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Size matters: Boar taint in relationship with body composition and testis volume measured by magnetic resonance imaging

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ABSTRACT

The aim of this study was to evaluate the possibility of predicting boar taint in live pigs non-invasively. For this, different magnetic resonance imaging based body composition traits (including testis volume) were compared with androstenone, skatole, and indole levels (ng/g fat) of the carcass` fat tissue after slaughtering. Additionally, in order to find traits which could help in predicting boar taint, the related sensory test results were included in the analysis.

A number of 34 entire boars (EB) and 34 immunocastrated boars (IB; first injection at an age of 77 ± 1 days and second injection at an age of 137 ± 1 days) were scanned two times during growth (at 60 and 90 kg live body weight) using magnetic resonance imaging (MRI). Three body regions (shoulder, loin, and ham) were examined. Additionally the testes volume was calculated. After slaughtering, boar taint samples were taken for olfactory testing and stable isotope dilution assays. These data were compared with selected body composition traits in order to analyze the relationship between MRI traits and boar taint.

The results showed that IB tend to have greater subcutaneous fat layers (belly fat, shoulder fat, back fat) than EB. Within EB, larger testis volumes and a higher amount of body fat (especially belly fat) are associated with a higher level of androstenone.

1. Introduction

Worldwide, surgical piglet castration without anaesthesia is one of the biggest animal welfare issues in the current pig production. It causes tremendous stress and pain. Due to welfare issues of surgical castration and a growing public interest, the production system is under public debate. In Germany, this resulted in a prohibition of castration without anaesthesia by law in 2019 (BMEL, 2016; Weiß et al., 2016). Alternatives like castration under anaesthesia, boar fattening, or immunocastration are being discussed (Lundström et al., 2009; Albrecht, 2013; De Briyne et al., 2016); and mainly boar fattening or immunocastration might become alternative solutions for pork production (Albrecht, 2013; European Commission, 2017).

In the European Union and other selected countries, 246.8 million pigs were slaughtered in 2006 (Fredriksen et al., 2009). Nearly 80% of the male pigs were castrated, resulting in 94.52 million male piglets castrated without anaesthesia per year (Fredriksen et al., 2009). Surgical castration of piglets is performed to fully prevent the development of boar taint in pork. Therefore, the main problem besides animal welfare issues is the occurrence of boar taint in non-castrated boars (Aldal et al., 2005; Albrecht, 2013; Backus et al., 2016; De Briyne et al., 2016). Boar taint is an abnormal smell and taste of meat, which is mostly detected in cooked meat (Lundström et al., 2009; Albrecht, 2013; Bilić-Šobot et al., 2014). The main components of boar taint are androstenone and skatole (plus indole), both incorporated in fat tissue due to their lipophilic character (Andresen, 2006; Fuchs et al., 2009; Bonneau and Chevillon, 2012; Bilić-Šobot et al., 2014). An objective detection of boar taint is still not possible with 100% accuracy and depends on various factors as described in many scientific publications (e.g. Bonneau, 2006; Haugen et al., 2011; Meier-Dinkel et al., 2015; Backus et al., 2016; De Briyne et al., 2016; Mörlein et al., 2016; Trautmann et al., 2016).

Androstenone as the main component of boar taint is synthetized in the testis and accumulates in the fat tissue; its occurrence is linked to testicular anabolic hormones. Meat affected with androstenone has a urine-like odor. Skatole serves as the second boar taint component. It is produced in the colon when energy is limited during microbial degradation of tryptophan and is also stored in the fat tissue. Skatole

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causes a faecal odor in the meat (Aldal et al., 2005; Andresen, 2006). Indole or androstenols seem to be less important in causing boar taint (Albrecht, 2013). Several factors affect the development of boar taint, like housing, feeding, age at slaughter or genetics (Grindfleck et al., 2010; Große-Brinkhaus et al., 2015; Backus et al., 2016). Androstenone development is connected to the testis development; therefore adolescence is an important point in time for synthesis (Albrecht, 2013).

Immunocastration is dealt as one possible solution in order to decrease the number of tainted carcasses and to reduce animal behavioral problems (Dunshea et al., 2001; Zamaratskaia and Rasmussen, 2015).

As boar taint affects the acceptability of meat to consumers, affected carcasses must not enter the food chain. One possibility to detect boar taint at the slaughterhouse is to develop an electronic nose, which can detect boar taint (components) on-line (Lundström et al., 2009; Haugen et al., 2011). So far - to our knowledge - there is no device available for commercial use (Liu et al., 2017). In most of the slaughter houses, still the trained human nose serves as subjective indicator (Mathur et al., 2012). For industry and food producers, a method to predict boar taint by measuring carcass or morphological traits would be an excellent way to detect or predict carcasses affected with boar taint without the need of additional tissue sampling and analysis. Therefore, carcass composition traits which are associated with boar taint should be identified. If such traits could be identified and successfully measured on the carcass or even better in the live animal, animals could be selected according to their morphological or carcass composition traits and corresponding boar taint indicators.

Magnetic resonance imaging (MRI) or other non-invasive methods like computed tomography are meanwhile widely used in animal science and performance testing to measure the whole body or carcass composition in combination with other important traits (Bernau et al., 2015; Scholz et al., 2015; Font i Furnols et al., 2016).

