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Vaccination against boar taint – effect of restrictive and *semi ad libitum* feeding on production and behavior

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Vaccination mot galtlukt – Effekt av restriktiv och *semi ad libitum* utfodring på produktion och beteende

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ABSTRACT

Male piglets have been castrated for centuries to avoid contamination of their meat with boar taint, a strongly unpleasant odour that makes the meat inedible. Today boar taint can be prohibited by vaccination against gonadotropin releasing hormone (GnRH) using Improvac®. The aim of this study was to evaluate the efficiency of vaccination on growth performance and behaviour of vaccinated male pigs compared to surgically castrated male pigs. The effect of two feeding regimes, restricted (SLU-norm) and *semi ad libitum*, was also included in the study. At birth, pigs (n=206) were randomly allocated to the two treatment groups; surgically castrated and vaccination. The study comprised six batches. In batches 1 and 2, vaccination took place 8 and 4 weeks before slaughter and in batches 3-6 10 and 6 weeks before slaughter. Surgical castration was performed before one week of age. The study showed that vaccinated male pigs had a higher growth rate and a lower feed conversion ratio in the interval between first and second vaccination than castrates, irrespective of feeding regime. When fed *semi ad libitum*, vaccinated pigs had a significantly higher daily weight gain during the total growing/finishing period than castrates (1083 *vs.* 1040 g). They also had a higher daily lean meat growth (350 *vs.* 334 g) and a lower feed conversion ratio (2.58 *vs.* 2.66 kg/kg) compared to castrates. For restrictively fed pigs no such effect could be seen. Vaccinated male pigs were more aggressive until they have got their second vaccination, however, sexual behaviour and skin lesion declined to the same level as for castrates already after the first vaccination. The results in this study showed that vaccination against GnRH has the potential to improve growth rate, daily lean meat growth and feed conversion ratio when fed *semi ad libitum*. Vaccination was also effective in reducing aggressive and sexual behaviour to same levels as for castrates. Restrictive feeding did not improve performance or carcass characteristics of vaccinated compared to castrated male pigs in this study.

SAMMANFATTNING

Kastrering av hangrisar har under lång tid varit den metod som använts för att undvika galtlukt. Galtlukt är en mycket stark och obehaglig doft som kan finnas i kött från vissa intakta hangrisar som uppnått könsmognad och som gör köttet oätligt. Idag kan hangrisarna vaccineras mot galtlukt med Improvac®, vilket innebär att de vaccineras mot en kroppsegen substans som styr könsmognaden och därmed minimeras förekomsten av galtlukt. Syftet med denna studie var att utvärdera effekten av vaccination på tillväxt och beteende hos vaccinerade hangrisar jämfört med kastrerade hangrisar. I studien ingick även en utvärdering av två olika utfodringsnormer, restriktiv (SLU-normen) och *semi ad libitum*. Vid födseln fördelades grisarna slumpvis på de två olika behandlingsgrupperna, kirurgiskt kastrerade och vaccinerade hangrisar. Studien bestod av sex omgångar. I omgångarna 1 och 2 vaccinerades grisarna 4 och 8 veckor före slakt och i omgångarna 3-6 6 och 10 veckor före slakt. Kirurgisk kastrering gjordes innan smågrisen var en vecka gammal. Studien visade att vaccinerade hangrisar hade i jämförelse med kastrerade grisar, en högre tillväxt och ett bättre foderutnyttjande i intervallet mellan första och andra vaccinationen. Vid *semi ad libitum* hade de vaccinerade hangrisarna en högre daglig viktökning under hela tillväxtperioden än de hangrisar som kastrerats (1083 *vs.* 1040 g). De hade också en högre daglig köttansättning (350 *vs.* 334 g) och en högre foderomvandlingsförmåga (2.58 *vs.* 2.66 kg/kg. Vid restriktiv utfodring kunde inte motsvarande skillnad observeras mellan behandlingarna. De vaccinerade hangrisar var mer aggressiva fram till dess att de vaccinerats två gånger, medan sexuellt beteende samt riv- och bitskador minskade till samma nivå som för kastraterna redan efter första vaccinering. Resultaten i denna studie visar att vaccination mot GnRH har potential att förbättra tillväxt, daglig köttansättning och foderomvandling utan att frekvensen aggressiva och sexuella beteenden ökade jämfört med kirurgisk kastrering.

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1. INTRODUCTION

One of the main reasons why many countries systematically uses surgical castration of new born male piglets is because the males, when reaching puberty, produce hormones that can cause boar taint. Boar taint causes a strong unpleasant cooking-odour and is therefore a problem since it is unwanted by consumers. The taint is described as a ‘urine/perspiration-like‘ odour (Sinclaire *et al*., 2005). To avoid boar taint in meat different techniques have been investigated (Bonneau & Prunier, 2005; Lundström & Zamaratskaia, 2006). New techniques has several different criteria and demands to live up to, such as maintained growth performance, low sexual and aggressive behaviour and also the technique has to be easy and safe to handle. These criteria are compared to entire males and surgically castrated males. Slaughtering male pigs before reaching sexual maturity is one technique (Dunshea *et al*., 2001), but increasing growth rate due to breeding has led to earlier maturity making it harder for the producer to estimate the right time for slaughter. For entire males it is important to be slaughtered before boar taint is developed. In EU only Portugal, Spain, Ireland, Denmark and the UK use entire males for meat production (EFSA journal, 2004). Another reason for not keeping intact male pigs is because they exhibit more aggressive behaviour (Fábrega *et al*., 2010) negatively affecting animal welfare. Several attempts to inhibit fertility by active immunization against gonadotropin-releasing hormone have been successful in various animal species (Goubau *et al*., 1989; Adams *et al*., 1996).

Immunovaccination has both advantages and disadvantages. One of the main advantages is of course that there is no surgical procedure, which is associated with stress and pain (Horn *et al*., 1999; Prunier *et al*., 2005) and also increased risk of chronic inflammation (de Kruijf & Welling, 1988). Injection of the vaccine has resulted in little or no irritation at the injection site (Einarsson, 2006). Use of Improvac® in a Swedish integrated pig production has resulted in fewer arthritis incidents and therefore the use of antibiotics has declined (Christer Hylander, 2014. Personal information). Vaccination has also shown to be effective in reducing both skatole (Dunshea *et al*., 2001) and androstenone (Jaros *et al*., 2005; Aleksić *et al*., 2012) concentration, compounds responsible for boar taint and also to reduce aggressive behaviour, commonly higher in entire males, to same levels as in surgically castrated males (Fábrega *et al*., 2010). One risk with surgical castration is that cryptorchids are sent to slaughter as barrows. Cryptorchids secrete the same level of boar taint as entire males (Einarsson, 2006).

Factors included in the vaccination procedure that could be thought of as disadvantages is that vaccination of older pigs could be difficult, it requires a safe vaccinator employed with a needle safety shield to avoid accidental self-injection by personnel (Einarsson, 2006) and the risk of some individuals still having too high levels of androstenone due to individual immunological response to Improvac® (Jaros *et al*., 2005).

In Sweden farmers are required by law to use pain relief for castration of male piglets that are older than seven days. On the first of January 2016 the law will be changed to include anaesthesia for all castrations on piglets even if not older than seven days (Svensk författningssamling 1988:539). This means that pig producers have to make a decision to start using anaesthesia or to change from surgical castration to immunovaccination. Immunovaccination with the use of Improvac® has been approved in the European Union since 2009 (Pfizer, 2013).

2. LITERATURE STUDY

2.1. Boar taint

2.1.1. Hormonal background

Attempts to find the cause for boar taint have been made since 1959 (Craig & Pearson; Dutt *et al*. 1959). The "sex odour", boar taint, was concluded to be strongest in the parotid gland, fatty tissue, testicles, penis and preputial diverticulum. Boar taint is referred to as a 'urine/perspiration-like' odour and is released when heating boar fat making it unpalatable for consumers (Sinclaire *et al*., 2005).

When male pigs reach sexual maturity the release of gonadotropin-releasing hormone (GnRH) increases from the hypothalamus. This increase and the binding of GnRH to receptors on the anterior pituitary result in the release of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) from the anterior pituitary. LH acts on the Leydig cells, located in the testes, which secrete testosterone and androstenone (Sjaastad *et al*., 2010). This can be described as the hypothalamic–pituitary–gonad axis (HPG) (Oonk *et al*., 1998).

