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Evaluation of production performance and carcass quality characteristics of boars immunised against gonadotropin-releasing hormone (GnRH) compared with physically castrated male, entire male and female pigs

J. Morales[1]*, M. Gispert[2], M. Hortos[2], J. Pérez[3,4], P. Suárez[3] and C. Piñeiro[1]

[1] *PigCHAMP Pro Europa S.A. C/ Gremios Segovianos, 13. 40195 Segovia. Spain*
[2] *IRTA. Finca Camps i Armet. 17121 Monells. Spain*
[3] *Pfizer Salud Animal. Avda. de Europa, 20B. Parque Empresarial La Moraleja. 28108 Alcobendas (Madrid). Spain*
[4] *NUTEGA. C/ Marconi, 9. 28823 Coslada (Madrid). Spain*

Abstract

The objectives of this study were to assess the performance and carcass quality characteristics of boars immunised against gonadotropin-releasing hormone GnRH (IM) compared with physically castrated males (PM), entire males (EM) and entire female pigs (EF). For the study 288 crossbred (Large White × Landrace) pigs were used comprising four equal groups of 72 IM, 72 PM, 72 EM and 72 EF. The study period was from 74 days of age (31.2 ± 5.57 kg body weight; mean ± std. dev.) to slaughter at 172 days of age (107.7 ± 14.82 kg body weight). PM were physically castrated at 5 days of age and IM pigs were vaccinated with the GnRH vaccine Improvac® (Pfizer Animal Health) at 74 and 145 days of age (89.1 ± 15.93 kg body weight). Across the duration of the study period, growth rate was numerically highest in IM group and significantly higher than EF ($P < 0.01$). This was also reflected in respective slaughter weights. EM had the lowest feed:gain ratio ($P < 0.001$) followed by IM which had a lower ratio than both PM and EF. At slaughter, testes weights were reduced in IM by approximately 55% ($P < 0.001$) compared with EM. Fat content (backfat thickness and intramuscular fat) was higher and lean percentage of carcass lower in PM compared to all other groups ($P < 0.05$), with no differences between EF, EM and IM. Boar taint compounds, skatole and androstenone, were lower in IM pigs compared with EM ($P < 0.05$), and not differing from the concentrations measured in PM and EF. Immunisation of entire male pigs against GnRH allows improved feed efficiency compared with physical castrates with no detriment to carcass or meat quality.

Additional key words: boar taint, carcass quality, GnRH immunization, production performance, swine.

Resumen

Evaluación de los rendimientos productivos y de las características de la calidad de la canal de cerdos machos inmunizados frente a la hormona liberadora de gonadotropina (GnRH) en comparación con machos castrados quirúrgicamente, machos enteros y hembras

Los objetivos del presente estudio fueron evaluar la productividad y características de la calidad de la canal de cerdos inmunizados frente a GnRH (IM) en comparación con machos castrados físicamente (PM), machos enteros (EM) y hembras (EF). Se utilizaron un total de 288 híbridos comerciales (Large White × Landrace). Los PM fueron castrados a los 5 días de vida, mientras que los cerdos IM se vacunaron con GnRH Improvac® (Pfizer Animal Health) a los 74 (31,2 ± 5,57 kg peso vivo; media ± desv. est.) y 145 días de edad (89,1 ± 15,93 kg peso vivo). La ganancia de peso diaria fue numéricamente mayor en el grupo IM, y de forma significativa frente a las EF ($P < 0,01$). Este efecto también se reflejó en los pesos de sacrificio. EM mostraron el menor valor de índice de conversión ($P < 0,001$) seguidos por IM, que mostraron un menor índice que PM y EF. En el sacrificio, el peso testicular se redujo en IM un 55% ($P < 0,001$) en comparación con EM. El contenido de grasa (espesor de grasa dorsal y grasa intramuscular) fue mayor y el porcentaje magro de la canal menor en PM en comparación al resto de grupos ($P < 0,05$), sin diferencias entre EF, EM e IM. La concentración de los componentes del olor sexual, escatol y androsterona, fue menor en cerdos IM que

* Corresponding author: joaquin.morales@pigchamp-pro.com
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en EM ($P < 0,05$), sin ser diferente de las concentraciones medidas en PM y EF. La inmunización de EM frente a GnRH permite mejorar el índice de conversión en comparación con la castración física en cerdos, sin perjudicar la calidad de la canal o de la carne.

