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The effect of immunization against gonadotropin-releasing factor on growth performance, carcass characteristics and boar taint relevant to pig producers and the pork packing industry: A meta-analysis

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ABSTRACT

Meta-analysis was used to compare pigs immunocastrated (IC) with Improvac® versus physically castrated (PC) or entire male (EM) pigs. Performance and carcass data as most relevant for producers and packers were analyzed and the risk of boar taint was assessed by comparing the number of pigs exceeding the consumer thresholds of detection (ToD) for skatole and androstenone.

A total of 78 articles fulfilled pre-defined inclusion criteria. Compared to PC pigs, IC pigs have a higher average daily gain (ADG; +32.54 g/day, $P < 0.0001$) and more favorable feed conversion ratio (FCR; −0.234 kg/kg, $P < 0.0001$), higher live weight and percentage lean, and lower hot carcass weight (HCW) and dressing percentage. Compared to EM pigs, IC pigs have a higher ADG (+65.04 g/day, $P < 0.0001$), FCR (+0.075 kg/kg, $P < 0.0001$), live weight and HCW, and a similar dressing percentage.

Conventionally raised IC pigs yield more valuable meat compared to PC (+0.628 kg) and EM (+1.385 kg) pigs. Heavy IC pigs (HCW > 97.7 kg) destined for the production of high-quality cured products gain approximately 0.3 kg more ham than their PC counterparts, with backfat and intramuscular fat still fulfilling the requirements for high-quality cured products.

The risk of exceeding the ToD for skatole and androstenone is similar in IC and PC pigs, but significantly higher in EM pigs.

Results from our meta-analyses confirm growth performance advantages of IC pigs compared with PC or EM pigs, and reveal a higher gain of valuable meat and a similar risk of boar taint as estimated for PC pigs.

1. Introduction

Physical castration of male piglets is a traditional practice to avoid boar taint, an unpleasant odor and flavor of meat from entire male (EM) pigs. Boar taint has been mainly attributed to the presence of androstenone and skatole. The sexual steroid androstenone is produced in the interstitial tissue of the testes. Accordingly, the level of androstenone is directly influenced by the activity of the testes and increases dramatically with puberty. Skatole is produced in the large intestine by microbial breakdown of the amino-acid tryptophan. The metabolism of skatole in the liver is reduced by sexual steroids, resulting in increased accumulation in the fat in male pigs as the testes start to produce more testosterone at puberty (Mackinnon and Pearce, 2007a).

Physical castration is, however, a painful and stressful procedure to the piglets (Prunier et al., 2006). Therefore, physical castration without analgesia or anesthesia has been banned in many countries.

As an alternative to physical castration immunocastration has become available. The first vaccine against the gonadotrophin releasing factor (GnRF) was launched in 1998 in Australia and New Zealand (Mackinnon and Pearce, 2007b) and has been subsequently released in numerous countries all over the world (Improvac®, Improvest®, Vivax®, Innosure®; from here forward referred to as Improvac®).

Male pigs are given Improvac® twice: the first dose is administered after 8 to 9 weeks of age and the second dose is given a minimum of 4 weeks after the first dose and between 4 and 6 weeks before slaughter, although in some markets the latter timing may be from 3 to 10 weeks before slaughter. The first dose primes the pig's immune system, but does not cause any relevant physiological change in the animal. The second dose creates the effective immune response, stimulating the immune system to produce specific antibodies resulting in a

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suppression of testicular function. The hormonal status rapidly adjusts to resemble that of a barrow (Dunshea et al., 2013). As a result, male pigs do not have to experience the pain and stress associated with physical castration and additionally are able to fully express their inherent potential for feed-efficient growth for the majority of their production cycle as an EM, before the effect of immunocastration applies. The productivity advantages of raising EM pigs compared to physically castrated (PC) pigs mainly include improved feed efficiency, less backfat and leaner carcasses (Xue et al., 1997).

Numerous studies have been conducted, evaluating different aspects of immunocastration such as performance parameters and carcass characteristics or the risk of boar taint. In brief, immunocastrated (IC) pigs grow faster and have a better feed conversion ratio than PC pigs. Compared to EM pigs, IC pigs consume more feed and also grow faster. IC pigs have a lower carcass yield than PC pigs and EM pigs, whereas lean meat percentage is intermediate (see review from Millet et al., 2011). Immunocastration significantly reduces androstenone and skatole levels in fat compared with EM pigs, and sensory studies confirmed that Improvac® effectively and consistently reduces the risk of boar taint (see review from Mackinnon and Pearce, 2007a).

Additionally, statistical analyses have been conducted, which combine results from different studies and focus on different key aspects: Trefan et al. (2013) put emphasis on the effect of gender on pork quality parameters, whereas Harsh et al. (2017) and Pauly et al. (2012) assessed carcass and pork quality parameters. The most widespread meta-analysis from Batorek et al. (2012a) evaluated the effect of immunocastration on production performance, carcass traits, meat quality, reproductive organs and boar taint compounds.

