Effect of vaccination against gonadotrophin-releasing factor of male pigs on meat and fat quality

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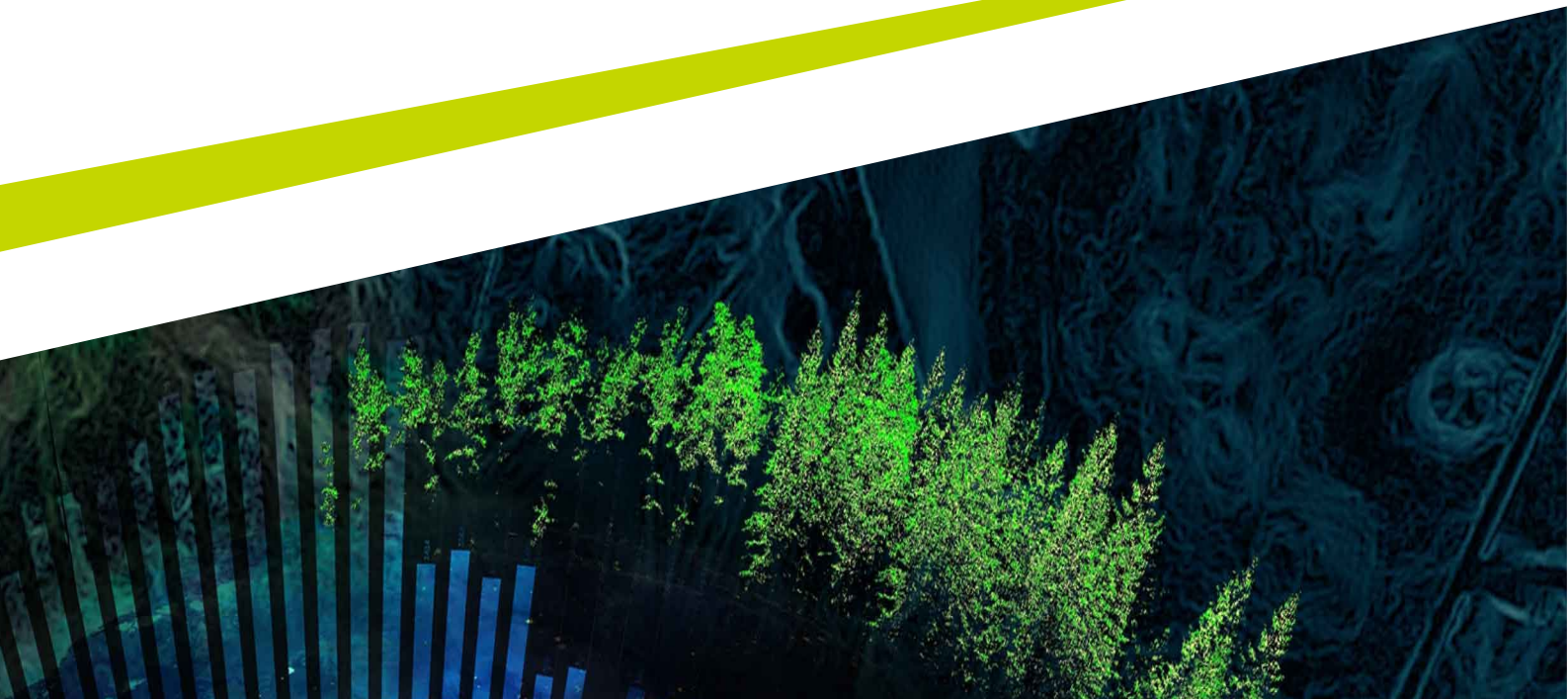

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Abstract

The aim of this thesis was to investigate if meat and fat quality are influenced by castration, and hence examine if it is possible to improve animal welfare by introducing immunological castration (immunocastration) as an alternative to the stressful and painful procedure of surgical castration. Immunocastration is used as an alternative to surgical castration (removal of the testes) to reduce boar taint. Boar taint is an offensive odor detectable by sensitive consumers in meat from some mature male pigs.

This literature study was performed in order to evaluate the effects of surgical and immunocastration on various aspects of meat quality. The quality aspects were subdivided into carcass quality, sensory quality, technological quality and sensory quality, particularly boar taint.
Immunological castration effectively reduce boar taint. This has been demonstrated with sensory evaluation in consumer trials, trained panels and by chemical analysis of skatole and androstenone. Overall the method of castration seems to have a weak impact on sensory quality.

