

CASTRATION IN THE SWINE INDUSTRY AND THE IMPACT ON GROWTH PERFORMANCE – PHYSICAL VERSUS VACCINATION

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ABSTRACT

In most parts of the world, male pigs that are destined for the market are physically castrated very soon after birth in order to reduce the risk of boar taint. However, entire male pigs are more efficient and deposit less fat than barrows, particularly at high slaughter weights. Also, animal welfare activists are lobbying for a cessation of physical castration in many parts of the world, particularly the EU, with a high likelihood that this could lead to inferior pork and processed products. A welfare friendly alternative is vaccination against gonadotrophin releasing factor (GnRF) which allows producers to capitalise on the superior natural growth and carcass characteristics of intact boars without the risk of boar taint. Vaccination against GnRF results in superior feed efficiency and carcass lean yield over physical castration, while maintaining pork eating quality. There have been very few studies that have compared the lysine requirements of boars and barrows, and none with contemporary genotypes. Recent data suggests that the lysine requirement of boars is slightly higher (ca. 0.6 to 0.9 g/kg) than for gilts and barrows. Given that the penalty in growth performance for having inadequate dietary lysine is greater in boars than in gilts or barrows, it is important to ensure that dietary lysine requirements are met to obtain the maximum benefits of boar production coupled with vaccination against GnRF.

INTRODUCTION

The castration of male domestic animals of most species, with the exception of breeding stock, has been practiced for centuries. Traditionally, the major reasons for castration were to control the reproductive state of contemporary females (as often male and female animals were grazed or housed together), to take advantage of the propensity for castrate animals to fatten (fat is (was) highly valued in some cultures) and to reduce the incidence of rutting and aggressive behaviours often observed in entire animals.

Another issue, which is particularly pertinent to pork production, is that non-castrated male pigs (boars) may exhibit flavours and odours, collectively called boar taint, that are offensive to many consumers. During sexual development and when mature, boars accumulate substances, predominantly androstenone and skatole, in their fatty tissue that are regarded as the main contributors to this boar taint in pork (Bonneau, 1982). To avoid tainting of the meat, boars destined for fresh meat consumption in Australia, New Zealand, the UK and South Africa have, until recent years, been slaughtered before full sexual maturity. For example, in the UK it is stipulated that weight of carcasses utilized for fresh pork production must be less than 85 kg (MLC, 2003). In other countries (Asia, North America, much of the EU) taint has been

overcome by physical castration of the boar before weaning. For example, in the EU approximately 100 million male pigs are physically castrated every year, representing 80% of the male population (EFSA 2004). However, physical castration results in significant reductions in growth performance and excess deposition of fat (Campbell and Taverner, 1988; Dunshea et al. 1993; 1998; 2001, Suster et al., 2006). In many markets there is a penalty for having over fat pigs as consumers and processors alike are demanding leaner and generally heavier pigs. For example, over recent years, the average weight of pigs at slaughter in most countries has increased, driven by the efficiencies associated with the slaughter of heavier pigs (MLC, 2003). While genetic selection has meant that carcass fatness is continually being reduced, the upward pressure on slaughter weights has placed a conflicting pressure on carcass fatness. This is particularly so for physically castrated male pigs (barrows) that have a declining rate of lean tissue deposition during the late finishing phase (Suster et al., 2006).

