



Effect of various castration protocols on production indicators in pigs: meta-analysis



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Abstract:

The objective was to evaluate the effect of various castration protocols through a meta-analysis of indicators of daily feed intake, feed conversion, daily weight gain, slaughter

weight, hot carcass weight, and carcass yield. 179 publications from three electronic sources (Scopus, PubMed, and Web of Science) were reviewed over a 24-year period, out of which the 26 studies that met the inclusion criteria were selected. The effect was analyzed with six comparisons: C1=surgical castration vs whole; C2=standard immunocastration vs whole; C3= standard immunocastration vs surgical castration; C4= alternative immunocastration vs whole; C5= alternative immunocastration vs surgical castration, and C6= alternative immunocastration vs standard immunocastration. Averages were estimated for feed intake (kg) (0.23, 0.23, -0.05, 0.32, 0.11, -0.09), feed conversion (kg:kg) (0.27, 0.05, -0.16, 0.11, 0.11, -0.19), daily weight gain (g) (-9.54, 39.08, 40.70, 107.63, -53.0, 69.14), carcass weight (kg) (-9.54, 39.08, 40.70, 107.63, -53.0, 69.14), and hot carcass weight (kg) (1.23, 0.85, 0.46, 1.03, 1.02, -0.42) respectively. The indicators of feed consumption, feed conversion, daily weight gain, slaughter weight, and hot carcass weight proved different ($P<0.05$); only the carcass yield variable exhibited no difference ($P>0.05$). The conclusion is that immunocastration improves performance in production and carcass indicators; surgical castration improves carcass yield; whole pigs have better feed conversion, and standard and alternative immunocastration differ in their response in terms of production and carcass measurement indicators.

Keywords: Immunocastration, GnRH, Meta-analysis, Carcass, Stockbreeding.

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Introduction

In whole pigs for slaughter, the sexual taste and odor in the meat is perceptible⁽¹⁾. Therefore, at early ages, it is preferable to castrate pigs surgically; this technique is the most commonly used, while it is also invasive⁽²⁾. Various methods of castration were addressed in the 1990s⁽³⁾, among which the results of the application of immunization against GnRH on sexual odor, the response in production and carcass indicators were most prominent^(4,5).

The standard immunization protocol consists of two subcutaneous doses at 12 and 16 wk of age⁽⁶⁾. The former allows for immune recognition, antibody production, and anchoring to gonadotrophs. The second dose increases the immune response, causing gonadal atrophy and eliminating androstenone as a sexual odor precursor⁽⁷⁾.

An increase in daily weight gain, higher carcass weight at slaughter and a reduction in back fat thickness have been reported to occur with immunocastration^(8,9); however, other authors report the opposite, observing a lower carcass yield and a lower daily weight gain^(10,11).

Studies have been published in which different GnRH immunization protocols involving age, interval, and number of doses have been applied. Some of the results observed in these studies in the protocols that had 4- and 6-wk intervals between doses were improvements in feed conversion and carcass weight⁽¹²⁾ and improved growth performance indicators in late immunocastration and prepubertal protocols⁽¹³⁾, while the standard and delayed immunization protocols resulted in better feed efficiency⁽¹⁴⁾.

The results of the different studies on castration methods have been analyzed with the statistical tool of meta-analysis. An example of this can be seen in the 2012 paper by Batorek *et al*⁽¹⁵⁾, where the comparison between immunocastration *versus* surgical castration and whole pigs showed that immunocastrated pigs had longer carcasses compared to surgically castrated and whole pigs, as well as a faster growth rate and a better feed conversion than whole pigs.

In another 2018 study⁽¹⁶⁾, immunocastration in pigs produced a higher daily weight gain and a lower feed conversion rate than surgical castration. On the other hand, higher daily weight gain, feed intake, trace weight and back fat were observed in immunocastrated sows compared to whole sows⁽¹⁷⁾.

The objective of the present meta-analysis was to evaluate the effect of the different castration protocols used until 2020, with an emphasis on the analysis of the castration technique, as well as the effect on the age of application of the immunocastration protocol, and to compare between standard and alternative immunization application, through the production indicators daily weight gain, daily feed consumption, feed conversion, and carcass evaluation based on live slaughter weight, hot carcass weight, and carcass yield.