2.1.2. Androstenone

In 1968 Patterson identified 3α-hydroxy-5α-androst-16-ene in the submaxillary salivary gland of boars (Patterson, 1968b) and 5α-androst-16-ene-3-one in boar fat (Patterson, 1968a), both compounds contributing to boar taint. These compounds are generally called androstenone and are testicular steroids. They have no hormonal activity but they act as sex pheromones (Claus *et al*., 1994). Androstenone is produced in the Leydig cells and transported to the liver. In the liver it is metabolized (Doran *et al*., 2004) and either transported to the salivary gland or accumulated in the adipose tissue. In the saliva, androstenone acts as a pheromone to stimulate females in heat (Lundström & Zamaratskaia, 2006) and might also have an effect on the establishing of a hierarchy between male pigs (Bonneau, 1987). Androstenone levels are low in young pig and increases at sexual maturity. Accepted levels of androstenone in meat for consumption is 0.5 µg/g fat (Jaros *et al*., 2005). In young pigs both live weight and age has an effect on the concentration of androstenone in adipose tissue. Age has no effect on older pigs, but live weight has and the individuals potential to produce (Bonneau, 1987) and metabolize steroids (Sinclaire *et al*., 2005). Breeding also has an effect on the plasma concentration of androstenone. Andresen (1976) found significantly higher levels of 5α-androstenone in boars selected for fatness and a low growth rate compared to boars selected for low fatness and high rate growth rate.

2.1.3. Skatole

The second compound known to produce boar taint is skatole, which is produced by bacteria from tryptophan (Yokoyama & Carlson, 1974) in large intestine of pigs. Recommended value of skatole in meat for consumption is 0.2 µg/g fat (Zamaratskaia *et al*., 2008a). Skatole is not only produced in male pigs but also in female pigs. From the large intestine is it excreted with faeces or absorbed and metabolized in the liver. If not metabolized in the liver, skatole can be accumulated in adipose tissue causing boar taint (Lundström & Zamaratskaia, 2005). Key enzymes for metabolism of various compounds, such as steroid hormones, in the liver are cytochromes P450 (CYP450) (Tsuchiya *et al*., 2005) and testosterone is thought to have a suppressing effect on CYP450 (Zamaratskaia *et al*., 2009).

Skatole, like androstenone, is affected by age and sexual maturity (Zamaratskaia *et al*., 2005) but also by breed. Babol *et al*. (2004) observed that skatole levels in entire male pigs increased at 180-200 days of age. Skatole level then decreased, but the decrease differed between breeds (Yorkshire and Landrace: 240-260 days, Hampshire and Duroc: 310-360 days). Also rearing conditions has an effect on skatole levels in subcutaneous fat. Hansen *et al*. (1994) found that pigs heavily fouled with faeces had higher skatole levels than "clean" pigs, and also that air temperature influenced the level of skatole regardless of how heavily fouled the pigs were. In hot summer temperatures, above 30°C, the risk of contaminated meat is higher than in the winter temperatures.

2.2. Alternatives to castration

2.2.1. Production of entire male pigs

Growth hormones (GH) and insulin like growth factor 1 (IGF-1) are secreted by all genders. Androgen and oestrogen are secreted by the testes and ovary, respectively, and enhances the anabolic effect of GH and IGF-1. In most mammals androgen and oestrogen are only secreted by the testes and ovary. But in boars, Leydig cells produce both androgen and oestrogen (Claus *et al*., 1983). Androgen interacts with the glucocorticoid receptor, an interaction that lowers degradation of protein (Snochowski *et al*., 1981), and oestrogen increases protein synthesis by a stimulatory effect on both GH and IGF-1 (Claus *et al*., 1994).

Charette (1961) reported from their study that entire male and late castrated male pigs had better growth performance and more favourable carcass traits, such as less fat covering shoulder and back, longer carcasses and a larger loin area. The better feed conversion ratio of entire male pigs has also been reported by Newell and Bowland (1972). Charette (1961) recommended that castration of males could be delayed to make profit of the positive effects of entire male pigs. But they pointed out that the procedure of castration would probably be more difficult to perform at a higher age. Today this is not accepted by Swedish law due to animal welfare concerns.

2.2.2. Immunovaccination

Immunovaccination is accomplished by disruption of the HPG, which inhibits growth of testes and synthesis of sexual steroid hormones (Oonk *et al*., 1998; Jaros *et al*., 2005). This is done by activating the pigs own immune system so it produces specific antibodies against GnRH. The vaccine (Improvac® also called Improvest®) is made up of a GnRH analogue conjugated to a carrier protein, which prevents it from binding to the pituitary GnRH receptor. By preventing GnRH from binding to the pituitary receptor, LH is not released and therefore testosterone and androstenone is not secreted from the Leydig cells (Zoetiz, 2009b).

Vaccination is performed in a two-dose administration, the first dose can be administered earliest at 8 weeks of age and the second dose should be given at least 4 weeks later but not later than 4-5 weeks before slaughter (Zoetiz, 2009a). First dose of Improvac® primes the pig's immune system and the second stimulates the release of antibodies against GnRH, which reduces the effect of the body's own GnRH. Vaccinated male pigs are therefore not considered as castrates until after second dose of Improvac® (Andersson *et al*., 2012).

Before the development of Improvac® a number of other vaccines were tested, but problems such as necessity of many injections or site reactions after vaccination that required a long vaccination to slaughter interval (Claus & Karg, 1971; Dunshea *et al*., 2001) made different vaccines inappropriate for large scale use.

As mentioned earlier entire male pigs have a more favourable feed conversion ratio and better carcass traits than castrated males (Charette, 196; Newell and Bowland, 1972) and this effect is also seen in late castrated males. As castration of larger male pigs is more difficult than of piglets and also not accepted by Swedish law, vaccination of male pigs provides a solution of the problem. Vaccination prolongs the positive effect of entire male pigs and the procedure of vaccination is much easier to perform at a higher age than surgical castration.

2.3. Effects of immunovaccination

2.3.1. Anti-GnRH antibody titres

Antibody titres are low in entire males and it is not until after second vaccination that the level of antibody titres increases in immunovaccinated male pigs. In a study by Brunius *et al*. (2011) the concentration of antibody titres after first injection of Improvac® was at the same level in vaccinated pigs as in entire male pigs, but after second injection all vaccinated pigs had elevated levels of antibodies.

Zamaratskaia *et al*. (2008b) evaluated how long anti-GnRH antibody titres persisted in male pigs, vaccinated with Improvac®, and found that antibody titres were still detectable after 16-20 weeks after second vaccination. Levels of testosterone were low or even undetectable at 22 weeks. This resulted in testes weight still being significantly reduced 16 weeks after second vaccination but at 22 weeks two vaccinated pigs had rather large testes. This could be favourable for producers that want a higher slaughter weight, like producers in Spain who want an increase in slaughter weight to improve their production of high-quality cured products (Latorre *et al*., 2004), but still want to vaccinate rather early to reduce aggressive behaviour due to sexual maturity.

2.3.2. Skatole and androstenone levels

Many studies have focused on comparing androstenone levels in meat from immunovaccinated and castrated male pigs. Most of them have found that there are no differences and that meat from immunovaccinated pigs are at no greater risk to be contaminated by high levels of androstenone (Jaros *et al*., 2005; Aleksić *et al*., 2012).

Jaros *et al*. (2005) found two pigs out of 270 that had androstenone levels above the allowed level, probably due to low or no immunological response to the vaccine. They concluded that these pigs had larger testes size and would therefore easily be detected at the slaughterhouse.

Also the level of skatole in meat from vaccinated males has been reported to be below the recommended value. These low levels can be related to the levels of testicular steroids, such as androstenone, testostereone and. As vaccinated males have very low levels of testosterone the levels of CYP450 are higher and therefore the degradation of skatole can be improved (Zamaratskaia *et al*., 2009).

2.3.3. Growth performance and feed conversion ratio

Different parameters are used to measure animal's growth performance, for example average daily gain, average daily feed intake and feed conversion ratio are the most commonly used. Several studies have been performed to evaluate the effect of vaccination on these traits and only a few have found any statistical differences when compared with surgically castrated male pigs.

Average daily gain of vaccinated pigs compared to castrated male pigs does not seem to differ over the total growing/finishing period. Slightly higher growth rate in the period before second vaccination was seen for castrates but after second vaccination the reversed effect was seen for vaccinated pigs. Thus, the average daily weight gain of the whole period was similar for both treatments (Dunshea *et al*., 2001; Jaros *et al*., 2005; Zamaratskaia *et al*., 2008a). This increase in average daily gain of vaccinated male pigs after second injection was connected to an increase in average daily feed intake in this period. Pauly *et al*. (2009) reported average daily feed intakes of 2.10 kg for vaccinated male pigs and 2.57 kg for castrates in the early growing/finishing period, vaccinated male pigs where more similar to entire males (2.19 kg). In the late finishing vaccinated males increased their intake to the same level as castrates (3.10 and 3.09 kg per day). The increase is probably due to reduced expression of aggressive and mounting behaviour (Cronin *et al*., 2003; Dunshea *et al*., 2001; Rydmer *et al*., 2010). Compared to entire males, growth rate after second vaccination has although been reported to be significantly higher for vaccinated males (Oliver *et al*., 2003; Pauly *et al*., 2009; Zamaratskaia *et al*., 2008a).