When differences in carcass quality were found, the effect was small, or results were inconclusive. Furthermore, the effect sizes were low to moderate, which indicates that the impact of castration method may be of low relevance.

The castration method does not have a large impact on technological quality. In some studies, a small difference was found in the degree of saturation of the fat.

Immunological castration is valid alternative to surgical castration. A late vaccination schedule may even improve some quality parameters and be economically favourable.

Keywords: Immunological castration, meat quality, boar taint

Table of contents

1. Introduction

1.1 Boar taint

Boar taint is an offensive odor detectable by sensitive consumers in pork from some mature uncastrated male pigs. Two compounds are considered mainly responsible for the taint; androstenone and skatole. Androstenone is a pheromonal steroid with a urine-like odor. It is produced in the testes, and the production increases at sexual maturity. Skatole has a fecal odor and is produced by the bacterial flora in the large intestine from tryptophan. Skatole is produced in gilts as well, but the levels are not sufficiently elevated to be considered a meat quality draw back. Both compounds are fat-soluble, and accumulate in fat tissue (European Food Safety Authority, 2004).

Consumer acceptability of tainted pork is influenced by several factors such as culinary habits, age and gender of pigs, and age and gender of consumers (Font-i-Furnols et al., 2003). A majority of the consumers is able to perceive skatole, but insensitivity to androstenone is more common due to genetic inheritance. The perception of androstenone can be enhanced by skatole. However, not all sensitive consumers dislike the odor (European Food Safety Authority, 2004). The compounds are to some extent volatile and the perception may be enhanced by heat (Babol & Squires, 1995; Font-i-Furnols et al., 2008; Lundström et al., 2009).

1.2 Castration methods

1.2.1 Reasons for castration

Castration of male pigs reduce boar taint compounds and aggressive behavior. Castrated animals also tend to grow fatter; and this characteristic was highly appreciated during the times when high-energy diet was necessity. Today, however, the market demands low fat meat. Entire males are leaner and are considered as healthier alternative to meat from castrated pigs (European Food Safety Authority, 2004)

1.2.2 Surgical castration

Surgical castration effectively prevents boar taint. It is usually carried out within the first days of the piglet's life. In some countries, castration is performed traditionally without anesthesia or analgesia and the open wound is left to heal without further treatment. Neonates were believed to not experience pain, but research has demonstrated this presumption false (European Food Safety Authority, 2004; Jordbruksverket, 2013). Since 2016, castration without anesthesia is prohibited by law in Sweden (Jordbruksverket, 2013) and the European Commission committed a voluntary declaration with a plan to end surgical castration of pigs in Europe by 2018 (European Commission, 2011). However, this deadline has not been met, Many EU countries continue to castrate pigs surgically, because of either lack of optimal alternatives or insufficient encourage to change the production system.

1.2.3 Immunological castration

Immunological castration is an alternative castration method that increases animal welfare. The testicular function is temporarily blocked when the vaccine provokes an immunological response against an endogenous hormone that controls stimulation of steroid production and spermatogenesis; gonadotropin-releasing hormone (GnRH) (European Food Safety Authority, 2004).

The vaccine is administered twice, at least four weeks apart. The first dose primes the immune system and the second dose induce a strong immunological reaction with production of anti-bodies against GnRH. The first dose can be given from week eight, and the second dose at least four weeks later, usually 4-6 weeks before slaughter. The manufacturer recommends that a third dose be administered if slaughter is performed later than 10 weeks after the second injection, as the effect is reversible. However, Zamaratskaia et al. (2008b) reported full effect 22 weeks after second injection, when the trial ended.

1.2.4 Meat quality

There are five major components of meat quality: yield and gross composition, appearance and technological characteristics, palatability, wholesomeness and ethical quality (Warriss, 2009). The importance of the categories varies greatly in different parts of the production chain. Yield and gross composition, or carcass quality, is important to the farmer, as it will decide the payment and thus the economy of the farm. Appearance and technological characteristics are of high importance to the food industry where uniform and high quality are demanded. Conformance and good processing qualities are necessary in large food industries. Palatability, or sensory quality, is of highest value to the consumer.