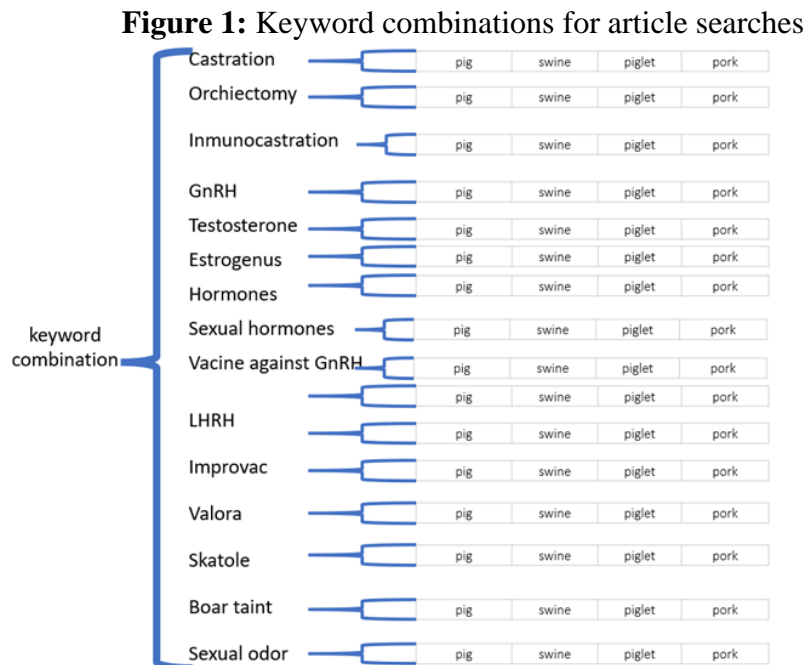
Material and methods

The development of the present work included a literature review of the publications related to the different castration protocols (surgical castration, standard GnRH immunization, and alternative immunocastration) and also considered whole pigs. The methodological procedure was: information search; systematic review; quantitative synthesis; categories of analysis, and statistical analysis.

Information search

The search began with the approach and the research question of this work, which brought the focus of the literature review to those publications that studied the effect of castration protocols, either surgical or immunological, on the production process of pigs for slaughter during breeding and the subsequent output of finished pigs to the slaughterhouse, as well as the collection and measurement of the carcass. The search for information began in 1994, when the first results on this subject were reported, up to 2020. In the systematic review, the electronic meta-search engines Scopus, PubMed, and Web of Science were used to search for papers.

The primary search was performed by mixing keywords related to the topic (Figure 1). The available publications in the fields of biological sciences, animal production sciences, and meat science and technology were segregated, and the corresponding results, mean values, and dispersion measures were published.



Systematic review

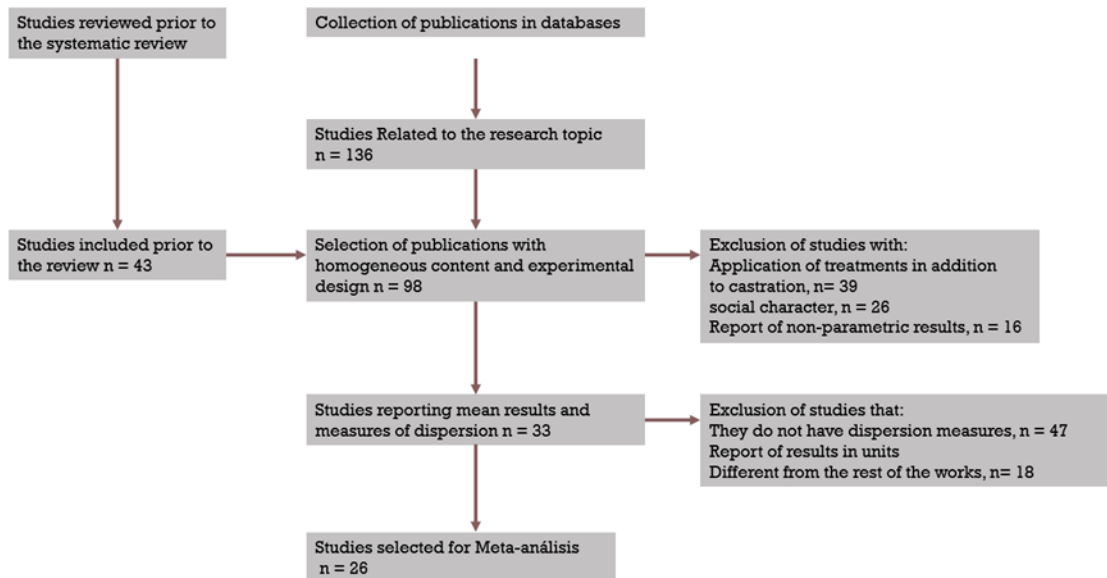
The selection of the papers was applied to 179 articles by two team members, who determined the criteria for selection and exclusion of the articles based on the initial research

question and approach (Figure 2). Once these criteria were established, the selection process resulted in 26 articles for analysis (Figure 3).