Dunshea *et al*. (2011) showed that after second injection vaccinated males got a higher average daily feed intake and also a better average daily weight gain than castrates but castrates had a lower feed conversion ratio. In this study they reported a decreased variation in bodyweight at the time of slaughter which could be a positive aspect for sales and nutritional management. A small study by Metz *et al*. (2002) showed that feed conversion ratio in vaccinated- and castrated males was higher compared to entire male pigs. Also Zamaratskaia *et al*. (2008a) reported that vaccinated and castrated male pigs had similar feed conversion ratio.

Pauly *et al*. (2009) reported that vaccinated male pigs had a lower feed conversion ratio than castrates during all stages of the growth period and therefore also a significantly lower ratio for the whole period than castrates(2.41 vs. 2.54 kg/kg). After second injection of Improvac®, vaccinated male pigs increased their feed intake, which also resulted in increased feed conversion ratio (2.49 kg/ kg before second vaccination and 2.74 kg/ kg after).

2.3.4. Carcass and meat quality characteristics

Brunius *et al*. (2011) reported higher levels of IGF-1 in vaccinated pigs compared to castrates, although entire male pigs had significantly higher levels than the other pigs. The higher level of IGF-1 in vaccinated male pigs implies that they have a higher anabolic potential compared to castrated male pigs, which could be associated with better lean meat content and feed efficiency.

Gispert *et al*. (2010) compared lean meat content of vaccinated, castrated and entire male pigs and did not find any differences between treatments. Vaccinated pigs had highest fat content in the loin area, similar to castrates, intermediate in the ham and no difference in intramuscular fat compared to the other pigs. This is in agreement with the results by Oliver *et al*. (2003) who reported that lean meat content was not higher in vaccinated males compared to entire male pigs; this study did not include surgically castrated males.

Andersson *et al*. (2012) found that, when comparing standard vaccinated (vaccination at 16 and 20 weeks of age) with early vaccinated (10 and 14 weeks of age) pigs, there was a difference in lean meat content. Early vaccinated pigs were more similar to castrates with a lower lean meat content compared to standard vaccinated, which were more similar to entire males with a higher lean meat standard. These results are in agreement with Jaros *et al*. (2005), Fábrega *et al*. (2010) and Pauly *et al*. (2009) who all presented results with a higher lean meat content for vaccinated male pigs. Zamaratskaia *et al*. (2008a) showed that an increase in feed intake after second injection did not seem to affect commercial lean meat content (Hennessy grading probe) of the carcass but when looking at estimated lean meat content the result differ significantly with a higher value for vaccinated male pigs.

2.3.5. Behaviour

Since vaccinated male pigs are regarded as entire male pigs until after second injection of Improvac® (Dunshea *et al*., 2001; Fábrega *et al*., 2010; Pauly *et al*., 2009) their behavioural pattern are similar. Entire male pigs exhibit more sexual and aggressive behaviour than castrates and vaccinated male pigs have shown the same pattern until after second injection (Brewster and Nevel., 2013; Fábrega *et al*., 2010).

Andersson *et al*. (2012) and Rydhmer *et al*. (2010) reported that there was no difference in inactive (sleeping or resting) behaviour between vaccinated and castrated pigs at any observation occasion in their studies. Total interactions and non-problematic interactions of vaccinated male pigs decreased, from the level of entire male pigs to the level of castrates, after second vaccination. Brewster and Nevel (2013) compared entire and vaccinated male pigs and could not see any differences in active behaviour between treatments at any observation point. In this study recordings were only performed after second vaccination and they found that active behaviour decreased for both treatments from one week after second vaccination until slaughter. Fábrega *et al*. (2010) observed a decline in active behaviour already after first vaccination. Before first vaccination, entire male pigs were more active than castrates. A few days after first vaccination, activity of the vaccinated male pigs declined compared to entire males. Although, when activity was measured again 9 week later (age 20 weeks) it had increased slightly. In the weeks following second vaccination, activity behaviour decreased and was at slaughter at the same level as for castrates. Activity of entire male pigs remained at a higher level compared to vaccinated and castrated male pigs throughout the study. Cronin *et al*. (2003) reported that vaccinated and entire male pigs were more active than castrates in the beginning of growing/finishing period, but at an age of 21 weeks there were no significant differences between the three genders. Aggressive and mounting behaviours were higher for entire males.

Rydhmer *et al*. (2010) and Andersson *et al*. (2012) did not find any differences in sexual or aggressive behaviours between vaccinated and castrated pigs before second injection, but significant differences compared to entire males. After second vaccination, mounting and aggressive behaviour was reduced to the same level as for castrated male pigs for vaccinated male pigs. Brewster and Nevel (2013) reported a decline in both sexual and aggressive behaviour three weeks after second injection, whilst sexual behaviour of entire males increased at this point. Also Fábrega *et al*. (2010) reported reduced sexual behaviour for vaccinated males after second vaccination, but they could see a reduction already two weeks before second vaccination (9 weeks after first vaccination).

2.3.6. Skin lesions

Number of skin lesions has been used as an indicator of aggressive behaviour after mixing pigs in new groups (Turner *et al*., 2006). Highest frequency of bites is targeted at ears (55%), neck (23%) and face (17%) (McGlone, 1985). Rydhmer *et al*. (2010) reported that aggressive behaviour followed the same pattern as frequency of skin lesions. Number of pigs with skin lesions, recorded before and after first injection of Improvac®, was higher for vaccinated (64% before and 60% after, respectively) than for castrated pigs (26% and 22%) i.e. aggressive behaviour was higher in vaccinated pigs at this time. Before second injection and at slaughter skin lesions on vaccinated males decreased to approximately the same level as castrates and remained at that level at slaughter. Both Dunshea *et al*. (2011), Fábrega *et al*. (2010) and Zamaratskaia *et al*. (2008a) measured frequency of skin lesions at slaughter and did not see any difference between vaccinated and castrated males.

2.4. Feeding and diets

2.4.1. Feeding regimes

The possibility of vaccinated male pigs profiting from a higher growth performance, a better feed efficiency and better carcass characteristics has been investigated by several authors. Entire males have a higher growth performance on restrictive feeding than castrated males. At *ad libitum* feeding castrates consume more feed but there is no significant difference in growth performance (Campbell & Taverner, 1988).

Batorek *et al*. (2012) compared entire, castrated and vaccinated male pigs fed *ad libitum* with vaccinated male pigs fed restrictively, 2.76 kg/day and pig (80 % of *ad libitum)*. Restrictive feeding was applied one week after second vaccination. The vaccinated pigs fed *ad libitum* increased their feed intake after second vaccination to similar level as castrates and had a growth rate that was higher than the other pigs. They suggested that this was probably due to the fact that vaccinated pigs are not considered to be castrates until after the second vaccination and at this time they start to exhibit behavioural and immunological patterns similar to castrated pigs. Restrictively fed pigs had a lower growth rate after second vaccination but the overall growth rate for the experimental period was not significantly different from *ad libitum* fed vaccinated male pigs. Vaccinated pigs restrictively fed decreased their feed intake after second vaccination according to the design of the experiment, which resulted in the lowest feed conversion ratio compared to the other treatments. Overall feed efficiency did however not differ between vaccinated males fed *ad libitum* or restrictively. Lean meat content of vaccinated male pigs fed restrictively (60.7 %) was significantly higher than for castrated pig (58.3 %) and more similar to that of entire males (62.0 %), whereas vaccinated pigs fed *ad libitum* (59.6 %) were between vaccinated male pigs restrictively fed and castrated male pigs.

Also Quinou (2012) reported that growth rate of pigs restrictively fed declined after restriction was applied. In this experiment two different levels of restriction was used, 2.75 and 2.50 kg/day and pig. They concluded that average daily growth rate was significantly lower for pigs on 2.50 kg/day restriction compared to pigs on *ad libitum* feeding but not significantly different to pigs on 2.75 kg/day restriction. Feed conversion ratio for the whole period did not differ between treatments and neither did lean meat content.

No difference between treatments in average daily gain or feed conversion ratio was seen by Andersson *et al*. (2012), applying restricted feeding on early and standard vaccinated male pigs and castrated male pigs. Lean meat content was lower for early vaccinated and castrated males compared to entire males, whereas no difference was seen between standard vaccinated male and entire male pigs. Similar result was found in a study by Zamaratskaia *et al*. (2008a) who applied *semi ad libitum* feeding. In this study vaccinated pigs had a higher feed intake and higher daily weight gain after second vaccination compared to castrated pigs.

Similar pattern in growth rate was also seen by Pauly *et al*. (2009) who applied *ad libitum* feeding. They found that castrates had a higher growth rate (1037 vs. 866 g/day) before second vaccination, whereas vaccinated males had a higher growth rate during the period after that to slaughter (1136 vs. 1007 g/day). However, growth rate during the total growing-finishing period did not differ between treatments. Vaccinated male pigs had a generally lower feed conversion ratio for the whole period (2.41 vs. 2.54 kg/kg). Carcasses of vaccinated male pigs were leaner compared to castrates (56.3 vs. 54.5 %).

