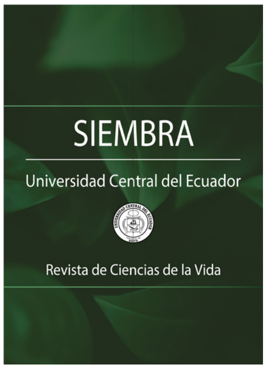
Review Article

Meta-analysis of the effect of the use of anti-GnRH vaccine on productive performance and carcass quality in pigs



Meta-análisis del efecto del uso de la vacuna anti-GnRH sobre el rendimiento productivo y la calidad de canal en porcinos

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Abstract

Surgical castration has been a common practice in pigs to prevent boar taint; however, it affects animal welfare. Immunocastration has been used as an alternative approach; it involves the administration of a vaccine that stimulates the production of antibodies directed against the GnRH hormone. This induces a temporary inhibition of testicular function accompanied by the release of steroids known to generate the characteristic boar taint odor. Substantial published information documents the utilization of this intervention, yielding variable outcomes for productive performance. The present study was conducted to evaluate the effect of the application of the anti-GnRH vaccine on productive performance and carcass quality in pigs. Sixteen meta-analyses were performed to determine the effect size, with two types of control groups (castrated and entire males), from 45 scientific articles (3,685 repetitions) under a random effects model. Results show that the utilization of the anti-GnRH vaccine significantly improved daily feed intake [DFI] (-78.78 g day^{-1}, $p = 0.00028$), feed conversion [FC] (-168.54 g kg^{-1}, $p < 0.00001$), feed efficiency [FE] (+35.58 g kg^{-1}, $p < 0.00001$) and lean percentage (+1.3%, $p < 0.00001$), in comparison with surgically castrated males. Control non-castrated pigs presented superior outcomes for all variables analyzed, except for daily weight gain (+32.67 g day^{-1}, $p = 0.00005$), which was favored by the use of the vaccine. It is concluded that the use of the anti-GnRH vaccine favors productive performance (DFI, FC and FE) compared to surgically castrated pigs, but not versus entire pigs.

Keywords: Vaccination, castration, pigs, boar taint.

Resumen

La castración quirúrgica ha sido una práctica común en el cerdo para evitar el olor sexual, sin embargo, afecta el bienestar animal. La inmunocastración se presenta como una alternativa, pues tras el uso de la vacuna se estimula la producción de anticuerpos contra la hormona GnRH. Se induce la inhibición temporal de la función testicular y de la liberación de esteroides, los cuales generan el olor sexual de la carne de cerdo. Existe gran cantidad de información publicada sobre el uso de este recurso con resultados variables en el desempeño productivo. Este estudio se realizó

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con la finalidad de evaluar el efecto de la aplicación de la vacuna anti-GnRH sobre el rendimiento productivo y la calidad de canal en porcinos. Se realizaron 16 meta-análisis para determinar tamaño de efecto, con dos tipos de grupo control (machos castrados y enteros), a partir de 45 artículos científicos (3.685 repeticiones), bajo el modelo de efectos aleatorios. El uso de la vacuna anti-GnRH mejoró el consumo diario de alimento [CDA] (-78,78 g día^{-1}, p = 0,00028), la conversión alimenticia [CA] (-0,16854 kg kg^{-1}, p < 0,00001), la eficiencia alimenticia [EA] (+0,03558 kg kg^{-1}, p < 0,00001) y el porcentaje magro (+1,3%, p < 0,00001) versus machos castrados quirúrgicamente. Los cerdos enteros (control) presentaron resultados superiores para todas las variables analizadas, a excepción de la ganancia diaria de peso (+32,67g día^{-1}, p = 0,00005) que se vio favorecida por el uso de la vacuna. Se concluye que el uso de la vacuna anti-GnRH favorece al rendimiento productivo (CDA, CA y EA) en comparación con los cerdos castrados quirúrgicamente, no así versus cerdos enteros.

Palabras clave: Vacunación, castración, cerdos, olor sexual.

1. Introduction

Surgical castration of male pigs intended for meat production has long been practiced, primarily during the piglet stage in the first week of life, with the aim of eliminating molecules (androsterone and skatole) responsible for undesirable odors and flavors known as "boar taint." It is also used to reduce behavioral problems that arise at puberty (Zamaratskaia and Rasmussen, 2015).