Carcass classification is the base for payment to the meat producer. The EU classification system of pig carcasses include five classes, EUROP, where each letter represents a span of lean meat percentage.

Table 1. Community scale for the classification of pig carcasses (Council of the European Union 2007)

Grade	Lean meat as percentage of carcass weight
E	55 or more[1]
U	50 or more but less than 55
R	45 or more but less than 50
O	40 or more but less than 45
P	Less than 40

[1]Member States may introduce, for pigs slaughtered in their territory, a separate class of 60 % or more of lean meat designated with the letter S.

2. Aim

The aim of this thesis was to investigate if meat and fat quality are influenced by the castration method (surgical vs immunocastration), and hence examine if it is possible to improve animal welfare by introducing immunological castration as an alternative to the stressful and painful procedure of surgical castration.

3. Method

A literature study was performed by using the database Web of Science. The selection of articles was made by searching for articles regarding the subject, using a combination of search terms such as immunocastration, gonadotropin-releasing hormone, male pigs, meat, and quality in various permutations.

The study includes an evaluation of the literature with respect to the following meat quality parameters; carcass quality, technological quality, sensory quality and boar taint. It does not include other possible treatment variables such as feed variations, ecological farming or feed additives.

4. Literature review

4.1 Carcass quality

A meta-analysis by Batorek et al. (2012a) compared carcass traits of immunocastrated males to surgically castrated males and entire males respectively. The effects varied from low to moderate in the cases where differences were found, which indicates that the impact of castration method may be of low relevance.

It is important to emphasize that small effect still may have significant value, depending on the importance of the trait. Fuchs et al. (2009) studied carcass classification of surgically castrated males and immunocastrated males and found that more immunocastrated male carcasses were rated in the highest category in the EUROP grading system. Since the classification of the carcasses is base for payment, even a small difference can be of significant economic value to the farmers.

4.1.1 Carcass weight

Carcass weight does not seem to differ between surgically- and immunocastrated male pigs (Font-i-Furnols et al., 2012; Fuchs et al., 2009; Morales et al., 2011; Yuan et al., 2012). Similarly, no differences were observed between castrated males and entire males (Zamaratskaia et al., 2008a; Pauly et al., 2009; Morales et al., 2011; Boler et al., 2012; Škrlep et al., 2012; Aluwé et al., 2013).

However, diverging results have been reported. Turkstra et al. (2002) reported heavier carcasses from entire males, but immunocastrated males could not be differentiated from either the entire males or the surgically castrated males. Škrlep et al. (2010b) also reported heavier carcasses in entire males, and intermediate values for immunocastrated males. In contrast higher carcass weight in the castrated animals compared to entire males, was reported in some studies (Dunshea et al., 2001; Gispert et al., 2010; Batorek et al., 2012b).

A recent meta-analysis reported intermediate carcass weight in immunocastrated males Poulsen Nautrup et al. (2018).

4.1.2 Lean meat percentage

Entire males were reported to have the highest percentage of lean meat, followed by immunocastrated and surgically castrated pigs (Pauly et al., 2012; Batorek et al., 2012a; b; Poulsen Nautrup et al., 2018). A Belgian study reported similar results, but immunocastrated males and entire males did not statistically differ (Aluwé et al., 2013). A study that evaluated immunocastrated and surgically castrated males did not observe any effect of the castration methods regarding lean meat percentage (Yuan et al., 2012).

4.1.3 Dressing percentage

Several studies reported higher dressing percentage in surgically castrated males than in immunocastrated males (Boler et al., 2012; Yuan et al., 2012; Poulsen Nautrup et al., 2018). Two meta analyses (Batorek et al., 2012a; Poulsen Nautrup et al., 2018) and a trial by Pauly et al., (2009) reported similar results, and that immunocastrated males were comparable to entire males in regard to carcass percentage.

Dunshea et al. (2001) evaluated two vaccination schedules with similar injection times prior to slaughter, but different slaughter age, to investigate the impact on meat quality by age at castration and slaughter. Surgically castrated males exhibited the largest dressing percentage in both trials. Immunocastrated males were equal to entire males in the group slaughtered at a younger age, but the researchers detected a lower dressing percentage in immunocastrated males in the group slaughtered at an older age.

In contrast, no differences were found between immunocastrated and surgically castrated males in a Brazilian study (Caldara et al., 2013).