Palabras clave adicionales: calidad de canal, inmunocastración GnRH, olor sexual, porcino, rendimientos productivos.

Introduction

Physical castration of male pigs slaughtered at heavy body weight is a common practice, in order to prevent the occurrence of boar taint in pork. According to the report of the European Food Safety Authority prepared for the European Commission (EFSA, 2004), approximately 100 million pigs are castrated every year in the European Union (EU), representing more than 80% of the male pigs population. Surgery without anaesthesia is by far the most common castration procedure, but because it causes pain and distress (McGlone and Hellman, 1988) this practice is under social pressure in the EU to be significantly curtailed. Castration without anaesthesia has been banned in Norway and likewise will be banned in Switzerland in 2010 and is also coming under increasing scrutiny by the retail industry and regulatory authorities in the EU. Currently, legislation in the EU mandates that where castration is carried out after the seventh day of life, it must be performed under anaesthetic and additional analgesia by a veterinarian. Physical castration also adversely affects growth performance (Stamer *et al*., 1993; Walstra and Vermeer, 1993; Dunshea *et al*., 2001; Turkstra *et al*., 2002) increases the excretion of nitrogen and phosphate in the manure by affecting feed efficiency (Vermeer *et al*., 1992), and increases carcass deposition of fat impacting carcass quality (Campbell and Taverner, 1988).

Active immunization against gonadotropin-releasing hormone (GnRH) (also known as immunocastration) is viewed as one of the most promising alternatives to physical castration (Meloen *et al*., 1994; Hennessy *et al*., 1997; Oonk *et al*., 1998; Turkstra *et al*., 2002; Font i Furnols *et al*., 2007). Various alternative methods of castration were reviewed in the report of the EFSA (EFSA, 2004), including the local destruction of testicular tissue by chemical compounds (*e.g.* formaldehyde, acids and salts), down-regulation of the hypothalamic-pituitary-gonadal axis by the administration of exogenous hormones, and vaccination against GnRH. Vaccination was concluded to be very effective in inhibiting sexual development and reducing boar taint. Immunization against GnRH suppresses testicular activity by the stimulation of the antibodies against GnRH production, which is the hormone responsible for the testicular function in the hypothalamus. This results in reduced testicular size as well as decreased levels androstenone and testosterone (Dunshea *et al*., 2001; McCauley *et al*., 2003; Jaros *et al.,* 2005; Evans, 2006). Indeed, studies using boars that were immunized against GnRH demonstrated that fat concentrations of androstenone and skatole (both contributing to boar taint) were at the same levels as found in physical castrates, resulting in taint-free pork (Hennessy *et al*., 1997).

Immunisation against GnRH comprises two vaccinations with the second dose causing the desired physiological effects. The administration of the second dose is timed to occur in the late finishing phase in order to maximise the production benefits of raising entire boars and yet provide sufficient time for any boar taint compounds present in the body to be depleted. The objectives of this study were to assess the efficacy of vaccination against GnRH in allowing improved growth performance and carcass quality, in terms of fat deposition, in boars while controlling boar taint at slaughter. In the present study, the vaccination of boars was compared with physical castration, and also included comparisons against entire males and female pigs.

Material and methods

Animals, facilities and experimental design

Two hundred and eighty-eight piglets from 36 litters of [Large White (LW) × Landrace (LR)] × LW crossbred pigs were selected in the first week after birth. Litters were selected from multiparous sows (3rd to 6th parity),

Abbreviations used: ADFI (average daily feed intake), ADG (average daily gain), BW (body weight), EF (females), EM (entire males), FCR (feed conversion ratio), GnRH (gonadotropin-realeasing hormone), IM (males immunised against GnRH), LR (landrace), LW (Large White), PM (physically castrated males), SEM (standard error of mean).

and born in the same origin farm within 48 hours. During the first 3 days after birth, crossfostering took place in order to equalise experimental litters to 10 piglets. From each litter, six male and two female piglets were chosen. Of these, two males were physically castrated at 5 days after birth (PM), two males were vaccinated with Improvac® (Pfizer Animal Health) by subcutaneous injection in the neck at 74 and 145 days of age (IM), and the other two males were left entire (EM) in addition to the two females (EF). The six male piglets from each litter were randomly assigned to the treatment groups.