INCENTIVES FOR UTILIZING BOARS IN A PORK PRODUCTION SYSTEM

The potential lean tissue growth and efficiency of weight and lean tissue gain are greater in boars than in barrows, prompting the cessation of castration 30 years ago in some markets, particularly those that are focused on lean meat production. Some of these differences in tissue nutrient partitioning rates were elegantly demonstrated in a recent study designed to investigate the interactions between housing and sex in contemporary genotypes (Suster et al., 2006). Suster et al. (2006) found that under group-housed conditions there was very little difference between boars and barrows in daily gain and lean tissue content until 122 d of age (ca. 77 kg). Beyond 17 weeks of age, the barrows grew faster than the boars but deposited less lean tissue and more fat. Thus, at 154 d of age the boars weighed 5 kg less than the barrows (103 vs. 108 kg) but contained 3 kg more lean tissue (69.1 vs 66.2 kg), almost 6 kg less fat (18.2 vs 23.8 kg) and 2 mm less P2 back fat (15.1 vs 17.1 mm). In pigs raised in ideal conditions, including individual penning, the differences were even more profound in favour of boars (112 vs 113 kg liveweight; 73.1 vs 66.8 kg lean tissue; 20.6 vs 27.1 kg fat; 15.9 vs 20.6 mm P2 back fat). Also, over the finisher phase the feed conversion ratio (FCR) was 13% higher in barrows than in boars (3.50 v. 3.10). These data for efficiency and P2 back-fat were very similar to that observed elsewhere (Dunshea et al., 1993; 2001). Indeed, a meta-analysis of up to 10 studies conducted with group-housed pigs shows that physical castration increases feed intake (+467 g/d, $P<0.001$), FCR (+0.48, $P<0.001$) and back fat (+4.9 mm, $P<0.001$) with modest increases in growth rate (+31 g/d, $P=0.011$) and carcass weight (+2.1 kg, $P<0.001$) over the finisher phase compared to entire boars (Table 1). While the differences in feed efficiency have been extensively chronicled during the finishing phase where they are most pronounced because of the decline in lean tissue deposition in the barrows, boars are actually more feed efficient and leaner than barrows throughout the entire post-weaning growth phase (Campbell and Taverner, 1988; Hennessy et al., 2009).

The relative efficiencies associated with boar and barrow production systems have been well summarized by the MLC in the UK (MLC, 2003). In this work, the MLC commissioned a desktop study to investigate the efficiencies associated with producing heavier pigs and found that 10% increase in slaughter weight would reduce the cost of production by € 0.05/kg. Based on slaughter weights of 108 and 130 kg for boars and barrows respectively, it was estimated that

the cost of production of boars was € 0.05 greater per kg carcass weight but € 0.17 less per kg of lean tissue. However, in this model the slaughter weight of the boars was limited to 108 kg to ensure that all carcasses were below 85 kg and so could enter the fresh pork market. Commercial pork producers should consider increasing pig slaughter weights as a means of lowering unit costs during both production and processing stages (King et al., 2000) but obviously cannot if legislation does not allow it or if meat quality is likely to be compromised. If the carcasses could be guaranteed to be free of boar taint, using a technology such as vaccination against GnRF, allowing boars to be safely slaughtered at 130 kg, then the cost of production of boars would be less than barrows on both a carcass weight and lean tissue basis.

Table 1. Average fixed effects of physical castration (barrows – boars) from meta-analyses of data from studies with group-housed pigs^a.

	Effect	sed	95% CI	P-value	# studies
ADG (g/d)	-31	15.5	(-61.4, -0.6)	0.011	8
ADFI (g/d)	-467	30.9	(-531, -40)	<0.001	7
FCR	-0.48	0.030	(-0.54, -0.42)	<0.001	7
Carcass weight (kg)	-2.14	0.656	(3.43, -0.86)	<0.001	10
Back fat (mm)	-4.9	0.29	(-5.1, -3.9)	<0.001	10

^a Analyses only included data from studies where data were collected over a nominal finisher phase.

CONSTRAINTS TO UTILIZING BOARS IN A PORK PRODUCTION SYSTEM

The major reason why male pigs are still castrated in much of the world is because of the issue of boar taint. The principal compounds contributing to taint in boars are androstenone and skatole, which are found at much higher levels in the carcasses from boars than from either gilts or barrows. As mentioned above, one approach to reduce boar taint, apart from physical castration, is to slaughter boars at light weights before they have reached sexual maturity. However, this runs counter to the desire to increase slaughter weights as a means of lowering unit costs during both production and processing stages. In the UK it is stipulated that weight of carcasses utilized for fresh pork production must be less than 85 kg (MLC, 2003). The European Community legislation (Directive 64/433/ EEC) decrees that carcasses from boars that are over 80 kg may only be allowed to be used for human consumption provided they are processed (used in smallgoods) or tested for taint. However, processing does not necessarily eliminate boar taint (McCauley et al., 1997). Pigs with the steroidogenic capacity to produce high concentrations of testosterone also have the potential to produce androstenone, and hence to have detectable levels of taint in the carcass. A survey of Australian and New Zealand boars revealed high concentrations of both androstenone and skatole in boars as light as 85 kg live-weight (Hennessy et al., 1997). Therefore, although slaughtering boars at lower weights may reduce the incidence of boar taint, it will not guarantee meat free from boar taint. Thus, boar taint remains the major impediment to the utilization of boars in a pork production system.