The aim of this study was to evaluate the possibility of predicting boar taint in live pigs non-invasively. Different MRI based body composition traits (including testis volume) were related to androstenone, skatole, and indole levels (ng/g fat) of the carcass` fat tissue after slaughtering and the related sensory test results in order to find traits which could help in predicting boar taint.

2. Material and methods

2.1. Animals

A total of 34 entire boars (EB) and 34 immunocastrated boars (IB) were examined. All animals were kept according to the German national animal welfare regulations (Directive 2010/63/EU, 2010; Tierschutz-Nutztierhaltungsverordnung, 2016; Tierschutzgesetz, 2017). The animal experiment was licensed by the District Government of Upper Bavaria (registry number: 55.2-1-54-2532.2-12-13).

All animals were born and raised on a conventional pig farm. The boars were offspring of German Landrace sows mated with Piétrain boars. Experimental animals of three batches with different slaughter seasons (December, February, July = batches 1–3) were randomly assigned to the two treatments (boar groups), with equal distribution within a litter. All experimental animals were housed in groups together with surgically castrated male pigs in an outdoor climate barn (individual space > 1.46 m^2) and were fed ad libitum with a diet containing 15 MJ ME/kg on a fully automatic feeding station (Double FitMix, PigTek®, now Fancom B.V., Panningen, Netherlands). The outdoor climate barn consisted of a concrete floor area (36 m^2) filled with deep straw. This part served as rest area which is separated by four stairs (5.4 m^2) and a ramp from the feeding area with fully slatted floor (18.3 m^2). Robes or jute sacks served as hanging “toys”. IB were injected an analogon-protein-conjugate of the gonadotropin-releasing-factor (Improvac™, Zoetis) at two times. First injection took place at an age of 77 ± 1 days and second injection at an age of 137 ± 1 days.

2.2. Magnetic resonance imaging

In order to evaluate the body composition and especially to measure further boar related traits, the boars were scanned two times during growth using an open low field magnetic system (Siemens Magnetom Open, 0.2 T). The first scan was performed at an age of 111 days (scan 60; average body weight 60 kg) and the second scan at an age of 152 days (scan 90; average body weight 90 kg) - 14 days before slaughter.

The boars were scanned in a prone position with front and hind limbs extended. A T1-weighted spin echo sequence was used (TR 380 s; TE 15 ms; 3:17 min examination time; 10 slices; 18.75 mm slice thickness, including distance factor) for whole body scanning. Depending on the length of the body, 6–8 sequences were necessary to scan the whole body. Animals were sedated using a combination of azaperone (2 mg/kg) and ketamine (15 mg/kg) administered intramuscularly in order to guarantee excellent image quality. Subsequently, an intravenous catheter was inserted into an ear vein in order to supplement the sedation with ketamine (7 mg/kg), if necessary.

The 3D Doctor Software® (Able Inc., Lexington, MA, USA; FDA approved) helped to perform the MR image analysis. A semi-automatic procedure applied grey scale based thresholds among body tissues. Shoulder outline, shoulder fat, loin outline, back fat, belly fat, ham outline (combined with slice thickness - each in cm^3) served as indicator traits for the body composition. “Outline” describes the volume of the contour of the evaluated MRI image of a region. The term “fat” describes the fat volume at the evaluated MRI image of the region. Left and right testes volumes were measured by manual definition of testes contours (Fig. 1). The results represent the sum of both volumes.

2.3. Boar taint samples

Two boar taint samples - one for a “subjective” sensory (organoleptic) analysis and the other for an “objective” stable isotope dilution assay (SIDA; Fischer et al., 2012) - were taken at the time of slaughtering at an age of 165 ± 1 days.

The sensory analysis was performed with cheek and salivary gland samples according to the directive AVVLmHyg (2011) starting with a microwave heating (=MWH) procedure. If the organoleptic test result turned out to be “positive”, the next step - only for the positive samples - was a so-called cooking procedure (=CP) followed again by organoleptic testing. Finally, if the cooking test was still positive, a fat rendering (melt out) test (=MT) followed as last (third) test stage. If the final step turned out to be positive the meat is considered tainted. Organoleptic testing was done by three trained persons at the Tiergesundheitsdienst Bayern e.V. in Poing (Germany) 24 hours after taking tissue samples.

In addition, a fat sample of the neck (4 × 4 × 4 cm) was analyzed by a stable isotope dilution assay (SIDA) at the ELFI Analytik GbR Neufahrn (Germany) in order to determine the levels of androstenone, skatole, and indole.

2.4. Statistical analysis

For statistical analysis, the organoleptic results were sorted by sensory test stages from 0 to 3, with 0 representing test-negative animals, 1 representing test-positive animals in MWH, 2 representing test-positive animals in CP and 3 representing still test-positive animals in MT.

In order to get reliable LSM estimates, test stage 2 was deleted, because only one EB stayed positive in stage 2. Because this boar (EB) – by definition of the testing procedure – was also positive in stage 1, we moved this EB to stage 1, as we did with the single test-positive IB in MT. That means, actually 8 EB and 3 IB remained only positive until stage 1 (MWH) and were tested negative in the following stage. The two additional boars (1 EB, 1 IB), however, were also tested positive in stage 1 (MWH).