At 60 days of age, experimental pigs were transferred to the experimental farm, a finishing unit including one barn with two identical rooms, each containing 18 pens of 8 pigs each (0.70 m^2 per piglet). Environmental conditions during the trial (temperature and ventilation) were automatically controlled, according to the age of the animals. Piglets were allotted to experimental pens based on initial body weight (BW) and treatment (sex), resulting in 9 pens per treatment (72 pigs per treatment). Pigs were fed commercial, non medicated, barley-corn-wheat grower-finisher diets for *ad libitum* consumption. The diet specifications were 2,350 kcal net energy and 17% crude protein.

Measurements

Pen feed intake and individual BW were recorded from 74 to 172 days of age every two weeks. Average daily gain (ADG, g day^{-1}), average daily feed intake (ADFI, g day^{-1}), and feed conversion ratio (FCR, g g^{-1}) were calculated for two different subperiods, up to the second GnRH vaccination with Improvac® (74-145 days of age) and after then to slaughter weight (145-172 days of age), and also for the total experimental period (74-172 days of age).

When pigs reached an average BW of 112.5 ± 1.42 kg (179 days of age), 180 pigs (45 per treatment) with homogenous BW were chosen and slaughtered in a commercial slaughterhouse. At slaughter, the testes were removed from both entire and vaccinated boars, and individual testis weights were recorded and then averaged for each animal. Warm carcass weight was recorded and the lean meat percentage and the yield estimation in the primal cuts was measured using the Auto-FOM (SFK, Denmark). Backfat thickness and loin depth were measured with a Fat'O'Meat'er (SFK, Denmark) at 60 mm from the midline between the $3^{rd}/4^{th}$ last ribs. Lean meat in the carcass was estimated (Gispert and Diestre, 1994). Minimum subcutaneous fat + skin depths was measured over the *Gluteus medius* muscle (ham) by a ruler.

Subcutaneous fat at the level of $3^{rd}/4^{th}$ last ribs was sampled at about 45 min *post-mortem* to analyse the boar taint compounds androstenone and skatole. Samples were kept in a vacuum bag at –18°C until analysis. At this time, about 90 g of the *Gluteus medius* was also taken to analyse percentage of intramuscular fat using the NIT technology (Infratec, 1625, Tecator, Foss). Only total content of triglycerides in muscle was determined (Wood, 1990).

Skatole and androstenone levels in fat were measured following the methodology described by García-Regueiro and Rius (1998) and Rius *et al*. (2005).

The animal care and experimental procedure used in this study were in compliance with regulations and guidelines of the Spanish Royal Decree 223/88 (BOE 67: 8509-8511), regarding the protection of animals used for scientific research.

Statistical analysis

Statistical analysis was performed using the pen as experimental unit for production performance, and the animal as statistical unit for testis weight and carcass quality data. Data were analysed by the GLM procedure of SAS (SAS vers. 6.12, Cary, NC). Treatment (sex) was included in the model as main effect. In the case of production performance data, the initial BW was introduced as a covariate and all means were corrected by least squares according to initial weight. In the case of carcass data, the final BW was also introduced as a covariate.

Results

Production performance

Production performance results are shown in Table 1. In the first subperiod (74-145 days of age), PM showed worse FCR than the other groups ($P < 0.01$), due to higher ADFI ($P < 0.01$). No significant differences were observed in the ADG.