2.4.2. Energy content

To better understand the energy requirement and to get the most effective feeding strategy for vaccinated pigs, energy content of feed should be considered. Their requirement could differ from surgically castrated male pigs but also from entire male pigs as they are more alike one of them at different stages during the growth.

Zeng *et al*. (2002) compared two different energy levels to entire, castrated and vaccinated male pigs fed *ad libitum*. The low energy diet contained 8.30 MJ NE/ kg and the high energy diet contained 9.70 MJ NE/ kg. Vaccinated male pigs grew better with the high energy diet in the first period of the growing period than they did in the second period. In the second period and for the whole period, their daily weight gain did not differ significantly between the two different diets or from the results of the castrated males. Meat percentage was lower in vaccinated males on high energy diet (51.79 %) than for the low energy diet (54.47 %), whereas weight at slaughter did not differ. The results from this study imply that to get good growth rate and a carcass with high lean meat yield a high energy diet is preferable in the first growth period and that a low energy diet is preferable in the second growth period.

2.5. Animal welfare

One of the main reasons to stop using surgical castration of young male piglets is to improve animal welfare. Castration without anaesthesia or analgesia is painful for the piglet (Horn *et al*., 1999; Hansson *et al*., 2011) and causes stress (Prunier *et al*., 2005). It has also been shown that castration affects the piglet's immune system. Studies have demonstrated that castrated males piglets are more susceptible to chronic inflammations (de Kruijf & Welling, 1988). Piglets that have been castrated also show behaviours associated with pain, for example reduced suckling and standing time and increased lying time (McGlone *et al*, 1993). Zamaratskaia *et al*. (2008a) found that castrated male piglets had lower daily weight gain in the birth to weaning period than entire male piglets, indicating that surgically castrated piglets are affected by stress caused by this procedure. The castration procedure can be made easier for the piglets with the use of pain relievers. Anaesthesia has shown to reduce pain in piglets during castration and the use of analgesia has shown to reduce pain after castration (Hansson *et al*., 2011).

Production of entire male pigs is a strategy to avoid surgical castration without vaccination, but entire male pigs show more aggressive behaviour and might therefore not contribute to better animal welfare (Rydhmer *et al*., 2010). More skin lesions during raising and on carcasses at slaughter have been recorded on entire male pigs compared to vaccinated and castrated males

(Batorek *et al*., 2012; Rydhmer *et al*., 2010). It has also been found that restrictively fed vaccinated male pigs have a higher prevalence of skin lesions than ad libitum fed pigs (Batorek *et al*., 2012; Quiniou *et al*., 2012) demonstrating the importance of satisfied pigs on welfare.

2.6. Aim

The objective of this study was to evaluate the efficacy of vaccination against GnRH on growth performance and behaviour of vaccinated male pigs compared to castrated male pigs. Furthermore, the effect of two different feeding regimes, restricted vs. *semi ad libitum*, on growth performance carcass and meat quality characteristics of vaccinated male pigs was studied.

3. OWN PROJECT

4. MATERIAL AND METHODS

4.1. Animals and housing

The study was performed at the Swedish Livestock Research Center at SLU, Uppsala and a total of 206 pigs were used. Out of these, 75 were offspring from Yorkshire sows and Yorkshire boars and 131 from Yorkshire sows and Hampshire boars. Sires were randomly selected from sires available for artificial insemination. The study comprised six consecutive batches. Two treatments were included in the study; surgically castrated and vaccinated entire male pigs. At birth, male piglets were randomly allocated to one of the treatments. Pigs were moved from the weaning unit to the growing-finishing unit at an average age of 68.5 ± 2.4 days (mean ± s.d.) and with an average live weight of 33.0 ± 5.4 kg. The growing-finishing unit included four identical sections, each containing 12 pens. The pigs were housed in pens (3.3 m x 3.5 m) that had a trough and two water nipples. Each pen held seven to nine pigs. Surgically castrated and vaccinated pigs were kept in separate pens, but in the same stable. Straw was provided to the pens every day manually or by a robot (JH ministrö, Mafa). The study was performed in accordance with Swedish regulations for use of pigs.

4.2. Feeding regimens

All pigs were liquid fed a commercial diet. The ingredient composition and the calculated nutrient content of the diet are shown in Table 1. In batches 1 and 2 pigs were fed restrictively following the recommendation of Swedish standard regimen (SLU-normen) for growing-finishing pigs (Andersson *et al*., 1997). In batches 3-6, pigs were fed *semi ad libitum* four times per day. Pigs had free access to water nipple drinkers.

Table 1. Ingredient composition of the diet and the calculated nutrient content

	Diet
Ingredients (%)	
Wheat	45.00
Barley	12.17
Wheat bran	12.00
Rapeseed cake	9.00
Oats	8.00
Soya bean meal	2.55
Middlings	6.00
Distiller's waste, dried	2.01
Limestone	1.65
Vegetable oil	0.50
L-lysine	0.42
Sodium chloride	0.35
Premix[1]	0.26
L-Threonine	0.06
DL-Methionine	0.03
Calculated nutrients	
MJ OE/kg	12.4
MJ NE/ kg	9.3
Crude protein, %	15.3
Crude fat, %	4.3
Ash	5.3
Crude fibre	6.6
Total lysine	0.9
SID lysine[2]	0.78
Calcium	0.75
Phosphorus	0.5

[1]Supplies per kg final feed: Vitamin A: 4000 IU; Vitamin D_3: 400 IU; Vitamin E: 50 mg; Vitamin K_3: 2.0 mg; Vitamin B1: 1.0 mg; Vitamin B_2: 3.0 mg; Vitamin B_6: 2.0 mg; Vitamin B_{12}: 20 µg; Niacin: 10 mg; Pantothenic acid: 7.0 mg; Fe: 56 mg (as $FeS0_4$); Mn: 50 mg (as MnO/Mn_2O_3); Zn: 60 mg (as $ZnSO_4$); Cu: 25 mg (as $CuSO_4 \cdot 5H_2O$); I: 0.2 mg (as $Ca(IO_3)_2$; Se: 0.4 mg (as Na_2SeO_3).
[2]SID=Standardised ileal digestible.

4.3. Castration & vaccination

Piglets belonging to the castrated group (n=103) were surgically castrated with analgesia before the age of one week (3.3 ± 1.0 days). Pigs in the vaccinated group (n=106) were given two injections of Improvac®, containing a modified form of GnRH (Pfizer Ltd; 2 ml per injection). The injections were given below the base of the ear. In batches 1 and 2, the pigs were vaccinated approximately 8 and 4 weeks before slaughter. Due to an unexpected high daily weight in the herd and that a higher feeding regimen was applied in batches 3-6, the injections had to be moved forward approximately 2 weeks to make sure that the time between second injection and slaughter should be at least 4 weeks according to the recommendations. Consequently, pigs in batches 3 – 6 were given their injections approximately 10 and 6 weeks before slaughter.

4.4. Recordings

All pigs were weighed individually four times during the study; at the beginning of the study, before first vaccination, before second vaccination and before slaughter. Feed consumption was recorded daily, residual feed was removed and weighed, and based on these data feed conversion ratio was calculated pen-wise.

In batches 1 and 2, pigs were sent to slaughter on three occasions per pen at an average live weight of 107.5 ± 10.1 kg and an average age of 150.7 ± 6.3 days and in batch 5 at two occasions at 120.2 ± 9.5 kg and 150.3 ± 4.5 days. In batches 3, 4 and 6, slaughter was performed at one occasion per batch (120.0 ± 19.3 kg and 150.0 ± 7.0 days). Before cooling, carcass weight was recorded and lean meat content was evaluated with the Hennessy Grading Probe (Hennessy Grading Systems, Auckland, New Zealand; Sather *et al.*, 1991).

Daily lean meat growth for the entire growing-finishing period was calculated using following formula: (% lean × carcass weight) - (initial weight × 0.72))/days in experiment, where the value 0.72 representing a hypothetical dressing percentage at start (Andersson *et al.*, 2011).

4.5. Behavioural studies

Behavioural studies were performed by direct observation at three times per batch; the week before first vaccination, the week before second vaccination and the week before slaughter. One person (same person during all observations) stood outside the pen, observation started when the pigs were accustomed to the observer. Each observation round started with a one minute instantaneous scanning where activity behaviours (sleeping, resting, active) were recorded, this minute was followed by a four minute long continuous recording of frequencies of social behaviours (aggressive, mounting, contact). Each observation round also ended with a one minute scanning. All pens were observed in a consecutive order, ten rounds at each observation occasion (in total 60 minutes per pen).

Definition of behaviour parameters are presented in Table 2. Every new interaction was recorded even if performed by the same pig. A new interaction by the same pig was recorded if the first interaction stopped for more than three seconds. Behaviours that lasted for more than four seconds were recorded as long-lasting.