Surgical castration has been widely questioned, as it is generally performed without anesthesia or analgesia, causing pain, stress, and a longer recovery period (compared to immunocastration), making it a highly controversial topic in terms of animal welfare (Kress et al., 2019). Not all consumers detect "boar taint," and there are alternatives to avoid its presence, such as slaughtering pigs before puberty (Wang et al., 2023). Currently, between 14% and 93% of male pigs in Europe are still surgically castrated (van Ferneij, 2022), with Belgium being one of the few countries where immunocastration is emerging as a promising alternative (de Briyne et al., 2016). In Australia, approximately 40% of pork production uses immunocastration—lower than the figures reported for Europe and Latin America. Brazil, as one of the world's largest meat exporters, predominantly uses immunocastration, with 65% of pigs undergoing this procedure. Notably, Brazil is home to two of the world's top ten meat producers—JBS S.A. (named after its founder, José Batista Sobrinho) and BRF (Brazil Foods)—both of which have adopted this alternative to promote animal welfare and meet consumer demands (de Roest et al., 2009; Iocca et al., 2015).

The World Organisation for Animal Health recommends the use of young intact males (before puberty) or immunocastrated pigs to promote animal welfare, as immunocastration is a minimally invasive practice. This method involves active immunization against gonadotropin-releasing hormone [GnRH], which suppresses testicular function and consequently prevents "sexual odor" in the meat (Morales et al., 2017). Immunocastration has been reported to reduce spermatogenesis and the number of Leydig cells. Additionally, changes have been observed in the accessory sex glands (Mitjana et al., 2020).

There is published scientific evidence on the effects of anti-GnRH vaccine application on productive performance and carcass quality in pigs. However, the results vary significantly and are influenced by numerous factors (age at application, interval between doses, dietary energy and protein levels, slaughter weight), which complicates the analysis and makes it difficult to determine the benefits of the vaccine (Basulto Baker, 2020). Therefore, this article aims to analyze the effect of anti-GnRH vaccine application on carcass quality and productive performance in pigs through a meta-analysis approach.

2. Materials and Methods

2.1. Scientific articles search

Between July and September 2023, an electronic search for scientific articles was conducted in indexed journals using the following databases: CAB Direct, Elsevier Biobase-CABS, Google Scholar, MEDLINE, PubMed, Science Direct (Journal), Scopus, Academic Search Complete, Scielo, CAB Abstract, and the Directory of Open Access Journals.

A combination of keywords was used (without Boolean operators), including anti-GnRH vaccine, carcass quality, feed conversion, feed intake, swine, carcass performance, and their equivalents in Spanish and Portuguese, with no date restrictions. It is worth noting that the period covered by the scientific articles included in the study spanned from 1982 to 2023, with a total of 289 articles identified.

2.2. Inclusion and Exclusion Criteria

Research articles written in Spanish, English, and Portuguese were included, if they used the anti-GnRH vaccine (immunocastration) exclusively on healthy pigs intended for fattening. To be included, studies had to involve male pigs and provide detailed information on the number of experimental units per treatment (replicates), include at least two treatments (control group: castrated or intact males), and report at least one of the dependent variables of interest along with corresponding measures of variability: standard deviation [SD], coefficient of variation [CV], or standard error of the mean [SEM].

2.3. Analyzed Variables

The variables of interest were: daily weight gain [DWG] (g day^{-1}), daily feed intake [DFI] (g day^{-1}), feeding conversion [FC] (kg kg^{-1}), feeding efficiency [FE] (kg kg^{-1}), lean percentage (%), redness, and pH (30–45 min and 24 h post-mortem). A total of 45 articles were ultimately selected (Figure 1): Aluwé et al. (2013, 2015), Andersson et al. (2012), Andreo et al. (2018), Argemí-Armengol et al. (2022), Batorek et al. (2012), Bonneau et al. (1994), Braña et al. (2013), Channon et al. (2018), Cronin et al. (2003), Dalla Costa et al. (2020), Daza et al. (2016), Dunshea et al. (2001), Fernandes et al. (2017), Font-i-Furnols et al. (2012), Fuchs et al. (2009), Grela et al. (2013, 2018), Iocca et al. (2015), Jeong et al. (2011), Kantas et al. (2014), Kress et al. (2019), Lealiifano et al. (2011), Metz et al. (2002), Molist et al. (2014), Morales et al. (2010, 2013), Needham y Hoffman (2015), Needham et al. (2017), Oliver et al. (2003), Oliviero et al. (2016), Pauly et al. (2009), Pérez-Ciria et al. (2022), Puls et al. (2014a, 2014b), Quiniou et al. (2012), Rikard-Bell et al. (2009), Seiquer et al. (2019), Škrlep et al. (2010, 2012, 2020a), Turkstra et al. (2002), van den Broeke et al. (2022), Zamaratskaia et al. (2008), Zoels et al (2020).