While it is accepted that boars are leaner and more efficient than barrows, the growth performance of boars in groups under commercial conditions is generally less than that of

individually-housed boars (McCauley et al., 2000; Suster et al., 2006) suggesting that the putative benefits may not be as marked as assumed when pigs are housed under commercial conditions. Furthermore, during the late finishing phase, group-housed entire males often grow at a similar or slower rate than barrows (De Haer and de Vries, 1993; Dunshea et al., 2001; Suster et al., 2006), possibly because of increased sexual and aggressive activities between entire males. From the peri-pubertal period onwards boars exhibit negative aggressive and sexual behaviours that can detract from feeding (Cronin et al., 2003). For example, Cronin et al. (2003) found that at 21 weeks of age, boars had more aggressive behaviours (27.9 vs 9.5 bouts/pig/d) and sexual activity (7.2 vs 0.1 mounts/pig/d) than barrows resulting in less time spent eating (5.3 vs 7.2% of time) and lower feed intake (2.69 vs 2.90 kg/d). These negative behaviours and reduced feed intake are major reasons why boars do not perform as close to their potential as barrows do when housed under commercial conditions (Suster et al., 2006). Also, the negative behaviours that occur with mixing of boars around slaughter causes carcass damage and reduced meat quality (Dunshea et al., 2009; Lealiifano et al., 2009).

THE ALTERNATIVE TO PHYSICAL CASTRATION – VACCINATION AGAINST GONADOTROPHIN RELEASING FACTOR (GNRF)

Growth and Behavioural Responses

An alternative method of inhibiting sexual development and aggressive behaviours and reducing the accumulation of boar taint compounds in carcass fat, is immunization against GnRF resulting in a reduction in plasma gonadotropins and testosterone (Bonneau et al., 1994; Dunshea et al., 2001; McCauley et al., 2003; Oliver et al., 2003; Nghia et al., 2008). Recently, a vaccine containing a modified form of GnRF in a low reactogenic adjuvant system has been developed to reduce the production and accumulation of both androstenone and skatole in pig carcasses (Dunshea et al., 2001). The vaccine formulation and dosage regimen allows pigs to be immunised relatively close to slaughter. Any taint substances already present are progressively metabolized, allowing the entire boar to be slaughtered at a higher live-weight without taint, having earlier benefited from the effects of its own testicular steroids on growth and carcass composition (Dunshea et al., 2001). The decrease in testosterone appears to also have some additional effects on sexual, aggressive and feeding activity (Cronin et al., 2003) with resultant positive effects on growth performance. Thus, vaccinated boars grow faster than non-vaccinated boars and at a similar rate to the barrows but with a similar FCR as the boars. Back fat depth was intermediate between the boars and the barrows.

The reduction in testosterone as a result of vaccination against GnRF has a profound effect upon behaviour. Cronin et al., (2003) found that there was a reduction in both aggressive and sexual activities in vaccinated boars who exhibited similar activities as barrows (Table 2). As a consequence the vaccinated pigs increased the amount of time they spent eating and their feed intake. Another indicator of reduced negative activities was the reduction in lesion scores in vaccinated pigs observed upon mixing in lairage (McCauley et al., 2001; Table 2). While comparison with individually-housed contemporary boars clearly showed that the growth performance of the group-housed boars was well below their potential during the finisher phase, vaccination against GnRF provided a means of ameliorating this reduction in performance

(Dunshea et al., 2000). Indeed, the growth rate of group-housed vaccinated boars and individually-housed entire boars were identical over the 5 week period after secondary vaccination (1090 vs 1099 g/d), being approximately 20 and 15% higher than the group-housed entire boars and barrows, respectively. Importantly, the variation in growth performance was also less, which makes nutritional and sales management easier (Dunshea et al., 2009). There are now a number of studies conducted with anti-GnRF vaccination across the globe and these have been incorporated into a series of meta-analyses. These analyses of up to 16 studies show that vaccination against GnRF increases feed intake (+512 g/d, P<0.001), ADG (+149 g/d, P<0.001) and carcass weight (+1.5 kg, P<0.001) over that of boars, with only small increases in FCR (+0.07, P<0.001) and back fat (+1.2 mm, P<0.001) (Table 3). The small increases in FCR appear to occur in smaller group sizes where negative activities may not be as great as in larger groups. Therefore, the increased growth rate and carcass weight of boars vaccinated against GnRF, combined with assurances of high quality pork free of boar taint, provide real incentives in markets where physical castration is not normally practiced. This becomes even more appealing in countries where metabolic modifiers such as porcine somatotropin (pST) or ractopamine are approved to ensure that additional feed consumed in the late finishing period is converted into lean meat (see below).