Table 2. Definitions of behaviour parameters used at the scan sampling and during continuous recording

Behaviour parameter	Definition
Scan sampling	
Sleeping	Pigs lying down with closed eyes.
Resting	Pigs lying down or sitting awake, can be sniffing, eating straw, manipulating interior etc.
Active	Standing, walking, running or jumping including activities like eating, drinking, fighting, playing etc.
Continuous recording	
Aggressive	Two or more pigs fighting or one pig biting or pushing another pig with its head.
Mounting	One pig mounting another pig.
Contact	Touching another pig in a non-aggressive way.
Long-lasting	Social interaction lasting for more than four seconds.

4.6. Skin lesions

At the same day as the behavioural study was performed, all vaccinated and surgically castrated pigs were inspected for skin lesions by the same person performing the behavioural study. Skin lesions were recorded as deep or light on head, front and back, see Figure 1. Deep wound was defined as open wound, wound with thick or large crust or infected. Light wound was defined as shallow scratch, red skin or small and shallow wound with or without crust. Number of skin lesions was recorded as no lesions, 1-3 lesions, 4-9 lesions or more than 9 lesions. According to these records the pigs were also classified into two groups, with skin lesions or without skin lesions. If pigs were recorded with 3 or less lesions they were included in the "without skin lesions" group and if they were recorded with more than 3 lesions they were included in the "with skin lesions" group.

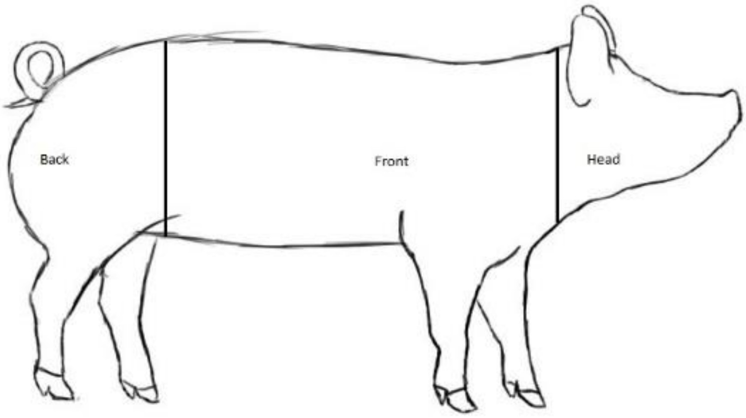

Figure 1. Skin lesions were recorded on head, front and back as shown in the figure (figure from draw-central.com).

4.7. Statistical analyses

4.7.1. Performance, carcass quality and skin lesions

Data were analysed with the Statistical Analysis System, version 9.3 (SAS Institute Inc., Cary, NC, USA). Analyses were done partly on combined data of batches 1 and 2 (restrictively feeding) and partly on combined data of batches 3–6 (*semi ad libitum* feeding). The effect of treatment on performance, carcass quality and number of skin lesions was evaluated with PROC MIXED procedure. The model included the fixed factor of treatment (surgical castration and vaccination with Improvac®) and the random factors of batch, pen within batch and litter. Pig was used as the experimental unit for carcass and all performance traits, except for feed conversion ratio, where pen was used as unit. Initial weight was included in the model for daily weight gain for the interval from start to first injection and for the total period, as a covariate and carcass weight for lean meat content. When analysing the effect of the two different feeding regimens for vaccinated pigs, the model included the fixed factor of feeding regimen (restrictively and *semi ad libitum* feeding) and the random factors of batch within feeding regimen, pen within batch and litter.

The impact of treatment on the occurrence of skin lesions (pigs with or without) were analysed with PROC GLIMMIX and the model included the fixed factor of treatment and the random factors of batch and pen within batch. Significance level was set at $P \leq 0.05$.

4.7.2. Behaviour

Activity behaviours were recorded as the percentage of pigs performing a specific behaviour at each observation occasion (10 rounds x 2 min). The social interactions were recorded as the total number of interactions performed per pen (10 rounds x 4 min) at each observation occasion and was then transformed to number of interactions performed per hour and pen. Pen was the experimental unit. All behaviour parameters were evaluated within each observation occasion on combined data from batches 1-6 with PROC MIXED procedure. The model included treatment (surgical castration and vaccinated with Improvac®) as fixed factor and batch (1-6) as random. The effect of time was evaluated within treatment with observation occasion as fixed factor and batch as random factor.

5. RESULTS

5.1. Performance and carcass quality

5.1.1. Lövsta, batches 1 and 2

One vaccinated pig died during the experimental period. Vaccinated pigs had a lower initial weight than castrated pigs (P=0.021; Table 3). Daily weight gain in the interval from start to first vaccination did not differ significantly between treatments. Vaccinated pigs grew faster than surgically castrated pigs in the interval from first to second vaccination, 1060 vs. 969 g per day. In the interval from second vaccination to slaughter and for the total daily weight gain there were no significant differences between treatments. Vaccinated pigs had more days in experiment than castrated pigs, 84 compared with 79 days (P =0.028). Daily feed consumption did not differ between vaccinated and castrated pigs in any of the intervals. Except for feed conversion ratio from first to second vaccination, where the value was significantly lower for vaccinated pigs (2.49 kg/kg) compared with castrated pigs (2.78 kg/kg), no significant difference could be observed. Lean meat content and dressing percentage did not differ significantly between treatments. Compared to surgically castrated pigs, vaccinated pigs tended (P=0.110) to have higher daily lean meat growth 299 vs. 270 g.

Table 3. Performance and carcass quality of castrated and vaccinated pigs in batches 1 and 2

Treatment	Surgically castrated pigs	Vaccinated male pigs	s.e	P-value
No. of pigs	31	31		
Initial weight (kg)	34.8	32.3	1.11	0.021
Daily weight gain (g)				
Start to 1st vaccination	851	855	39.7	0.957
1st to 2nd vaccination	969	1060	63.9	0.052
2nd vaccination to slaughter	807	877	23.2	0.211
Start to slaughter	877	924	86.2	0.198
Days in experiment	79	84	3.3	0.028
Daily feed consumption (kg)				
Start to 1st vaccination	1.29	1.22	0.168	0.186
1st to 2nd vaccination	2.76	2.72	0.401	0.450
2nd vaccination to slaughter	3.21	2.87	0.169	0.174
Start to slaughter	2.44	2.36	0.089	0.236
Feed conversion ratio (kg/kg)				
Start to 1st vaccination	2.08	2.03	0.357	0.658
1st to 2nd vaccination	2.78	2.49	0.285	0.047
2nd vaccination to slaughter	3.66	3.14	0.855	0.214
Start to slaughter	2.84	2.62	0.371	0.200
Final weight (kg)	104.4	110.4	6.32	0.073
Carcass weight (kg)	78.1	82.1	4.23	0.125
Lean meat content (%)	59.1	59.0	0.46	0.788
Dressing percentage (%)	74.8	74.4	0.53	0.365
Daily lean meat growth (g)	270	299	27.8	0.110

5.1.2. Lövsta, batches 3-6

In batches 3-6, three castrated pigs died during the experiment. Initial weight differed between treatments (Table 4), vaccinated pigs had lower initial weight than surgically castrated pigs (P =0.010). No difference was recorded in daily weight gain in the interval from start to first vaccination. In the interval from first to second vaccination, vaccinated male pigs had a higher growth rate than surgically castrated male pigs (P=0.025). After that, vaccinated pigs tended (P=0.092) to grew faster than castrated pigs (1216 and 1172 g per day). Total daily weight gain was significantly higher for vaccinated pigs (1083 g) compared with castrates (1040 g). Days in experiment did not differ between treatments. No significant difference in daily feed consumption could be seen between vaccinated and castrated pigs. Feed conversion ratio was significantly lower for vaccinated pigs from first to second injection than for castrates, 2.23 compared to 2.38 kg feed/kg weight gain. After second injection no difference was seen, whereas vaccinated pigs had lower feed conversion ratio for the total growing-finishing period than castrates (2.58 vs. 2.66 kg feed/kg weight gain).

No significant difference in carcass and lean meat content was found between vaccinated and castrated male pigs. Dressing percentage was significantly lower for vaccinated pigs than for castrated pigs (74.7 vs. 75.9 %). For vaccinated pigs daily lean meat growth was significantly higher (350 g) than for castrated pigs (334 g).