4.1.4 Back Fat Thickness

Numerous studies have demonstrated that surgical castration increased back fat thickness compared to entire males (Batorek et al., 2012b; Aluwé et al., 2013; Trefan et al., 2013).

The effect of castration method on back fat thickness however is not clear. A few studies and a meta-analysis report higher back fat thickness in surgically castrated males compared to immunocastrated males (Boler et al., 2012; Yuan et al., 2012; Batorek et al., 2012a; Poulsen Nautrup et al., 2018). Aluwé et al. (2013) reported immunocastrated males to be similar to entire males whereas Trefan et al. (2013) and Batorek et al. (2012b) found immunocastrated males similar to surgically castrated males.

Differences between immunocastrated males and entire males were only observed in the groups slaughtered and vaccinated at an older age in a single trial (Dunshea et al., 2001).

4.1.5 Prime cuts

Batorek et al. (2012a) stated that there are few studies reporting detailed data on prime cuts. When immunocastrated males were compared to entire males, the only difference observed was heavier belly weight in immunocastrated males.

When immunocastrated males were compared to surgically castrated males, the immunocastrated males exhibited lower or equal belly percentage, and higher ham and shoulder weight (Batorek et al., 2012a; Boler et al., 2012; Pauly et al., 2009; Poulsen Nautrup et al., 2018).

Boler et al. (2012) reported higher percentage of loin in immunocastrated males, whereas Pauly et al. (2009) reported that the loin was not influenced by castration method although entire males exhibited higher percentage than the castrated males. Similarly, Poulsen Nautrup et al. (2018) reported no difference between castration methods but found improved weight of loin in immunocastrated males compared to entire males.

Caldara et al. (2013) found prime cuts from immunocastrated males and surgically castrated males comparable.

4.2 Technological quality

4.2.1 pH

Castration does not seem to affect pH in the meat (Pauly et al., 2012; Trefan et al., 2013) and consequently the method of castration have no impact on pH either (Aluwé et al. 2022; Batorek et al., 2012a; Caldara et al., 2013).

4.2.2 Drip loss

The results regarding different water holding capacity aspects are inconclusive.

No difference was detected between the genders by Aluwé et al. (2022) nor in two meta-analyses (Pauly et al., 2012; Trefan et al., 2013). Increased drip loss in pork from immunocastrated males compared to entire males was indicated in a meta-analysis by Batorek et al. (2012a), but no significant difference was detected between immuno- and surgically castrated males. Aluwé et al. (2013) found enhanced drip loss in immunocastrated males compared to surgically castrated males.

4.2.3 Cooking loss

Castration does not seem to have an impact on cooking loss (Pauly et al., 2009; Jeong et al., 2011; Škrlep et al., 2012) and neither does the choice of castration method (Yuan et al., 2012; Caldara et al., 2013). When differences were found it was in favor of surgical castration. Boler et al. (2012) compared immunocastrated males and surgically castrated males and found that immunocastrated males had higher cooking loss. Batorek et al. (2012b) found immunocastrated males to be close to entire males and Aluwé et al. (2013) found that immunocastrated males exhibited increased cooking loss compared to entire males.

4.2.4 Shear force

Immunocastration seem to have a positive influence on shear force, with more tender meat compared to entire males (Pauly et al., 2012; Batorek et al., 2012a). Several studies have demonstrated that castration method does not influence shear force (Jeong et al., 2011; Boler et al., 2012; Yuan et al., 2012; Batorek et al., 2012a; b; Aluwé et al., 2013; Caldara et al., 2013; Aluwé et al., 2022).

A meta-analysis reported lower shear force in immunocastrated males compared to surgically castrated males (Pauly et al., 2012).

4.2.5 Color

Lightness, redness and yellowness of the meat did not differ between the genders (Pauly et al., 2012; Aluwé et al., 2013; Trefan et al., 2013; Batorek et al., 2012b). The meta-analysis by Batorek et al. (2012a) found no differences when meat from immunocastrated males were compared to meat from surgically castrated males.

There are some discrepancies in the data however. Batorek et al. (2012a) evaluated objective color in a meta-analysis and detected slightly lighter meat in immunocastrated males than entire males. This trend approached the level of significance in another meta-analysis by Trefan et al. (2013).