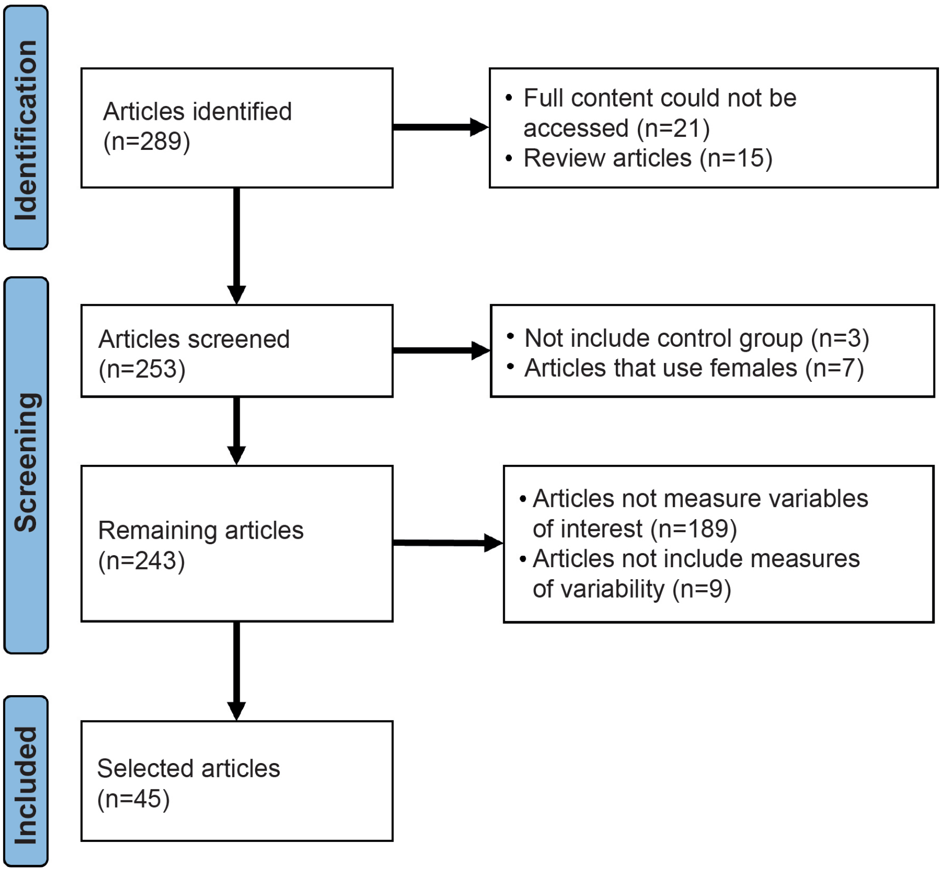

Figure 1. Flowchart for selection and discarding of scientific articles.

In all studies, two 2 mL doses were administered subcutaneously, with the dosing interval ranging from 14 to 84 days. The age at first dose ranged from 29 to 140 days, and the age at the second dose ranged from 84 to 182 days.

2.4. Statistical analysis

For statistical analysis, MIX 2.0 Pro software for Microsoft Excel was used (Bax, 2016), applying a random effects model. A total of 16 meta-analyses were conducted: eight for productive performance and eight for carcass yield and quality. Each analysis included two types of control groups (castrated and intact males), due to the biological differences between these categories. The effect size between the treatment and control groups was determined by mean difference (Ledesma et al., 2008).

The number of replications for the productive performance variables was 1,805, and for carcass yield and quality variables, 1,880, as shown in Table 1.

Table 1. Number of repetitions used for the meta-analysis of productive performance and carcass quality.

	Productive Performance	Replications (n)	Carcass Yield and Quality	Replications (n)
		Total		Total
Anti-GnRH vs Castrated Controls	DWG	541	Lean Percentage	128
	DFI	395	Redness	554
	FC	224	pH 30-45 min	364
	FE	197	pH 24 h	476
Anti-GnRH vs Intact Control	DWG	144	Lean Percentage	88
	DFI	142	Redness	46
	FC	110	pH 30-45 min	96
	FE	52	pH 24 h	128
TOTAL		1,805	TOTAL	1,880

3. Results

3.1. Productive Performance

The effect, expressed as the mean difference [MD] between the analyzed groups, indicated an increase in DWG of 16.78 g day^{-1} in the immunocastrated group compared to the surgically castrated control group. Likewise, an increase in DWG of 32.67 g day^{-1} ($p = 0.00005$) was observed in comparison to the intact male control group (Table 2).