Table 4. Performance and carcass quality of castrated and vaccinated pigs in batches 3-6

Treatment	Surgically castrated pigs	Vaccinated male pigs	s.e	P-value
No. of pigs	69	74		
Initial weight (kg)	33.5	31.5	1.29	0.010
Daily weight gain (g)				
Start to 1st vaccination	737	813	59.0	0.173
1st to 2nd vaccination	1029	1078	22.3	0.025
2nd vaccination to slaughter	1172	1216	45.5	0.092
Start to slaughter	1040	1083	17.0	0.017
Days in experiment	82	82	4.0	0.515
Daily feed consumption (kg)				
Start to 1st vaccination	1.00	0.98	0.090	0.698
1st to 2nd vaccination	2.35	2.35	0.070	0.991
2nd vaccination to slaughter	3.68	3.68	0.113	0.969
Start to slaughter	2.80	2.80	0.084	0.983
Feed conversion ratio (kg/kg)				
Start to 1st vaccination	2.40	2.18	0.228	0.104
1st to 2nd vaccination	2.38	2.23	0.060	<0.001
2nd vaccination to slaughter	2.86	2.84	0.029	0.470
Start to slaughter	2.66	2.58	0.021	0.001
Final weight (kg)	118.9	121.0	6.65	0.216
Carcass weight (kg)	90.0	90.1	4.91	0.980
Lean meat content (%)	57.4	57.4	0.36	0.865
Dressing percentage (%)	75.9	74.7	0.68	0.025
Daily lean meat growth (g)	334	350	9.7	0.050

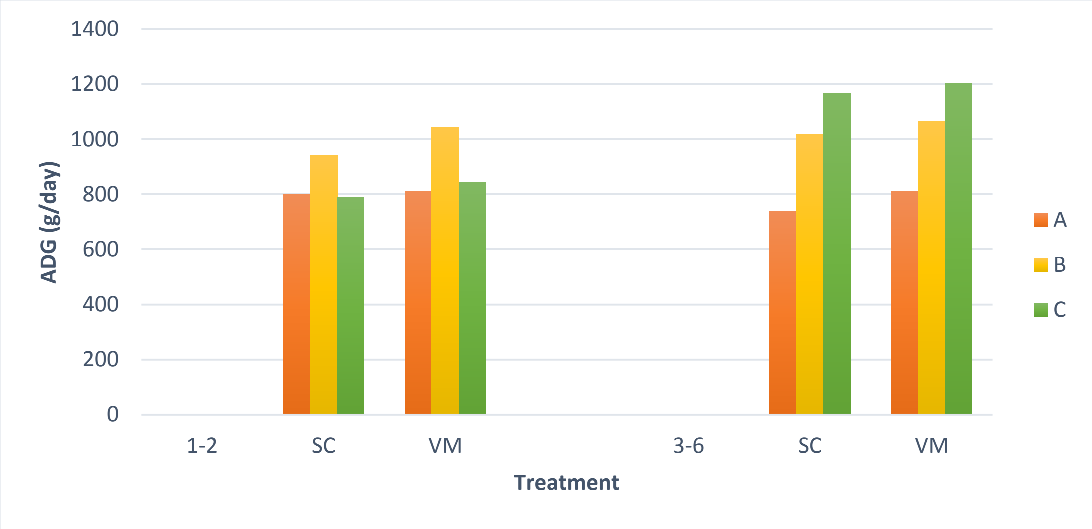

Figure 2. Average daily gain (ADG) for surgically castrated males (SC) and vaccinated males (VM) in batches 1-2 and 3-6, respectively.
A = start to 1st vaccination;
B = 1st to 2nd vaccination;
C = 2nd vaccination to slaughter.

5.2. Feeding regimen

Vaccinated pigs in batches 1 and 2 had an overall daily fed intake of 2.36 kg per day (29 MJ NE/day) which was 84 % of the intake of vaccinated pigs (2.80 kg per day, 35 MJ NE/day) in batches 3-6. Performance results from the two different feeding regimens are presented in Table 5. Comparison showed that vaccinated male pigs fed *semi ad libitum* (batch 3-6) had higher daily weight gain after second injection of Improvac® compared with the restrictively fed pigs in batches 1 and 2, 1227 vs. 863 g (P=0.061). For daily weight gain from start to slaughter corresponding values were 1078 and 910 g (P=0.020). Vaccinated male pigs fed restrictively tended to have a higher lean meat content than the *semi ad libitum* fed pigs (P = 0.100). Daily lean meat growth was higher for these *semi ad libitum* fed pigs, 352 g compared with 298 g for the restrictively fed pigs (P = 0.003). Number of skin lesions did not differ between vaccinated pigs fed *semi ad libitum* and restrictively (P<0.05).

Table 5. Performance and carcass quality of vaccinated males in batch 1-2, restrictively fed, and 3-6, *semi ad libitum* fed

Treatment	Vaccinated 1-2	Vaccinated 3-6	s.e	p-value
Initial weight (kg)	32.4	31.6	1.64	0.775
Daily weight gain (g)				
Start to 1st vaccination	842	807	49.5	0.644
1st to 2nd vaccination	1057	1083	27.3	0.547
2nd vaccination to slaughter	863	1227	100.7	0.065
Start to slaughter	910	1078	31.3	0.020
Days in experiment	84	82	4.8	0.779
Daily feed consumption (kg)				
Start to 1st vaccination	1.22	0.99	0.115	0.225
1st to 2nd vaccination	2.72	2.36	0.187	0.251
2nd vaccination to slaughter	2.87	3.68	0.151	0.020
Start to slaughter	2.37	2.80	0.108	0.047
Feed conversion ratio (kg/kg)				
Start to 1st vaccination	2.03	2.18	0.248	0.702
1st to 2nd vaccination	2.49	2.23	0.174	0.177
2nd vaccination to slaughter	3.14	2.84	0.254	0.446
Start to slaughter	2.62	2.58	0.121	0.813
Final weight (kg)	110.2	122.0	8.18	0.373
Carcass weight (kg)	82.1	90.7	5.66	0.349
Lean meat content (%)	58.5	57.5	0.40	0.175
Dressing percentage (%)	74.4	74.7	0.77	0.804
Daily lean meat growth (g)	298	352	12.1	0.035

5.3. Activity behaviour

Treatment did not significantly affect activity behaviours, except for sleeping (P=0,016) and resting (P=0,013) at the third observation occasion (Table 6). At this occasion, more vaccinated pigs were sleeping (53.4 vs. 46.9 %) and fewer were resting (24.5 vs. 30.5 %) compared with the castrated pigs.

Table 6. Percentage of pigs performing different activity behaviours recorded at scan sampling

Treatment	Surgically castrated pigs	Vaccinated male pigs	s.e.	P-value
Before 1st vaccination				
Sleeping	35.8	34.7	3.47	0.777
Resting	27.5	26.1	1.19	0.406
Active	36.7	39.2	3.68	0.497
Before 2nd vaccination				
Sleeping	39.8	43.3	5.42	0.305
Resting	26.9	27.8	2.45	0.686
Active	33.3	28.9	4.75	0.216
Before slaughter				
Sleeping	46.9	53.4	3.87	0.013
Resting	30.5	24.5	3.52	0.016
Active	22.6	22.1	2.08	0.853

Age had an effect on the proportion of vaccinated pigs sleeping (P<0.001), with an increase from 34.7 % before first vaccination to 53.4 % before slaughter, whereas no age-related effect was found for castrates (P=0.122).

Proportion of pigs that were active were affected by age (P=0.012 for castrates and P<0.001 for vaccinated pigs). Before first injection of Improvac® both castrated and entire male pigs, intended to be vaccinated, were more active than later on (Figure 3). For vaccinated pigs the decrease was more distinct between first and second observation occasion than between second and third observation occasion (Table 6). For castrated pigs the relationship was the opposite with a larger decrease between second and third observation. No age-related effect was found for castrates (P=0.122), but for vaccinated pigs (P<0.001).

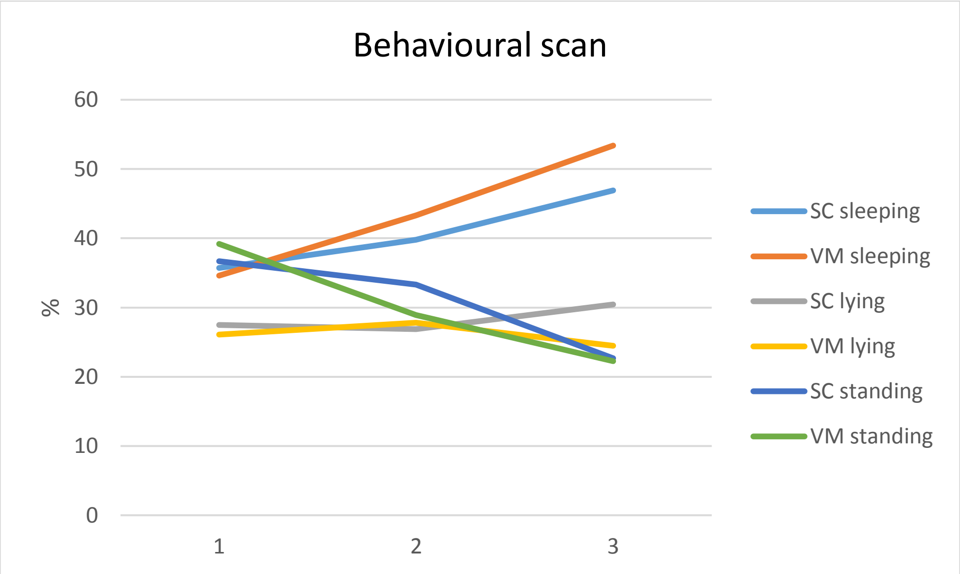

Figure 3. Percentage of pigs performing different activity behaviours recorded at scan sampling.