In the second subperiod (145-172 days of age), after the second Improvac® vaccine, ADG was lower in EF ($P < 0.001$), while no significant differences were ob-

Table 1. Growth performance of pigs in the experimental period[1]

Days of age		Entire male	Entire female	Castrated male	Immunocastrated male
74-145	ADG (g d^{-1})[2]	795 ± 22.4	776 ± 22.5	808 ± 22.6	809 ± 22.7
	ADFI (g d^{-1})[3]	1,854 ± 39.9^{b}	1,910 ± 39.9^{b}	2062 ± 40.1^{a}	1,935 ± 40.4^{b}
	FCR (g g^{-1})[4]	2.34 ± 0.04^{d}	2.46 ± 0.04^{bc}	2.56 ± 0.04^{a}	2.40 ± 0.04^{cd}
	ADG (g d^{-1})	904 ± 26.1^{a}	771 ± 26.1^{b}	879 ± 26.3^{a}	951 ± 26.4^{a}
145-172	ADFI (g d^{-1})	2,537 ± 75.9^{b}	2,490 ± 76.0^{b}	2,919 ± 76.4^{a}	2,935 ± 76.8^{a}
	FCR (g g^{-1})	2.82 ± 0.12^{b}	3.23 ± 0.12^{a}	3.33 ± 0.12^{a}	3.11 ± 0.12^{ab}
74-172	ADG (g d^{-1})	823 ± 18.5^{ab}	776 ± 18.5^{b}	824 ± 18.5^{ab}	845 ± 8.7^{a}
	ADFI (g d^{-1})	2,013 ± 37.6^{c}	2,052 ± 37.6^{bc}	2,253 ± 37.8^{a}	2,147 ± 38.0^{ab}
	FCR (g g^{-1})	2.45 ± 0.03^{d}	2.65 ± 0.03^{b}	2.74 ± 0.03^{a}	2.55 ± 0.03^{c}
	Final BW (kg)	107.2 ± 1.62^{ab}	103.7 ± 1.57^{b}	109.3 ± 1.69^{a}	111.7 ± 1.77^{a}

[1] Means ± SEM. Data were analyzed by analysis of variance. The model included the effect of sex as main effect. A total of 288 pigs, 72 per treatment were housed in 36 pens (8 pigs each; 9 pens per treatment). Pen of 8 pigs was the experimental unit for growth performance data. [2] ADG: Average daily gain. [3] ADFI: Average daily feed intake. [4] FCR: Feed conversion ratio (feed offered:gain). [abcd] Within a row, means without a common superscript letter differ significantly ($P < 0.05$).

served among the three groups of males (EM, PM and IM). However, differences among groups were observed in FCR ($P < 0.05$), being lower in EM than IM, and both lower than in PM and EF ($P < 0.05$). Consequently in the whole growing-finishing period PM and IM showed higher growth rate than EF ($P < 0.01$), while EM had an intermediate value. FCR differed among treatments; PM showed the highest FCR, followed by EF, IM and EM, with the latter having the lowest FCR.

Slaughter data

In Tables 2 and 3 results for carcass quality are presented. Despite no differences for carcass weight, carcass yield was higher in EF and PM pigs than in EM and IM ($P < 0.001$). For equal carcass weight, testes from EM were approximately double the weight of testes from IM ($P < 0.001$).

Body fat content and lean percentage also differed among sexes. Based on the Fat'O'Meat'er measurements, the subcutaneous fat thickness was higher in PM than in EM and EF with IM having intermediate values. For subcutaneous fat in the ham, PM showed significantly higher fat depths ($P < 0.05$) compared with IM and EM. No significant differences were observed in loin depth among sexes. The percentage of the estimated carcass lean showed the same tendency as the backfat (lower in PM than in EM and EF; $P < 0.001$, and intermediate for IM). PM also presented the lowest carcass lean percentage measured with AutoFOM ($P < 0.001$), while no differences were observed among the other groups. For the main primal cuts, EM had higher proportion of the ham, loin and shoulder than IM pigs and both EM and IM had higher proportion than PM. EF did not significantly differ from EM and IM pigs. Following the same tendency, PM showed a higher percentage of intramuscular fat than EM and EF ($P < 0.001$), while IM showed an inter-

Table 2. Carcass yield and weight of testes of experimental pigs at the slaughtering[1]

	Entire male	Entire female	Castrated male	Immunocastrated male
Carcass weight (kg)	85.37 ± 1.32	85.16 ± 1.27	86.54 ± 1.27	86.87 ± 1.30
Carcass yield (%)	76.05 ± 0.26^{b}	77.46 ± 0.25^{a}	76.98 ± 0.25^{a}	75.54 ± 0.26^{b}
Testes weight (g)	594.0 ± 16.06^{a}	—	—	259.4 ± 15.76^{b}
Testes/carcass weight (%)	0.70 ± 0.02^{a}	—	—	0.30 ± 0.02^{b}

[1] Means ± SEM. Data were analyzed by analysis of variance. The model included the sex as main effect. A total of 45 piglets per group of sex were slaughtered at 172 days of age. Pig was the experimental unit for slaughtering data. [abcd] Within a row, means without a common superscript letter differ significantly ($P < 0.001$).