Table 2. Behavioural traits of boars, barrows and boars vaccinated against GnRF at 21 weeks of age (data are from Cronin et al., 2003 and McCauley et al., 2001).

	Boar (B)	Barrow (Ba)	Vaccinate (V)	Δ B-V	Δ Ba-V
Aggressive bouts/pig/d	27.9	9.5	9.5	18.4	0.0
Mounts/pig/d	7.2	0.1	0.6	6.6	-0.5
Time feeding, %	5.3	7.2	7.7	-2.4	-0.5
Feed intake ^a , kg/d	2.69	2.9	3.32	-0.6	-0.4
Fighting lesion scores ^b	1.01	0.26	0.30	0.7	0.0

^a Determined over the last 4 weeks prior to slaughter.

^b Fighting lesion scores on a 4 point scale from 0 to 3 with 0 having no lesions and 3 severe number of lesions with carcass condemnation.

Table 3. Average fixed effects of vaccination against GnRF (vaccinates – boars) from meta-analyses of data from studies with group-housed pigs^a.

	Effect	sed	95% CI	P-value	# studies
ADG (g/d)	149	18.4	(113, 179)	<0.001	14
ADFI (g/d)	512	30.9	(469, 565)	<0.001	10
FCR	0.07	0.054	(-0.04, 0.18)	<0.001	10
Carcass weight (kg)	1.48	0.412	(0.67, 2.29)	<0.001	16
Back fat (mm)	1.2	0.17	(0.9, 1.6)	<0.001	16

^a Analyses only included data from studies where animals slaughtered between 4 and 5 weeks after the secondary vaccination.

^b Determined over the period between the secondary vaccination and slaughter.

The incentives for vaccinating against GnRF in markets where physical castration is practiced are even more compelling. There are now a number of studies comparing the finishing performance and carcass quality of vaccinated boars and barrows and these have been incorporated into a series of meta-analyses. These analyses of up to 11 studies show that vaccination against GnRF increased ADG (+173 g/d, P<0.001) and reduced FCR (-0.33, P<0.001) and back fat (-3.4 mm, P<0.001) with a small increase in ADFI (+115 g/d, P=0.004) and a small decrease in carcass weight (-1.16 kg, P=0.015) (Table 4). The large decrease in back fat combined with only a small decrease in carcass weight indicate a substantial increase in lean meat yield in the vaccinated pigs. McKeith et al. (2009) summarized 30 studies (internally- and externally-sponsored) and found that the average un-weighted carcass back fat, loin eye area and lean tissue in were -10.2, +1.7 and +4.6%. Also, it should be borne in mind that the improvements in FCR are cumulative across the entire grower/finisher period (Hennessy et al., 2009; Hanchun et al., 2009). For example, Hanchun et al. (2009) found that feed efficiency was improved by 6.5% from weaning to slaughter in vaccinated pigs compared to barrows.

Table 4. Average fixed effects of vaccination against GnRF (vaccinates – barrows) from meta-analyses of data from studies with group-housed pigs^a.

	Effect	sed	95% CI	P-value	# studies
ADG (g/d)	173	15.6	(142, 204)	<0.001	8
ADFI (g/d)	115	46.9	(23, 209)	0.004	5
FCR	-0.33	0.030	(-0.39, -0.27)	<0.001	8
Carcass weight (kg)	-1.16	0.616	(-2.37, 0.05)	0.015	11
Back fat (mm)	-4.9	0.29	(-5.1, -3.9)	<0.001	10

^a Analyses only included data from studies where animals slaughtered between 4 and 5 weeks after the secondary vaccination.