5.4. Social interactions

Before first vaccination, entire male pigs showed a tendency to be more aggressive and they performed more mountings than castrated pigs (P=0.073 and P=0.014, respectively). The proportion of long-lasting aggressive and mounting behaviours did not differ between treatments (Table 7). Before second vaccination, now vaccinated pigs still performed more aggressive behaviour than castrated pigs (P=0.045), and they also had a higher frequency of long-lasting aggressive interactions (P=0.034). At this occasion, number of mountings had decreased to the same level for vaccinated pigs as for surgically castrated pigs.

Before slaughter, aggression level had decreased significantly in comparison with the second occasion and was for vaccinated pigs similar to surgically castrated pigs (3.3 vs. 4.8 interactions). The frequency of long-lasting aggressive interactions was very low and none of the mounting interactions was long-lasting and was unaffected by treatment.

Table 7. Total number of observed social interaction per pen and hour and percentage of long-lasting interactions

	Surgically castrated pigs	Vaccinated male pigs	s.e.	P-value
Before 1st vaccination				
Aggressive	14.1	21.0	3.47	0.073
Mounting	2.8	9.3	2.34	0.014
Contact	136.1	131.1	11.05	0.752
Aggressive, long-lasting (%)	10.7	10.1	3.21	0.899
Mounting, long-lasting (%)	0	2.9	2.06	0.327
Contact, long-lasting (%)	23.0	23.2	3.03	0.921
Before 2nd vaccination				
Aggressive	11.1	16.1	2.90	0.045
Mounting	1.8	2. 8	0.87	0.431
Contact	104.7	108.1	12.56	0.806
Aggressive, long-lasting (%)	3.1	9.6	4.19	0.034
Mounting, long-lasting (%)	0	1.3	0.92	0.327
Contact, long-lasting (%)	28.1	25.6	2.59	0.400
Before slaughter				
Aggressive	4.8	3.3	1.37	0.233
Mounting	0.3	0	0.15	0.156
Contact	101.7	83.6	4.69	0.013
Aggressive, long-lasting (%)	1.0	6.8	4.88	0.412
Mounting, long-lasting (%)	0	0	-	-
Contact, long-lasting (%)	24.2	23.7	4.18	0.916

Number of contacts decreased over time, but in a different way for pigs from the two treatments. For castrates no time-related effect could be seen after the second occasion. For vaccinated pigs number of contacts had decreased significant also at the third occasion (Figure 4) and was lower than for castrated pigs (P=0.013).

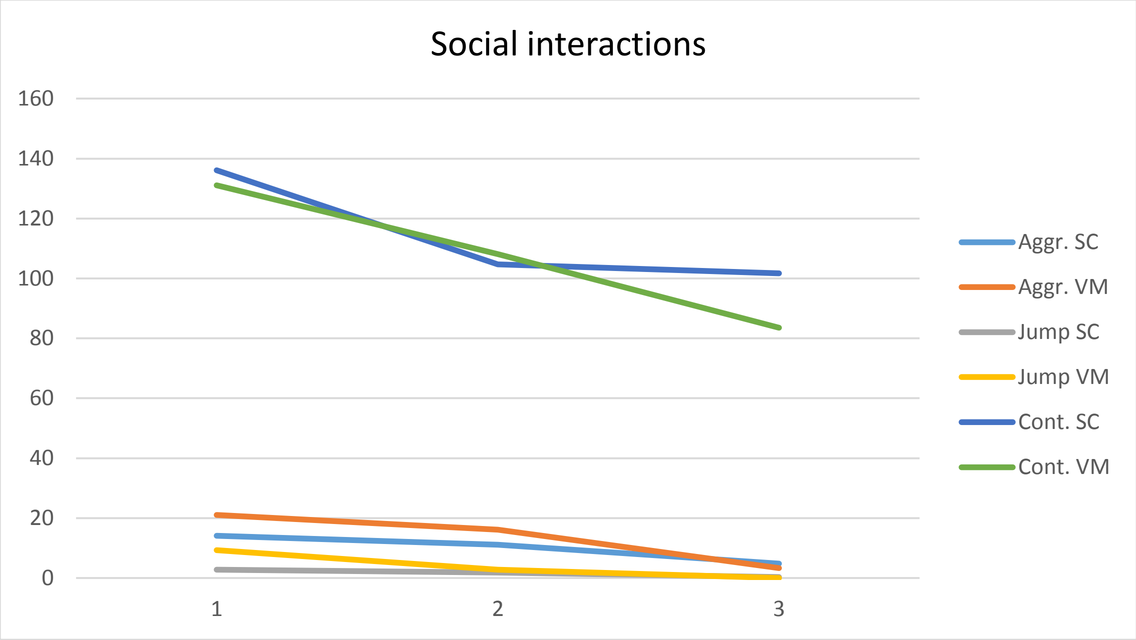

Figure 4. Number of social interactions per pen and hour at observation 1 – before first vaccination, 2 – before second vaccination and 3 – before slaughter.

5.5. Skin lesions

Before first vaccination, standard vaccinated pigs had significantly more skin lesions on front than castrates (Table 8), whereas no significant differences could be observed on head or back. After that, skin lesions did not differ between the two treatments. Number of deep skin lesions was consistently very low and with no difference between castrated and vaccinated pigs.

Table 8. Number of skin lesions per pig

	Surgically castrated pigs	Vaccinated male pigs	s.e.	P-value
Before 1st vaccination				
Head	2.7	3.3	0.38	0.241
Front	4.4	5.5	0.74	0.011
Back	0.8	1.2	0.36	0.279
Deep	0	0.2	0.14	0.284
Before 2nd vaccination				
Head	3.5	3.2	0.83	0.483
Front	5.8	6.5	0.74	0.184
Back	2.2	2.1	0.69	0.825
Deep	0	0.1	0.05	0.136
Before slaughter				
Head	4.7	4.1	0.43	0.270
Front	6.6	6.1	0.40	0.342
Back	2.7	3.0	0.64	0.620
Deep	0.1	0.7	0.45	0.301

Before first injection, percentage of pigs with skin lesions had a tendency (P=0,082) to be higher for entire males (68.4 %), intended to be vaccinated, compared to castrated pigs (53.3 %). Before second injection and before slaughter, percentage of pigs with skin lesions had increased but with no significant difference between castrated (78.0 and 80.8 %) and vaccinated (83.8 and 69.8 %) pigs.

5.6. Practical experience of vaccination against boar taint

The herd (Strömsnäs) has an integrated pig production. Piglets are moved from family pens to finishing units at 11.5 weeks of age and are given the first injection of Improvac® at approximately 12 weeks of age and the second injection at 16 weeks. The vaccination cannot be made earlier, as it is difficult to handle piglets in the family pens at vaccination. The producer and the staff consider that the vaccination procedure is easy, but it requires two persons. Nevertheless, vaccination is more time effective than surgical castration, especially if anaesthesia and/or analgesia has to be used. They also consider that it is easier to handle pigs when they are older and heavier than when they are young and light.

They have used Improvac® for nearly two years. Due to problems last spring, with bad quality of grain and structural problems at the slaughterhouse to document the results separately for vaccinated male pigs and females, they do not know the growth rate of vaccinated pigs. No distinct improvement of growth rate after second injection has been observed, but they have got a more even growth of the vaccinated pigs and therefore fewer slow-growing pigs left at the end of the raising period. They think that a higher growth rate do not have advantages in the applied production system.

Neither have they seen any noticeable differences in feed consumption or feed conversion rate, and thus no lower feed cost. One positive aspect both for economy and for animal welfare is that vaccination has resulted in less arthritis incidents of the pigs. Therefore, use of antibiotics has declined.

Despite vaccination of male pigs has positive advantages such as saving labour time and lowering the frequency of diseases, the producer consider that one of the main advantages is that it is a castration procedure that works well and that it is easy to handle. The producer also thinks that it is easier to change to a new castration system than it is to add extra working moments into an old system.

5.6.1. Growth performance

The aim to perform a comprehensive comparison for production data between castrated and vaccinated male could not be performed. Partly as surgical castration and vaccination were not performed during the same period, and partly because pigs were not sorted by sex at slaughterhouse. Therefore, the comparison is made between a period when piglets were surgically castrated and a period when the pigs were vaccinated.

Average lean meat content was 57.9 % and carcass weight was 85.4 kg when the herd used castration. These results are not different from the results of today with vaccination - lean meat content is 58.0 % and carcass weight is 85.2 kg.

6. DISCUSSION

Vaccination can be performed earliest at eight weeks of age and it should be at least four weeks between first and second injection according to the recommendation of the manufacture. In our study pigs in the two first batches were vaccinated at an age of 14 and 18 weeks, i.e. 4-6 weeks before slaughter, according to the recommendations. Due to very high growth rate in the herd this resulted in too heavy pigs at slaughter. Therefore, vaccination in batches 3-6 was performed earlier, at approximately 12 and 16 weeks of age. Results from previous studies have shown that vaccination can be performed even earlier (Andersson *et al*., 2012; Brewster and Nevel, 2013; Brunius *et al*., 2011) and that the effect of vaccination last at least 10 weeks making it possible to send pigs to slaughter during a longer period, than the recommended 4-6 weeks between second vaccination and slaughter.