Table 3. Subcutaneous fat thickness in the left ham, Fat'o'Meat'er and AutoFOM measures and percentage of intramuscular fat in the *Gluteus medium* in the different sexes[1]

	Entire male	Entire female	Castrated male	Immunocastrated male
Ham subcutaneous fat thickness (mm)	12.7 ± 0.56[c]	15.4 ± 0.54[ab]	16.7 ± 0.54[a]	14.4 ± 0.55[bc]
Fat'o'Meat'er measures:				
— Backfat thickness (mm)	16.2 ± 0.50[b]	16.6 ± 0.50[b]	19.3 ± 0.50[a]	17.6 ± 0.50[ab]
— Loin depth (mm)	53.3 ± 0.69	55.3 ± 0.69	54.6 ± 0.69	54.2 ± 0.69
— % lean	55.7 ± 0.44[a]	55.7 ± 0.44[a]	53.2 ± 0.44[b]	54.7 ± 0.44[ab]
AutoFOM measures (%):				
— Whole carcass	55.6 ± 0.43[a]	55.3 ± 0.43[a]	52.4 ± 0.41[b]	54.4 ± 0.45[a]
— Ham	68.8 ± 0.47[a]	68.3 ± 0.46[ab]	65.1 ± 0.45[c]	67.5 ± 0.48[b]
— Shoulder	62.9 ± 0.40[a]	62.4 ± 0.40[ab]	59.7 ± 0.38[c]	61.6 ± 0.41[b]
— Loin	56.4 ± 0.58[a]	55.6 ± 0.58[ab]	51.6 ± 0.56[c]	54.6 ± 0.61[b]
% intramuscular fat	1.6 ± 0.09[b]	1.5 ± 0.09[b]	2.1 ± 0.09[a]	1.9 ± 0.09[ab]

[1] Means ± SEM. Data were analyzed by analysis of variance. The model included the sex as main effect. [abc] Within a row, means without a common superscript letter differ significantly ($P < 0.001$).

mediate percentage ($P > 0.05$ comparing IM and the rest of groups).

Boar taint

Data on levels of the boar taint compounds androstenone and skatole in subcutaneous fat are provided in Table 4. Entire males had fat androstenone levels greater ($P < 0.001$) than those of IM, which were not different ($P > 0.10$) from PM and EF. Similarly, skatole levels were also low in all groups and all below the commonly accepted consumer sensory threshold of 0.2 μg g^{-1}, while EM had levels nearly twice those of IM ($P < 0.001$). There were no differences in skatole levels between IM, PM and EF.

Discussion

One of the main aims of this study was to ensure that zootechnical performance was not compromised by GnRH vaccination. In the overall fattening period, IM showed similar ADG to both EM and PM. However, voluntary feed intake did not differ between IM and PM, both being higher than that of EM. Consequently, FCR was lower in EM than in PM pigs, while IM pigs were intermediate. It is well known that physical castrates eat more than boars (Campbell and Taverner, 1988), and this is probably attributed to effects of testosterone and other testicular or sex hormones. Wild boars apparently refuse food when testosterone concentrations are at their seasonal peak (Weiler *et al.*, 1996). Therefore, reduction in testosterone may account for the increased feed intake that occurs after vaccination against GnRH with Improvac. Increase in feed intake might be due to direct effect of testosterone on satiety, less time involved in sexual or aggressive activities that detract from time spent eating, or more energy directed toward carcass growth rather than into these unproductive activities. Therefore, the improved growth performance of IM compared with EM results partially from reduced sexual and aggressive activities and less stress during the last weeks before slaughter.