Regarding DFI, a reduction of 78.78 g day^{-1} was observed in pigs that received the anti-GnRH vaccine ($p = 0.0028$) compared to the surgically castrated control group. Conversely, DFI showed a considerable increase of 132.92 g day^{-1} ($p = 0.00052$) in the treatment group compared to the intact male control group.

For the FC, a decrease was observed, indicating that the anti-GnRH vaccine significantly favored the treated group ($p \leq 0.00001$) compared to the surgically castrated pigs. In other words, pigs in the castrated control group consumed 168.54 g more feed than those treated with the anti-GnRH vaccine to gain 1 kg of live weight. In contrast, the intact control group exhibited a lower FC, as pigs vaccinated with the anti-GnRH vaccine consumed 73.11 g more feed to gain 1 kg of live weight.

Concerning FE, vaccinated pigs gained 35.58 g more weight per kg of feed consumed compared to the surgically castrated control group ($p \leq 0.00001$). On the other hand, when compared with the intact male control group, better FE was observed in the controls ($p = 0.00621$), as they gained 23.89 g more weight per kg of feed consumed than the treatment group.

Table 2. Effect size of anti-GnRH vaccine administration on ADG, ADFI, FC and FE in pigs.

	Productive Performance*	Treatment		Control		Size Effect**	
		Average	SD	Average	SD	MD	p
Anti-GnRH vs Castrated Controls	DWG	978.89032	120.04513	951.71613	135.53971	16.78075	0.11632
	DFI	2478.9583	687.94069	2543.16667	667.08462	-78.78727	0.00028
	FC	2.76222	0.47333	2.93778	0.59404	-0.16854	<0.00001
	FE	0.40727	0.0321	0.37027	0.03375	0.03558	<0.00001
Anti-GnRH vs Intact Controls	DWG	947.44545	88.92126	924.02727	77.19898	32.67982	0.00005
	DFI	2371.25	394.87566	2233.75	299.61583	132.92236	0.00052
	FC	2.661	0.52619	2.459	0.42855	0.07311	0.02574
	FE	0.3975	0.03748	0.4175	0.02899	-0.02389	0.00621

* DWG: Daily Weight Gain; DFI: Daily Feed Intake; FC: Feeding conversion; FA: Feeding efficiency.

** MD: mean differences; p: p-value.

3.2. Carcass yield and Quality

The administration of the anti-GnRH vaccine increased the lean percentage by 1.3% ($p < 0.00001$) compared to the surgically castrated pigs. Likewise, the pH (30–45 min postmortem) increased by 0.04835 ($p = 0.07738$) in the vaccinated group compared to the control group, as shown in Table 3. Conversely, redness was higher in surgically castrated pigs by 0.99668 ($p = 0.02495$) compared to vaccinated pigs. Similarly, pH at 24 hours postmortem was 0.01804 higher ($p = 0.04624$) in the surgically castrated pigs than in the vaccinated group.

Table 3. Effect size of anti-GnRH vaccine administration on post-mortem lean percentage, redness and pH (30 – 45 min and 24 h) in pigs.

	Productive Performance	Treatment		Control		Size effect*	
		Average	SD	Average	SD	MD	p
Anti-GnRH vs castrated Controls	Lean Percentage	55.33333	3.29886	54.06667	3.74933	1.30245	<0.00001
	Redness	7.13143	2.05404	8.08857	2.41538	-0.99668	0.02495
	pH 30-45 min	6.29615	0.23035	6.25	0.30635	0.04835	0.07738
	pH 24 h	5.49692	0.15887	5.51	0.1698	-0.01804	0.04624
Anti-GnRH vs Intact Controls	Lean Percentage	58.86667	3.75695	59.33333	3.11748	-0.56999	0.13119
	Redness	6.1	0	6.55	0.07071	-0.46318	0.01016
	pH 30-45 min	6.324	0.11718	6.306	0.04278	0.04863	0.14923
	pH 24 h	5.8	0.46472	5.64	0.42071	0.03859	0.20481

* DM: mean differences; p: p value.

