 27-37.
Škrlep, M., Tomažin, U., Batorek Lukač, N., Poklukar, K., Čandek-Potokar, M. Proteomic profile of longissimus dorsi muscle of entire male and castrated pigs as related to meat quality. Animals, 2019, 9, 1-14.

van Son, M.; Agarwal, R.; Grindflek, E.; Grove, H.; Kent, M.P.; Lien, S. Fine mapping of QTL regions for boar taint using whole genome re-sequencing data. *Adv. Anim. Biosci.* **2018***, Volume 9, Special Issue s1,* s06

von Borell, E., Baumgartner J., Giersing, N., Jäggin, M. Prunier, A., Tuyttens, F., Edwards S.A. 2009 Animal welfare implications of surgical castration and its alternatives in pigs. animal 3(11):1488-96. DOI: 10.1017/S1751731109004728

Walstra, P.; Claudi-Magnussen, C.; Chevillon, P.; von Seth, G.; Diestre, A.; Matthews, K.R.; Homer, D.B.; Bonneau, M. An international study on the importance of androstenone and skatole for boar taint: levels of androstenone and skatole by country and season. *Livest. Prod. Sci.* **1999***, 62,* 15-28, doi: 10.1016/S0301-6226(99)00054-8

Weiler, U.; Isernhagen, M.; Stefanski, V.; Ritzmann, M.; Kress, K.; Hein, C.; Zöls, S. Penile Injuries in Wild and Domestic Pigs. *Animals* ***2016****, 6, 25*, doi: 10.3390/ani6040025

Wesoly, R.; Jungbluth, I.; Stefanski, V.; Weiler, U. Pre-slaughter conditions influence skatole and androstenone in adipose tissue of boars. *Meat Sci.* **2015***, 99,* 60-7. doi: 10.1016/j.meatsci.2014.08.015.

Wesoly, R.; Weiler, U. Nutritional Influences on Skatole Formation and Skatole Metabolism in the Pig. *Animals* **2012***, 2,* 221–242, doi: 10.3390/ani2020221

Wiercinska, P.; Lou, Y.; Squires, E. J. The roles of different porcine cytochrome P450 enzymes and cytochrome b5A in skatole metabolism. *Animal* ***2012****, 6,* 834-845, doi: 10.1017/S1751731111002175.

Zamaratskaia, G.; Gilmore, W.J.; Lundström, K.; Squires, E.J. Effect of testicular steroids on catalytic activities of cytochrome P450 enzymes in porcine liver microsomes. *Food Chem. Toxicol.* **2007***, 45,* 676-681, doi: 10.1016/j.fct.2006.10.023

Zamaratskaia, G.; Rasmussen, M.K. Is it possible to reduce androstenone by dietary means? *Adv. Anim. Biosci.* **2018***, Volume 9, Special Issue s1,* s22

This fact sheet was published in August 2019 by the COST action IPEMA Core Group (Marijke Aluwe, Ge Backus, Giuseppe Bee, Michel Bonneau, Eberhard von Borell, Meta Candek-Potokar, Olena Doran, Maria Font-i –Furnols, Catherine Larzul, Martin Skrlep, Igor Tomasevic, Liliana Tudoreanu, Mandes Verhaagh, Ulrike Weiler). Translations into the national languages of the countries participating in the COST action IPEMA will follow.