Table 4. Effect of sex and Improvac vaccine on fat skatole and androstenone concentrations at slaughter[1]

	Entire male	Entire female	Castrated male	Immunocastrated male
Fat skatole, μg g^{-1}	0.05 ± 0.004[a]	0.02 ± 0.004[b]	0.02 ± 0.004[b]	0.03 ± 0.004[b]
Fat androstenone, μg g^{-1}	0.2 ± 0.10	ND	ND	ND

[1] Means ± SEM. Data were analyzed by analysis of variance. Sex was included in the model as main effect. [ab] Within a row, means without a common superscript letter differ significantly ($P < 0.001$). ND: not detected. The detection limit of the method was 0.02 μg g^{-1}.

This improvement was numerical in the present experiment and did not reach significance except for ADFI following the second vaccination, but other studies did demonstrate this effect (Dunshea *et al*., 2001).

Conversely, as expected, FCR of PM was higher (less efficient) than for EM, while the IM were intermediate. Therefore, vaccination against GnRH compared with physical castration allowed an improvement of 7% in overall FCR. These results are consistent with results found by other authors with GnRH vaccines (Dunshea *et al*., 2001; Oliver *et al*., 2003), who also observed a FCR for IM in between EM and PM. Furthermore, comparing with the IM group, EF showed lower ADG and higher FCR, indicating that different feeding programs might be considered for both, as in the case of PM.

As expected, PM showed higher fat content than EM (higher backfat thickness, low percentage of lean and higher percentage of intramuscular fat). This result is well known and reported in bibliography by several authors (Walstra, 1977; Zeng *et al*., 2002), and it is mainly attributed to higher voluntary feed intake of PM compared with EM. In this regard, in the experiment of Turkstra *et al*. (2002) the feed intake of pigs was restricted and they did not show a difference in fat deposition between PM and EM. IM showed, in general, higher fat content (backfat thickness or percentage of intramuscular fat) than for EM and lower than for PM.

Anti-GnRH immunization inhibited testes growth in IM to about 55% of that found for EM, as has been reported by other authors (Meloen *et al*., 1994; Dunshea *et al*., 2001; Zeng *et al*., 2002). The difference in testis size between EM and IM pigs was also visible by the outside appearance of the scrotum. IM exhibited a flat scrotal sac, while the scrotum of EM had a bulbous appearance. Thus IM could be distinguished from EM by the size of the testes and the appearance of the scrota.

According to previous studies with Improvac, anti-GnRH vaccination is very efficient in controlling boar taint (Dunshea *et al*., 2001). In the present experiment, all pigs showed low concentrations of compounds associated with boar-taint, skatole and androstenone. In fact, most of the pigs showed concentrations of both compounds lower than those commonly accepted as the consumer threshold concentrations, 1.0 and 0.2 μg g^{-1} fat for androstenone and skatole, respectively (Desmoulin and Bonneau, 1982; Bonneau *et al*., 1992). A large multisite European study demonstrated that both androstenone and skatole have negative effects on consumer perception of pork quality, although there are clearly differences between men and women. Sensitivity to perceive boar taint also appears to differs among people from different regions (Bonneau *et al*., 2000a; Matthews *et al*., 2000; Weiler *et al*., 2000). Although the authors stated that it was not possible to determine threshold values, they presented regression equations to predict consumer dissatisfaction (Matthews *et al*., 2000). Their model predicts that the adoption of threshold values of 1.0 and 0.20 μg g^{-1} fat for androstenone and skatole, respectively, would essentially halve the differences in dissatisfaction (Bonneau *et al*., 2000b). Based on these values, in the current study only one EM would have been rejected by the consumer due to high skatole content (0.26 μg g^{-1} fat). The rest of the pigs had concentrations lower than the threshold values proposed. In any case, vaccination was effective in reducing the concentrations of both androstenone and skatole, being much lower than those found in EM and not differing from PM and EF.

As final implications: i) under the conditions of this study, vaccination against GnRH, besides being a friendly pig production alternative to physical castration also allows improved feed conversion ratios; ii) under the conditions of this study, vaccination against GnRH also reduces skatole and androstenone concentrations, not affecting intramuscular fat, and with low impact of lean percentage compared with entire males; iii) the current study demonstrates that the performance of boars that were immunised against GnRH could be a practical and effective alternative to physical castration of pigs.

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