When comparing immunocastrated pigs to entire males, the lean percentage ($p = 0.13119$) and redness ($p = 0.01016$) were higher in the control group by 0.56999 and 0.46318, respectively, compared to the anti-GnRH-treated pigs. The pH measured at 30–45 minutes ($p = 0.14923$) and at 24 hours ($p = 0.20481$) postmortem was higher in the treatment group by 0.04863 and 0.03859, respectively.

4. Discussion

The administration of the anti-GnRH vaccine improved productive performance, as improvements were observed in DFI ($p = 0.00028$), FCR ($p < 0.00001$), and FE ($p < 0.00001$) compared to surgically castrated pigs. These results are like those reported by Kantas et al. (2014), in which surgically castrated pigs showed an 11% higher FC ($p = 0.0005$) compared to immunocastrated pigs. However, the DWG was higher in the immunocastrated pigs (892 g day^{-1}) than in the castrated pigs (820 g day^{-1}) ($p < 0.05$).

In contrast, when compared to entire males, the administration of the anti-GnRH vaccine did not improve productive performance, as better FI ($p = 0.00052$), FCR ($p = 0.02574$), and FE ($p = 0.00621$) were observed in the control group, except for ADG, which favored the vaccinated group ($p = 0.00005$). Nevertheless, in the study conducted by Kantas et al. (2014), no differences were found in ADG between entire males (888 g/day^{-1}) and immunocastrated pigs (892 g/day^{-1}).

Immunocastration has been evaluated in numerous studies aimed at improving meat quality, demonstrating that, compared to surgical castration, it enhanced carcass quality and productive performance (Wang et al., 2023). During the immunocastration process, about two weeks after the booster dose, testosterone levels begin to decrease due to the absence of GnRH, FSH, and LH hormones, causing the metabolism of immunocastrated pigs to progressively shift to that of surgically castrated males. This leads to increased appetite and reduced feeding efficiency (Brunius et al., 2011). As a result of increased feed intake (+10 to 12%), higher energy levels are consumed, leading to greater fat deposition (+9%), especially compared to entire males (Moore et al., 2016). Therefore, this meta-analysis demonstrated the benefit of administering the anti-GnRH vaccine on productive performance when compared to surgically castrated pigs. It is important to note that the vaccine becomes effective from the second to third week after the second booster dose, causing a decrease in androsterone and skatole concentrations for approximately 10 weeks after the second vaccination, preventing immunocastrated pigs from emitting “boar taint” (Reyes-Bermúdez & Marín-Hernández, 2018).

On the other hand, Jaros et al. (2005) indicated that the absence of GnRH hormone limits performance during the growing and finishing phases, as entire males show higher protein deposition rates and lower fat deposition due to the action of testosterone, resulting in better feed conversion, lean yield, and average daily gain. However, the fattening of entire males presents a major disadvantage: the presence of “boar taint” in the carcass. In this meta-analysis, entire males showed better productive performance than immunocastrated pigs, because of testosterone. This is consistent with the findings of van den Broeke et al. (2016), where entire males across different stages (between 20 and 105 kg) tended ($p > 0.05$) to outperform immunocastrated pigs in DWG. However, between 105 and 133 kg, immunocastrated pigs had a higher DWG compared to entire males—984 vs. 877 g day^{-1}, respectively ($p = 0.014$). Another drawback of using entire males is their lower feed intake; they expend more energy and reduce their growth rate below optimal potential due to increased aggressiveness and sexual behavior (Pauly et al., 2009). In the study by Metz et al. (2002), entire males weighing 116 kg consumed 2.60 kg day^{-1} compared to 2.78 kg day^{-1} in immunocastrated pigs ($p < 0.01$). This aligns with van den Broeke et al. (2022), who reported that entire males consumed 2.48 kg day^{-1}, while immunocastrated pigs consumed 2.97 kg day^{-1} ($p < 0.001$).

Regarding carcass yield and quality, this meta-analysis showed that pigs vaccinated with anti-GnRH had a higher lean percentage and pH (30–45 min) compared to surgically castrated pigs. Castrated pigs had greater redness and a higher pH (24 h *post mortem*) than vaccinated pigs. Conversely, vaccinated pigs showed a lower lean percentage and redness, and a higher pH (30–45 min and 24 h) compared to entire males. Rosenvold and Andersen (2003) state that factors such as production system, breed group, feeding, *ante mortem* handling, and *post mortem* meat processing can influence carcass yield and quality traits. *Ante mortem* handling is especially important, as factors such as fasting, transport, stunning, and species influence stress physiology, which can affect carcass quality (Rosenvold & Andersen, 2003).