Two of the reviewed studies diverge regarding redness/yellowness scores. Jeong et al. (2011) reported higher redness scores of meat from immunocastrated males than of meat from surgically castrated males, and higher scores for yellow compared to entire males. In accordance, Aluwé et al. (2013) found meat from immunocastrated males to be redder than meat from surgically castrated males but less yellow than meat from entire males.

4.2.6 Intramuscular Fat

Two meta-analyses came to the same conclusions that intramuscular fat content is not influenced by castration method, but entire males were found to have lower intramuscular fat content than the castrated males (Pauly et al., 2012; Trefan et al., 2013). Similarly Batorek et al. (2012a) found no statistical difference between

immunocastrated males and surgically castrated males, but intramuscular fat was more abundant in immunocastrated males than in entire males.

Intermediate values of fat content for immunocastrated males were found by Jeong et al. (2011) and Batorek et al. (2012b). Aluwé et al. (2022) reported higher intramuscular fat content in surgically castrated males, compared to immunocastrated males and entire males.

4.2.7 Saturation

The data regarding saturation of fat in entire males, surgically castrated males and immunocastrated males are conflicting and inconclusive. This might be due to the fact that the samples are taken from different parts of the carcasses.

In a meta-analysis by Pauly et al. (2012), the fatty acid composition was measured in adipose tissue. Entire males had lower percentage of saturated fatty acids and higher percentage of polyunsaturated fatty acids than the castrated animals. Mono-unsaturated fatty acid percentage was also higher than in surgically castrated animals. There was no difference in saturation between fat from immunocastrated males and surgically castrated males, but the data was restricted as only two studies were included.

Boler et al. (2012) evaluated fatty acid composition in bellies from immunocastrated males and surgically castrated males. The animals were slaughtered at 23 or 25 weeks of age, 4 or 6 weeks post the second injection of the vaccine. When the results were averaged over slaughter times, a higher mono unsaturated fatty acid and polyunsaturated fatty acid content were observed in fat from immunocastrated males compared to surgically castrated males.

Yuan et al. (2012) measured fatty acid composition in subcutaneous fat and in longissimus muscle in immunocastrated males and surgically castrated males. The saturated fatty acid and mono-unsaturated fatty acid content did not differ, but immunocastrated males had higher content of polyunsaturated fatty acids.

A Spanish study reported no important difference in saturation between immunocastrated males and surgically castrated males (Font i Furnols, 2012).

4.3 Sensory quality

The sensory parameters investigated in this thesis are aroma, taste, color, tenderness, juiciness, marbling scores and general appreciation.

4.3.1 Tenderness and juiciness

Two meta-analyses found no statistical difference between the genders when tenderness and juiciness were evaluated by consumers and trained panels (Pauly et al., 2012; Trefan et al., 2013).

A Brazilian study reported similar results when a non-trained panel compared the texture of meat from surgically castrated and immunocastrated males (Caldara et al., 2013).

A Spanish study used a trained panel and observed no impact on the castration method and meat texture, but pork from entire males exhibited higher toughness and lower juiciness than meat from the castrated animals (Font-i-Furnols et al., 2009) Similar results were reported by Aluwé, et al. (2022) in a study with consumer panels in six European countries.

When texture of pork bellies was evaluated by a trained panel in a Korean study (Jeong et al., 2011), the bellies from surgically castrated males were perceived as the most tender and juicy. Meat from immunocastrated males could not be differentiated from surgically castrated males or entire males when tenderness was considered, and juiciness scores were equal to entire males.

When a home consumer panel in a Belgian study evaluated sensory quality of pork loin, the only statistically significant differences were found in tenderness and juiciness. Meat from surgically castrated males received higher scores; immunocastrated males were intermediate in tenderness and could not be differentiated from entire males regarding juiciness (Aluwé et al., 2013).

4.3.2 Aroma and taste

Castration method does not seem to influence aroma and taste of pork (Poulsen Nautrup et al., 2018). D'Souza et al. (2002) used a consumer panel and Caldara et al. (2013) used a non-trained panel to evaluate pork from immunocastrated males and surgically castrated males. No differences were observed.

Font-i-Furnols et al. (2008; 2009) observed similar results but found that entire males got lower scores by both a trained panel and a consumer panel.