The aim of our study was not only to update previous meta-analyses with studies published until end of first quarter 2017, but also to focus the analyses on aspects most relevant for the stakeholder groups of pig producers and the pork packing industry, respectively. The following research questions were defined in advance of the study:

1) What is the effect of immunocastration compared to physical or no castration of male pigs on performance and carcass data most relevant for the producers and how are these parameters influenced by (a) the feed additive ractopamine, (b) the pork production system, i.e. raising light, medium or heavy pigs, and (c) the time between the 2nd GnRF immunization (V2) and slaughter? (In the following 'producer's perspective'.)
2) What is the effect of immunocastration compared to physical or no castration of male pigs on carcass data most relevant for the packers, while differentiating between (a) conventional pork production and (b) pork destined for the production of high-quality cured products, and how are these parameters influenced by ractopamine or the pork production system? (In the following 'packer's perspective'.)
3) What is the risk of boar taint in meat from IC pigs compared to meat from PC or EM pigs as evaluated by (a) objective, i.e. quantitative measurements and (b) subjective sensory assessment? (Results can be regarded as relevant for both stakeholder groups.)

These research questions constituted the basis for the definition of inclusion criteria.

2. Materials and methods

2.1. Data search

An electronic database previously developed by the company marketing Improvac® (Zoetis) served as the source of literature. The database included all publications identified for Improvac® and contained 305 articles at the time of study initiation (second quarter of 2017). Studies were not restricted to English language and were derived from peer-reviewed papers, congress proceedings, and grey literature. In order to ascertain the completeness of the database, bibliographies of relevant articles, meta-analyses and literature reviews were searched for potentially missing papers.

The following eligibility criterion was applied to identify studies for further evaluation: any article reporting comparative efficacy of immunocastration with Improvac® versus physical castration or no castration of male pigs. All studies were eligible, regardless of the reporting of randomization or blinding or of the level of scientific credibility (peer-reviewed and non peer-reviewed articles). The latter, however, was recorded in order to assess any impact of study credibility on the results. Review articles or meta-analyses were not considered for inclusion, but used to assess completeness of database.

Inclusion criteria varied according to the research questions defined in advance.

2.1.1. Inclusion criteria and data extraction for analyses relevant from the producers' perspective

In order to answer the research question defined for the pig producers, articles were included which reported average daily gain (ADG) AND [feed conversion ratio (FCR) OR feed efficiency (FE)] AND [live weight at slaughter OR hot carcass weight (HCW)]. ADG and FCR as reported for the entire observation period were used for the analyses. Results reported for FE were calculated to FCR, using the following formula: $FCR = 1/FE$. In order to allow for additional subgroup analyses, the potential use of the feed additive ractopamine as well as the time between V2 and slaughter (IC pigs) were recorded, and studies were categorized according to the pork production system (light, medium, or heavy pig production).

If reported in the included studies, dressing percentage, percentage lean, and backfat thickness were also collected for analyses.

2.1.2. Inclusion criteria and data extraction for analyses relevant from the packers' perspective

Separate searches were run to identify articles reporting data from conventional pork production and pork production destined for high-quality cured products.

Studies of conventional pork production were included if the following parameters were available: weight of ham AND weight of loin AND weight of shoulder AND weight of belly AND (live weight at slaughter OR HCW). The latter allowed for subgroup analyses of the pork production system. Additionally, the use of ractopamine was recorded. For analyses relevant for the pork production destined for high-quality cured products the following inclusion criteria applied: studies reporting weight of ham AND percentage intramuscular fat AND backfat thickness AND (live weight at slaughter OR HCW). Although not an inclusion criterion, dressing percentage was also recorded if available. Pork production for high-quality cured products requires a reasonably high fat content (minimal backfat thickness of 20 mm and 2.5% intramuscular fat (IMF) for European production (Morales et al., 2011a)); therefore, no use of ractopamine, which improves carcass leanness, was expected even in those countries where ractopamine use is permitted. Accordingly only one subgroup analysis on the weight classification was foreseen. In addition to the comparative analyses, absolute values of backfat thickness and IMF were used to assess if the minimum requirements were fulfilled.

2.1.3. Inclusion criteria and data extraction for boar taint analysis (relevant from both perspectives)

Separate searches were run to identify articles reporting objective measurements of level of boar taint compounds in fat and subjective sensory evaluations of pork meat or fat. For the analysis of objective measurements, studies had to report the number or proportion of pigs exceeding at least one of the following thresholds of consumer detection as defined for the main boar taint compounds: skatole threshold: 0.2 μg/g fat (Dunshea et al., 2001); androstenone intermediate threshold: 0.5 μg/g fat (Dunshea et al., 2001; Andresen, 2006) and androstenone high threshold of detection: 1.0 μg/g fat (Dunshea et al.,