In this study, no significant differences were found in the pH measured between 30- and 45-minutes *post mortem* in any of the comparisons made. In all groups, the pH ranged between 6.25 and 6.32, suggesting the absence of PSE meat and a tendency toward DFD (dark, firm, dry) meat (pH ≥ 6.3). This agrees with Castrillón et al. (2005), who noted that normal meat can have a pH ranging from 5.9 to 6.2 (measured at 45 min). Similarly, in the study by Dalla Costa et al. (2020), no differences were found between immunocastrated and surgically castrated pigs, though high values of 6.5 to 6.65 were recorded. These higher pH values may result from early depletion of muscle glycogen reserves (Henckel et al., 2002).

For the pH measured 24 hours *post mortem*, a significant difference was found: immunocastrated pigs had a lower pH (5.49) compared to surgically castrated pigs (5.51). This agrees with Dalla Costa et al. (2020), who also reported a lower pH in immunocastrated pigs (5.68) versus surgically castrated pigs (5.72). A 24-hour pH is significantly affected when muscle glycogen reserves are below 53 µmol/g, which in the case of immunocastrated pigs is associated with lower feed intake compared to surgically castrated pigs (Henckel et al., 2002). No differences were found between immunocastrated pigs (5.8) and entire males (5.64), although the latter had a slightly lower pH. Entire males deplete their glycogen stores earlier due to greater physical activity associated with testosterone (Batorek et al., 2012). pH values below 5.5 indicate a tendency toward PSE meat. Dalla Costa et al. (2017) consider pH values between 5.5 and 5.8 (measured at 24 h) to be within the normal range.

Regarding the lean percentage in pigs under intensive production conditions (balanced feeding), a lean meat percentage above 50% (live weight of 100 kg) is expected (Overholt et al., 2016). In the present study, all the analyzed groups showed lean meat percentages above 50%. Surgically castrated males had a lean percentage of 54.06%, while immunocastrated pigs reached 55.33%. Although this was a better result, the difference was not statistically significant. These findings are consistent with Andersson et al. (2012), who reported that immunocastrated pigs (56.9%) and surgically castrated pigs (57%) had lower values compared to entire males (57.7%). Similarly, Pauly et al. (2009) reported that immunocastrated pigs (56.3%) had leaner carcasses compared to surgically castrated pigs (54.5%), favoring the use of the anti-GnRH vaccine.

Lastly, in terms of the visual characteristics of the carcass, redness was analyzed, even though various factors and pigments influence muscle coloration. The oxidation of myoglobin to oxymyoglobin is the main contributor to the bright red color of meat (Wallace et al., 1982). The literature presents inconsistent results regarding meat color determinants (Pauly et al., 2009). In the present meta-analysis, castrated pigs exhibited greater redness compared to immunocastrated pigs—similar results were found by Daza et al. (2016). This effect is associated with greater feed intake and consequently higher nutrient availability for hematopoiesis (Henckel et al., 2002; Wang et al., 2023). This meta-analysis also showed that entire males had greater redness than immunocastrated pigs. However, some authors found no significant differences (Aluwé et al., 2013; Gispert et al., 2010) when comparing immunocastrated pigs with entire males. In entire males, the presence of testosterone results in greater physical and metabolic activity, which demands higher oxygen levels and hematopoietic activity, leading to increased tissue coloration (Škrlep et al., 2020b). Various factors can influence pork meat color, such as handling during transport and at the slaughterhouse, the slaughter method, and data collection conditions (Mancini & Hunt, 2005).

5. Conclusions

The use of the anti-GnRH vaccine improves productive performance (DWG, FC, and FE) and lean yield compared to surgically castrated pigs, although not when compared to entire males.

Contributor roles

- Debra Andrea Trujillo-Torres: investigation, data curation, resources.
- Eduardo Fabián Aragón-Vásquez: conceptualization, writing - original draft.
- Renán Patricio Mena-Pérez: validation, writing – original draft.
- Jimmy Rolando Quisirumbay-Gaibor: formal analysis, methodology, project administration, writing – review & editing.

Ethical implications

The authors declare that there are no ethical implications.

Conflict of interest

The authors declare that there are no financial or non-financial conflicts of interest that could have influenced the work presented in this article.

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