In contrast, a home consumer panel did not differentiate pork loin from entire males, immunocastrated males or surgically castrated males, in a Belgian study by Aluwé et al. (2013). Similar results were observed in a Korean study even though a panel trained for androstenone was used (Jeong et al., 2011). Unfortunately, the sensory evaluation was not supplemented by a chemical analysis. As not all entire males exhibit levels of androstenone and skatole above sensory threshold, the possibility that the samples were not tainted cannot be excluded.

4.3.3 Subjective color

Similar color of pork loin from immunocastrated males, surgically castrated males and entire males was observed in a Belgian home consumer test (Aluwé et al., 2013).

A Korean study compared pork bellies of entire males, surgically castrated males and immunocastrated males. The trained panel preferred meat from

immunocastrated males to meat from surgically castrated males. Pork from entire males was perceived as comparable to both immunocastrated males and surgically castrated males. Jeong et al., (2011) observed that the sensory evaluation agreed with trends in the subjective color evaluation, and concluded that Korean consumers seemed to appreciate redness in pork.

4.3.4 Marbling scores

Data regarding marbling scores are scarce. A meta-analysis by Trefan et al. (2013) evaluated marbling scores in pork from surgically castrated and entire males and found that surgical castration improved marbling scores. Gispert et al. (2010) reported similar results, but immunocastrated males could not be differentiated from either surgically castrated males or entire males. Boler et al. (2012) compared immunocastrated and surgically castrated males, and found that surgically castrated males exhibited higher subjective marbling scores.

4.3.5 General appreciation

Only five of the articles reviewed evaluated general appreciation. Castration method did not affect the overall appreciation when a consumer panel in an Australian study (D'Souza & Mullan, 2002) evaluated steaks. Similar results were achieved when entire males were included in a Belgian study. A home consumer panel, free to choose cooking preparations, evaluated pork loin samples and rated the gender similarly (Aluwé et al., 2013). Spanish consumers did not either differentiate between loins from the castrated animals, but were more dissatisfied with loins from entire males (Font-i-Furnols et al., 2008). Aluwé et al. (2022) reported lower scores for entire males and mostly similar scores in surgically castrated and immunologically castrated males. Some differences in overall liking between the participating countries were found. Poulsen Nautrup et al. (2018) found no difference in general appreciation between the castration methods.

Only one study observed a difference between surgically and immunocastrated males. A trained panel in a Korean study preferred bellies from immunocastrated males whereas entire males and surgically castrated males got similar ratings (Jeong et al., 2011).

4.4 Boar taint

Both surgical and immunological castration effectively reduce boar taint. This has been demonstrated with sensory evaluation in consumer trials, trained panels and by chemical analysis of skatole and androstenone (Font-i-Furnols et al., 2008; Font-i-Furnols et al., 2009; Pauly et al., 2009; Weiler et al., 2012; Batorek et al., 2012b; Aluwé et al., 2013; Poulsen Nautrup, et al., 2018). A meta-analysis detected a small

but significant difference between immunocastrated males and surgically castrated males where immunocastrated males had higher levels of androstenone and skatole (Batorek et al., 2012a). Weiler et al. (2012) reported similar results, though skatole levels were low in all treatments (immunocastrated, surgically castrated and entire males).

5. Discussion and conclusion

5.1 Boar taint

All scientific articles reviewed in this study have shown that immunocastration is successful in reducing the compounds that are responsible for boar taint. There seems to be a lower effect on skatole than androstenone in both the castration methods (Batorek et al., 2012a). The androstenone levels in fat tissue drops rapidly after the second injection. Complete clearance requires at least three weeks, but the half-life is a few days (Skrlep et al., 2010a).

According to the manufacturer, the animals should be given the first injection from week eight. The injections should be given at least four weeks apart. The effect of immunocastration is reversible, and if slaughter is performed as late as ten weeks after the second dose, a third dose should be provided to ensure complete androstenone depletion. However, it has been demonstrated that immunocastration can be effective much longer than ten weeks (Zamaratskaia et al., 2008b). The immunocastrated pigs keep the anabolic advantages of uncastrated males until the second injection. (Morales et. al 2011)

Some concerns regarding immunological castration have been discussed. There have been observations of non-responders to the vaccine, and the human factor may result in animals that are not properly vaccinated. In addition, late vaccination schedules might not reduce the sizes of the testes enough to make them easily distinguishable from intact males at the slaughter line (European Food Safety Authority, 2004).