^b Determined over the period between the secondary vaccination and slaughter.

Antibody, Endocrinal and Metabolic Responses

Antibody titres to GnRF peak a week after vaccination and gradually decline over the next 8 weeks (Claus et al., 2007; Bauer et al., 2008; Dunshea et al., 2008). The intensive bleeding studies of Claus et al. (2007) and Bauer et al. (2008) show that plasma androstenone, testosterone and LH had all reached a nadir 6-10 days after the second vaccination. Plasma urea nitrogen (PUN), an accurate proxy for excess amino acid catabolism (Dunshea, 2002), was found to be increased at 14 and 28 days after vaccination against GnRF (McCauley et al., 2003) as a result of either increased protein intake, decreased lean tissue deposition or both. Temporal studies (Claus et al., 2007; Bauer et al., 2008) indicate that PUN begins to increase within the first few days after vaccination, certainly before any increase in feed intake, suggesting that changes in protein metabolism occur very quickly. Indeed, when feed intake was restricted to either 2 or 3 kg there was a rapid increase in PUN between 8 and 10 days after the second vaccination (Bauer et al., 2008). Plasma IGF-I, which has been shown to be positively related to previous growth rate, decreased more gradually and did not reach a plateau until beyond 14 days after the second vaccination (Claus et al., 2007; Bauer et al., 2008). Plasma leptin concentrations were increased at 14 and 28 days after vaccination against GnRF (McCauley et al., 2003), possibly in response to increased feed intake and fat deposition that occurs around this time. However, there are no

data investigating the temporal pattern of plasma leptin in the immediate period after vaccination. These data suggest that boars that are vaccinated against GnRF have reduced steroidogenic capacity very soon after the second vaccination with the accompanying effects on muscle and fat metabolism and feed intake occurring very soon after. The effects on steroidogenic capacity seem to be still at least 8 weeks after secondary vaccination even though antibody titres decrease by 6 to 8 weeks post-vaccination (Dunshea et al., 2008).

Androstenone and skatole are both fat soluble and highly labile and freely exchange between adipose tissue and plasma. Therefore, reductions in plasma androstenone and skatole should theoretically precede reductions in the concentrations of these compounds in adipose tissue. Dunshea et al. (2008) found that vaccination decreased adipose tissue androstenone over the first 2 weeks (0.40 v. 0.17 $\mu\text{g/g}$, $P<0.01$) after the second vaccination and it remained lower until at least 8 weeks (1.12 v. 0.14 $\mu\text{g/g}$, $P<0.01$). On the other hand, adipose tissue skatole was not decreased at 2 weeks after the second vaccination but was at 4, 6 and 8 ($P<0.05$) weeks (Dunshea et al., 2008). In another study, Dunshea et al. (2009) found that adipose tissue skatole concentrations were decreased by 17 days after the secondary vaccination and continued to decline until at least 28 days after the vaccination. Also, Lealiifano et al. (2009) found that adipose tissue androstenone was decreased at 2 weeks after secondary vaccination and remained low until at least 6 weeks after injection. Adipose skatole was very low in the control boars and so there was no significant difference between samples taken at 0, 2, 3, 4 and 6 weeks after secondary vaccination. However, the pooled adipose tissue skatole concentrations from 2, 3, 4 and 6 weeks after secondary vaccination were lower ($P<0.05$) than those obtained from pigs that did not receive a secondary vaccination. Thus, it appears that vaccination against GnRF decreases boar taint compounds and improves carcass weight for between 4 and at least 8 weeks after the secondary vaccination. If the major source of boar taint is androstenone then pigs may be slaughtered as early as 2 weeks after the secondary vaccination. However, in markets where skatole is an issue, further work is required to describe the temporal pattern of adipose tissue skatole.