In the interval from birth to weaning, it could be expected that growth performance of castrated pigs should be lower than that of females and entire male pigs, as they undergo a surgical procedure that could affect their general health. However, in this study the castrated males had a higher initial weight than the entire male pigs implying that their growth rate was higher during the suckling period. These results are in contrast with the results of Zamaratskaia *et al*. (2008a), who found that surgical castrated piglets had a lower daily growth gain during the suckling period compared to entire male piglets. Also Cronin *et al*. (2003) found a lower growth gain in this period for castrated piglets compared to entire male piglets. Previous studies have shown that growth performance does not differ in this period (Andersson *et al*., 2012; Pauly *et al*., 2009). None of the authors sited in this paper have reported a higher growth performance for castrated than for entire pigs.

Between first and second vaccination, both restrictively and *semi ad libitum* fed vaccinated male pigs had significantly higher growth rate and lower feed conversion ratio than castrates. This indicates that vaccination might have had an effect already after first injection. Dunshea *et al*. (2001) reported a higher growth rate of castrated male pigs in this period, whereas Andersson *et al*. (2012) and Zamaratskaia *et al*. (2008b) found similar growth rate for castrates and vaccinated pigs. One reason for the difference in growth rate in this study could be that pigs are produced in a Specific Pathogen Free (SPF) production. Pigs in such systems are not exposed to pathogens which are common in commercial pig production and they have therefore a higher feed intake and growth rate.

After second vaccination, growth rate of vaccinated and castrated male pigs on both feeding regimens was similar, whereas many authors have reported an increased growth rate similar to castrates and in many cases even higher for vaccinated male pigs than for castrates in this period (Cronin *et al*., 2003; Dunshea *et al*., 2001; Zamaratskaia *et al*., 2008a). Results for the whole experimental period showed that vaccinated male pigs on *semi ad libitum* feeding had significantly higher daily weight gain than castrates, whereas no difference was found when the pigs were restrictively fed. Some authors have concluded that the increase in growth rate after second vaccination is related to a higher feed intake. However, in this study daily feed consumption during the different periods of rearing and for the whole growing-finishing period was similar for vaccinated and castrated male pigs. Consequently, the total feed conversion ratio was lower for vaccinated male pigs than for castrates when fed *semi ad libitum*.

Dressing percentage of *semi ad libitum* fed vaccinated male pigs was lower (P=0.025) compared to castrated male pigs, which was also found by Andersson *et al.* (2012). The lower dressing percentage could partly be due to the weight of reproductive organs (Einarsson *et al.*, 2011) of vaccinated male pigs. However, this measurement was not included in this study. The lower dressing percentage could also be due to higher content of abdominal fat. For restrictively fed pigs, dressing percentage was similar between treatments. Commercial lean meat content did not differ between vaccinated and castrates regardless of feeding regimen. However, Andersson *et al*. (1997) found that lean meat content of vaccinated male pigs is underestimated by the commercial grading system used in Sweden. Previous studies have shown that vaccinated pigs had lean meat content between entire male pigs and castrates (Jaros *et al.*, 2005; Fàbrega *et al.*, 2010).

Daily feed consumption after second vaccination was approximately 78 % (2.40 kg per day) of the daily feed intake of *semi ad libitum* (2.80 kg per day) fed pigs. Growth rate for restrictively fed pigs declined after second vaccination, when the maximum feed allowance according to the applied feeding regimen (SLU-normen) was reached. This is in line with the results of Quinou (2012) who saw that a restriction at a lower level (2.50 kg per day) reduces total average daily gain. Batorek *et al*. (2012) used a higher level (2.75 kg per day) of restriction and did not find any effect on growth rate. But the restricted feeding regime in the study by Batorek *et al* (2012) is almost as high as the *semi ad libitum* feeding regime in our study which could be a possible explanation why they could not see any effect on growth rate. Higher daily lean meat growth for vaccinated male pigs on *semi ad libitum* feeding regime was the only significant difference seen between the two feeding regimens. .

Results for the whole experimental period showed that vaccinated male pigs on *semi ad libitum* feeding had significantly higher daily weight gain, lower feed conversion ratio and higher daily lean meat growth compared to castrates with similar feed consumption. The results indicate that the higher growth potential of entire males can be utilised when vaccination is used and that the growing-finishing period can be shortened. Our results are not in agreement with Dunshea *et al*. (2001), Jaros *et al*., (2005) and Zamaratskaia *et al*. (2008a), who could not find any difference in total daily weight gain. For restrictively fed pigs the growth rate and feed conversion ratio were similar for vaccinated and castrated pigs. Our results showed that a higher feeding regimen than the recommended feeding regimen in Sweden should be applied to vaccinated male pigs to use their potential.

Before second vaccination, activity behaviours such as sleeping, lying down and standing, did not differ significantly between treatments. At the third observation occasion, after second vaccination, a higher frequency of vaccinated pigs was sleeping, whereas more castrated pigs were resting. Inactive behaviours, resting and sleeping, increased over time and active behaviour decreased for both treatments. Similar pattern was seen by Brewster and Nevel (2013) although in their study they reported an increase in active behaviour at 21 weeks of age, 7 weeks after second vaccination. This increase in activity at an age of 20 weeks was also seen by Fàbrega *et al*. (2010). In our study, behaviour was recorded at approximately 12, 16 and 21-22 weeks of age (last recording differing because we had to adjust time of slaughter to the slaughter house) and therefore we might have missed the time when the increase in activity occurred. In our study pigs had a high growth rate and were slaughtered at approximately 22 weeks of age, in the studies by Fábrega *et al*. (2010) and Brewster and Nevel (2013) where pigs were slaughtered at approximately 25 weeks of age. However, slaughtered occurred at the same live weight as in the study by Fábrega *et al* (2010), indicating that our pigs might have passed this stage.

Before first vaccination, there was a tendency that entire male pigs (intended to be vaccinated) were more aggressive and they performed more sexual behaviour than castrates. This resulted in more vaccinated pigs with skin lesions. However, the proportion of long-lasting behaviours was low and was not higher than for castrates, indicating that the interactions were not so severe. Just as stated previously, entire male pigs express more sexual and aggressive behaviour than castrates (Dunshea *et al*., 2001; Fábrega *et al*., 2010; Pauly *et al*., 2009). Andersson *et al*. (2011) reported more aggressive and sexual behaviour of entire male pigs. They also reported that at this time the vaccinated pigs had more contact with each other than the castrates had, which is in disagreement with our results where no difference was observed.

At the second observation occasion, which took place just before second vaccination, the vaccinated pigs still were more aggressive than the castrates. However, their sexual behaviour and skin lesions had decreased to similar level as for castrates, although, they are expected to still behave like entire male pigs. Andersson *et al*. (2011) reported that the vaccinated pigs at this time had decreased sexual behaviour to a level between castrates and entire male pigs.

After the second vaccination, the number of aggressive behaviour of vaccinated pigs had decreased and was similar to castrates. This is in agreement with those results published by other authors (Andersson *et al*., 2011; Brewster and Nevel, 2013). At this time, no mountings were observed at all, in line with Brewster and Nevel (2013).

7. CONCLUSION

Vaccination against GnRH with Improvac® was successfully accomplished in this study. Results showed that vaccination has potential to increase daily weight gain, daily lean meat growth and to get a lower feed conversion ratio compared to castrated male pigs under a *semi ad libitum* feeding regime. Vaccination was also effective in reducing aggressive and sexual behaviour to same levels as for castrates and is not affecting animal welfare negatively. Restrictive feeding did not improve performance or carcass characteristics of vaccinated compared to castrated male pigs in this study.

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APPENDIX 1.

Figure XX. Protocol for activity behaviour observation.

Activity behaviour					Start		End	
Date			Pen		Pigs			
Paus								

Round 1	Aggr												
	Jump												
	Contact												
	Long-last												
Round 2	Aggr												
	Jump												
	Contact												
	Long-last												
Round 3	Aggr												
	Jump												
	Contact												
	Long-last												
Round 4	Aggr												
	Jump												
	Contact												
	Long-last												
Round 5	Aggr												
	Jump												
	Contact												
	Long-last												
Round 6	Aggr												
	Jump												
	Contact												
	Long-last												

Figure XX. Protocol for scan sampling and skin lesions observation.

Scan sampling				Start		End	
Date			Pen			Pigs	

Round	sleeping	lying	standing	**sum**
1a				
1b				
2a				
2b				
3a				
3b				
4a				
4b				
5a				
5b				
6a				
6b				
7a				
7b				
8a				
8b				
9a				
9b				
10a				
10b				

Date			Pen			Pigs

Skin lesions

	Head		Front		Back	
Id	deep	light	deep	light	deep	light

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