Improvac®, manufactured by Pfizer (Zoetis), is the only commercially available castration vaccine on the European market and is therefore involved, in one way or the other, in all the studies reviewed. The possible influence of this fact is not taken into consideration in this thesis.

5.2 Carcass quality

It has been found that the growth rate of tissue is not proportional, i.e. the phenomena called allometric growth has been observed. Fat tissue, for example, has been shown to be the last tissue to mature (Warriss, 2009). Muscles involved with posture, such as longissimus dorsi also mature relatively late compared to ham and shoulder, and will therefore benefit less from the prolonged anabolic potential of immunocastrated males.(Pauly et al., 2009). The effect of the prolonged anabolic potential of immunocastrated males and allometric growth is demonstrated in this thesis.

Carcass weight did not differ between the genders, but the weight of prime cuts varied to some extent. A meta-analysis (Batorek et al., 2012a) concluded that surgically castrated males had heavier belly and lower ham and shoulder weight than immunocastrated males and entire males. Immunocastrated males were similar to entire males beside heavier belly weight. Other studies came to similar conclusions; surgically castrated males either were similar to entire males or were intermediate regarding prime cuts (Boler et al., 2012; Pauly et al., 2009; Poulsen Nautrup et al., 2018).

When immunocastrated males were compared to surgically castrated males, the immunocastrated males exhibited lower or similar belly percentage, and higher ham and shoulder weight (Batorek et al., 2012a; Boler et al., 2012; Pauly et al., 2009; Poulsen Nautrup et al., 2018).

Boler et al. (2012) reported higher percentage of loin in immunocastrated males, whereas Pauly et al. (2009) reported that the loin was not influenced by castration method but that entire males exhibited higher percentage than the castrated males. Poulsen Nautrup et al. (2018) reported similarly no difference between castration methods but found improved weight of loin in immunocastrated males, compared to entire males.

Caldara et al. (2013) found prime cuts from immunocastrated males and surgically castrated males comparable.

Entire males exhibit thinner back fat thickness, but the influence of castration method was not clear. One meta-analysis (Batorek et al., 2012a) reported higher back fat thickness in surgically castrated males whereas another meta-analysis (Trefan et al., 2013) reported no statistical difference between surgically and immunocastrated males. When Dunshea et al. (2001) used the same vaccination protocol regarding time prior to slaughter, but with slaughter at different ages, a difference between the castrated males was only detected in the older group, where immunocastrated males got intermediate values.

Lealiifano et al. (2011) evaluated different vaccination schedules and observed a linear increase of back fat with time between second vaccination and slaughter. The authors concluded that the timing for vaccination is very important. They demonstrated that the second injection could be done as late as two weeks before

slaughter with appropriate clearance of androstenone, and with maximal utilization of the positive anabolic growth associated with entire males.

Dressing percentage of entire males is often lower than of surgically castrated males due to larger genital tract (Babol & Squires, 1995). Immunocastrated males have smaller genital tract than entire males, but it is not completely regressed, which partly explain the lower dressing percentage compared to surgically castrated males (Batorek et al., 2012a).

Interestingly, when Lealiifano et al. (2011) evaluated how time between the second injection and slaughter affected meat quality, dressing percentage was not affected by timing.

The improved lean meat percentage in immunocastrated males compared to surgically castrated males was reported in two meta-analyses (Batorek et al., 2012a; Pauly et al., 2012). This may improve classing of carcasses, as demonstrated by Fuchs et al. (2009).

The commercial grading system commonly used underestimates lean meat percentage in entire males (Babol & Squires, 1995; European Food Safety Authority, 2004). Zamaratskaia et al. (2008a) used two different methods to measure and compare lean meat percentages of immunocastrated, surgically castrated and entire males. Entire males received the highest scores but immunocastrated and surgically castrated males were statistically different only when a partial manual dissection method was used. The discrepancy indicates that the Hennessy probe method may underestimate lean meat percentage in immunocastrated animals as well as entire males. The real difference might therefore be even larger.

5.3 Technological quality

Regarding technological quality, it seems that pH, drip loss and color were generally not affected by castration method or no castration.

Few studies found differences in yellowness and/or redness. However Gispert et al. (2010) and Jeong et al. (2011) found that these differences were not reflected in objective evaluation. Gispert et al. (2010) also stated that even though meat from entire male pigs was darker, this was not of importance since all animals were within the normal range.