Managing Vaccinated Boars

Despite the rapid antibody, endocrinal and metabolic responses to vaccination against GnRF, the effects on feed intake, growth and body composition do not become apparent until beyond 2 weeks after the secondary vaccination (McCauley et al., 2003; Oliver et al., 2003; Claus et al., 2007; Lealiifano et al., 2009). As adipose tissue androstenone is decreased by 2 weeks after the secondary vaccination, it should be possible to slaughter vaccinated boars at 2 week post secondary vaccination without any increase in back fat over that of the boars and with the surety that the boars taint compounds have been cleared from the carcass fat (Dunshea et al., 2008; Lealiifano et al., 2009). However, in practice most producers slaughter at 4 to 6 weeks after the secondary vaccination to be certain that all boar taint compounds have been cleared although this may be associated with some small increases in carcass fatness. In many markets the increase in fatness is not an issue and may really be desirable especially since it may be associated with an increase in intramuscular fat (D'Souza et al., 2000). These markets will be also those that can make use of the increase in carcass weight and indeed may wish to extend the slaughter age out to 8 weeks after vaccination to maximise carcass weight without compromising boar taint compounds (Dunshea et al., 2008). There needs to be research aimed at investigating the way in

which the additional energy consumed by vaccinated boars can be converted to carcass and/or carcass lean to maximise the profitability in various markets. These strategies will clearly not be the same in all markets.

In an attempt to reduce the effect of the increase in feed intake on back-fat after vaccination against GnRF, recent studies were conducted to investigate the interactions between vaccination against GnRF and ractopamine (Rikard-Bell et al., 2009; Moore et al., 2009). Ractopamine is currently registered in the USA and many other countries, but not the EU, for use as an in-feed metabolic modifier. Dietary ractopamine increased lean tissue and decreased fat mass, particularly in vaccinated boars (Rikard-Bell et al., 2009; Moore et al., 2009a). Therefore, dietary ractopamine may be a means of ensuring that the increased feed intake observed in vaccinated boars is directed towards lean tissue rather than fat over the last few weeks before slaughter. Similar synergies have been seen between vaccination against GnRF and pST treatment (McCauley et al., 2003; Oliver et al., 2003) although pST is unavailable in many markets.

Nutrition of Boars and Vaccinated Boars

In any production system it is important to pay attention to nutrition, particularly dietary protein and lysine. In order to model and estimate nutrient requirements in response to any management strategy, it is necessary to have accurate data on tissue deposition rates, maintenance requirements and feed intake (Schinckel and de Lange, 1996) and we know that vaccination against GnRF has the potential to impact on all of these parameters. To date, there have been no published studies conducted to investigate the effect of vaccination against GnRF on lysine requirements although it is realistic to assume that up until at least 2 weeks after the secondary vaccination their nutrient requirements should be similar to that of the boar since both lean tissue gain and feed intake are similar until 2 weeks after vaccination (Dunshea et al., 2008). Indeed, the rate of lean tissue deposition of vaccinated boars appears to be maintained (Oliver et al., 2003; Dunshea et al., 2008; Moore et al., 2009) or decreased only slightly (McCauley et al., 2003; Rikard-Bell et al., 2009) compared to that of entire boars until approximately 4 weeks after the secondary vaccinations. This would suggest a similar requirement for total available lysine intake, although it should be noted that feed intake is universally increased beyond 2 weeks after secondary vaccination and therefore the lysine content of the diet could likely be reduced beyond this point. Also, the PUN responses suggest that there is excess protein (lysine) by 2 weeks after the secondary vaccine (McCauley et al., 2003; Claus et al., 2007; Bauer et al., 2008) which indicates that lean tissue deposition is reduced relative to boars at this time. While there are no tissue deposition rate data beyond 4 weeks after secondary vaccination, it is likely that lean tissue would decrease and fat deposition increase relative to boars. It is important that the temporal pattern of tissue deposition rates and feed intake be further explored to be incorporated into models to predict nutrient requirements over this period of rapidly changing metabolism.

There are also very few data comparing the lysine requirements of boars and barrows, particularly in contemporary improved genotypes. Given that the lysine requirements of gilts are generally considered to be similar or slightly higher to that of barrows (NRC, 1998) and that there have been a number of studies comparing the lysine requirement of boars and gilts, it is realistic to use the gilt requirements as a reference point. During the early 1980's, a number of studies were conducted that suggested that the protein deposition potential and lysine