Shear force seemed to be decreased by castration and one meta-analysis (Pauly et al., 2012) observed lower shear force in immunocastrated males compared to surgically castrated males. Batorek et al. (2012a) proposed that the improved shear force in immunocastrated compared to entire males may be a result of increased intramuscular fat, but it could also be caused by the compensatory growth following the second vaccination. The increased growth rate causes enhanced protein turnover, which leads to increased proteolysis after slaughter.

Castration increased amount of intramuscular fat. No difference was observed between the two castration methods apart from two studies where immunocastrated pigs got intermediate values (Batorek et al., 2012b; Jeong et al., 2011).

According to Warriss (2009), allometric growth affects not only different tissues but also in what order fat deposits mature. First, the fat surrounding the kidney (perinephric), then intermuscular, subcutaneous and last intramuscular.

It was difficult to draw any conclusions about saturation of the fatty acids between the genders. Sampling method differed and the results were inconclusive, but entire males generally seem to have more unsaturated fat. The meta-analysis by Pauly et al. (2012) observed no differences between the two castration methods, but only two studies were included in the analysis. Two trials observed increased polyunsaturated acids in immunocastrated males, compared to surgically castrated males (Boler et al., 2012; Yuan et al., 2012). Boler et al. (2012) ascribe the lower saturation in immunocastrated males to the lower back fat thickness, and that leanness and unsaturation of fatty acids are generally known to be related in pigs.

5.4 Sensory quality

The effect of vaccination against gonadotrophin-releasing factor of the sensory quality is unfortunately least studied and methodical differences make the results difficult to compare. Overall, castration method seems to have a weak impact on sensory quality.

The studies reviewed reported that surgically castrated and immunologically castrated were similar regarding aroma and taste. This was shown by both trained panels and consumer panels (Aluwé et al., 2013; 2022, Caldara et al., 2013; D'Souza et al., 2002; Font-i-Furnols et al., 2008; 2009; Jeong et al., 2011; Poulsen Nautrup et al., 2018).

Aluwé et al. (2013) performed sensory and chemical analysis of boar taint compounds on pork from immunocastrated, surgically castrated and entire males and got strikingly different results. Approximately a third of the entire males had high androstenone levels, although the home consumer panel did not differentiate between the genders in terms of odor and flavor. Androstenone sensitivity tended to influence flavor and odor scores, but even the sensitive consumers judged the pork acceptable. The authors concluded that these observations further confirmed that high androstenone levels have a low impact of on odor and flavor scores if skatole levels are low. Aluwé et al. (2013) propose that tenderness and juiciness may be of higher concern to the consumers than boar taint, and that earlier vaccination of immunocastrated animals might improve consumer acceptability by increasing fat content.

Most studies found no statistically significant difference regarding tenderness and juiciness between the castration methods (Caldara et al., 2013) or even between

immunologically-, surgically castrated and entire males (Pauly et al., 2012; Trefan et al., 2013). Some studies found that castration improved the evaluation scores compared to entire males (Font-i-Furnols et al., 2009; Aluwé et al., 2022). Tenderness of meat from immunocastrated males was similar to surgically castrated males or intermediate, but juiciness scores were equal to entire males (Aluwé et al., 2013; Jeong et al., 2011).

Data regarding subjective marbling scores are scarce. Boler et al. (2012) evaluated the two castration methods and observed higher scores in surgically castrated males. Škrlep et al. (2010b) reported intermediate values for immunocastrated males when the three genders were compared.

A trained panel in a Korean study (Jeong et al., 2011) did not either differentiate pork bellies from immunocastrated males, surgically castrated males, entire males and females regarding odor and flavor. This is despite the fact that the panel had been trained for increased sensitivity for androstenone and skatole, and the most sensitive panelists then had been selected for the evaluation.

6. Conclusions

Generally, immunological castration is comparable to surgical castration regarding meat quality. Meat quality parameters from immunologically castrated animals are often similar to surgically castrated males, or intermediate between surgically castrated males and entire males. According to some studies, immunocastration might improve some meat quality parameters, such as lean meat percentage, shear force and prime cuts.

Several schedules for immunocastration were proposed. However, further research is needed to investigate timing of second injection.

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