requirements of grower boars (up to 60 kg) was slightly higher than that of gilts (Batterham et al., 1985; Giles et al., 1986). However, more recent studies suggest that, although the protein deposition and growth potential of boars is greater than that of gilts, there is little difference in the lysine requirements of grower and finisher boars and gilts (King et al., 2000; O'Connell et al., 2005;2006). For example, King et al. (2000) found that there was no difference in the lysine requirement to maximise protein deposition and feed efficiency in heavy (80 to 120 kg) finisher boars and gilts. O'Connell et al. (2005) found that, in three studies in grower boars and gilts (20 to 68 kg), there were no differences in the lysine requirements to maximise growth and feed efficiency. In heavier pigs (60 to 100 kg), these authors found lysine requirements were slightly higher in boars than in gilts in one study but not in two others (O'Connell et al., 2006). In the most recent study conducted with high-performing grower pigs, it was found that the lysine requirement of boars was higher than that of gilts (Moore et al., 2009b). The studies that have shown no difference in lysine requirement have often been conducted with individually-penned pigs where the full feed intake potential can be expressed and often in these cases boars consume more feed than gilts (Dunshea et al., 1998; King et al., 2004). However, in commercial conditions *ad libitum* feed intake of boars is well below (ca. 70%) that which is seen under ideal conditions (Dunshea et al., 2000) and slightly less than gilts (Dunshea, 2005) and this may be where the differences in lysine requirement between boars and gilts may be exhibited. Therefore, it appears that despite large differences in protein deposition rates between the sexes, boars have similar, or slightly higher, dietary lysine requirements, suggesting that boars use dietary lysine more efficiently than do gilts and barrows. Very recently, Quiniou et al. (2010) characterized the growth performance and feed intake patterns of gilts, boars and barrows and, according to simulations performed with the InraPorc software, the digestible lysine requirement was on average 0.1 g/MJ net energy higher for boars than for gilts and barrows.

In an effort to clarify the situation, the published data where lysine requirements of boars and gilts have simultaneously been determined were subject to a meta-analysis and the overall effect was that boars require a slightly (ca. +6%) higher dietary lysine content than gilts (10.9 vs. 10.3 g lysine/kg, $P < 0.001$). A multi-regression analysis of lysine requirement indicates that lysine requirement decreases with live weight (-0.076 g lysine/kg per kg), is greater for boars than for gilts (+0.88 g lysine/kg), and has increased over time (0.16 g/kg per year). It should also be noted that since the slopes of the lysine dose response curves are greater in boars than in gilts, the penalty in growth performance for having inadequate dietary lysine will be greater in the former. Also, the requirements of both boars and gilts estimated in this manner are greater at any live weight than those suggested by the NRC (1998). In part, this may reflect the fact that much of the data used to generate the NRC (1998) requirements were obtained some time ago and there has been steady improvement in lean tissue potential. An additional consideration when estimating lysine requirements of vaccinated is that because feed intake increases markedly over the period beyond 2 weeks after the secondary immunization, it may be possible to decrease both the lysine and energy contents of the diets or restrict feed beyond this point. Alternatively, growth modifiers such as ractopamine (Rikard-Bell et al., 2009; Moore et al., 2009a) or pST (McCauley et al., 2003; Oliver et al., 2003) may be used in some markets. In many production systems, the ability to change diets at this point is limited. However, another strategy may be to have a diet change and introduce a metabolic modifier for the final 2-3 weeks before slaughter.

CONCLUSIONS

Boars are more efficient and deposit less fat than barrows, particularly at high slaughter weights. However, the risk of boar taint in peri-pubertal boars has resulted in legislation or recommendations in some countries that boars are slaughtered before they reach 85 kg carcass weight. Animal welfare activists are lobbying for a cessation of castration in many parts of the world, particularly the EU. However, this could result in inferior pork products being placed in the market. A welfare friendly alternative is vaccination against GnRF which allows producers to capitalise on the superior natural growth and carcass characteristics of intact male pigs without the risk of boar taint. Recent data suggests that the lysine requirement of boars is slightly higher (ca. 0.6 to 0.9 g/kg) than for gilts but it is important that this is verified and quantified. Given that the penalty in growth performance for having inadequate dietary lysine is greater in boars than in gilts, it is important to ensure that dietary lysine requirements are met to obtain the maximum benefits of boar production, coupled with vaccination against GnRF. Also, it is important that the temporal pattern of tissue deposition rates and feed intake be further explored to be incorporated into models to predict nutrient requirements over this period of rapidly changing metabolism. This will be important to ensure that the benefits of vaccination against GnRF can be optimised in all the markets where it will be available.

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