Figure 2: Inclusion and exclusion criteria for article selection

Inclusion	Exclusion
<ul style="list-style-type: none"> • GnRH immunization, surgical castration and use of whole pigs. • Use of pigs for slaughter and consumption as research subjects. • Pigs with a terminal genetic basis in the conformation of different local genetic lines. • Work with results on growth, development and finishing indicators. • Papers with results on indicators of interest in meat science and technology. • All with results in the chemical and nutritional composition of the meat. • Works by various nationalities. • Works by different institutes and educational or governmental entities. 	<ul style="list-style-type: none"> • To have any other treatment in addition to surgical and immunological castration protocols. • Subjects of research not intended for consumption, slaughter or production processes. • Work directed to a social field to which no corresponding results were reported for pork production, procurement, or consumption processes. • Papers that reported nonparametric results, as well as those whose results were ranges or subjective values. • Observational studies with data reported by qualitative indicators.

Figure 3: Information selection flow



Quantitative summary

Table 1 shows the characteristics of the works included in the analysis in terms of technique and method of castration.

Table 1: Details of publications selected for statistical analysis

Author	Gentics	Sex	Experimental groups
Andersson <i>et al</i> ⁽¹⁹⁾	Yorkshire x Landrace	m, h	Q, Ie, aI, W
Bonneau <i>et al</i> ⁽³⁾	Large white x Pietrain	h	Q, Ie, W
Channon <i>et al</i> ⁽²⁰⁾	Large White x (Landrace x Duroc x Largewhite)	m	sI, W
Daza <i>et al</i> ⁽¹¹⁾	Duroc x (Landrace x Large white)	m, h	Q, sI, W
Di Martino <i>et al</i> ⁽²¹⁾	Terminal	h	sI, W
Dunshea <i>et al</i> ⁽⁸⁾	Large white x Landrace	m	Q, sI, sI, W
Font <i>et al</i> ⁽²²⁾	Terminal	m, h	Q, sI, W
Galleos <i>et al</i> ⁽²³⁾	Terminal	m	sI, Ia
Gamero <i>et al</i> ⁽²⁴⁾	Ibérico x Duroc	h	Q, sI, W
Gogic <i>et al</i> ⁽²⁵⁾	Swallow-bellied Mangalitsa	m	sI, W
Grela <i>et al</i> ⁽⁹⁾	Polish Zloynika	m	Q, sI, aI, W
Laeliifano <i>et al</i> ⁽¹²⁾	Large White x Landrace	m	sI, aI, W
Morales <i>et al</i> ⁽²⁶⁾	Terminal	m	Q, sI, W
Oliviero <i>et al</i> ⁽²⁷⁾	Landrace	m	Q, W,
Pauly <i>et al</i> ⁽²⁸⁾	Large white	m	Q, sI, W
Rikard-Bell <i>et al</i> ⁽²⁹⁾	Terminal	m	sI, W
Rodriguez <i>et al</i> ⁽³⁰⁾	Terminal	h	sI, W
Skrelep <i>et al</i> ⁽³¹⁾	Cerdos gordos eslovacos x Duroc	m	Q, sI, W
Skrelep <i>et al</i> ⁽³²⁾	Large white x Landrace x Duroc	m	Q, sI, W
Stupka <i>et al</i> ⁽³³⁾	Duroc x (Large White x Landrace)	m, h	Q, sI, W
Turkstra <i>et al</i> ⁽¹⁰⁾	(Deutch Landrace x Finnish Landrace) x Large White	m	Q, sI, aI, W
Van den Broeke <i>et al</i> ⁽³⁴⁾	Terminal	m, h	Q, sI, aI, W
Weiler <i>et al</i> ⁽³⁵⁾	Terminal	m, h	Q, sI, W
Yuan <i>et al</i> ⁽³⁶⁾	Duroc·(Landrace·x Large White)	m	Q, sI
Zoels <i>et al</i> ⁽¹⁴⁾	Piétrain × Large White x Landrace	m	Q, sI, aI, W

*sex: f=females, m=males; Experimental group: Q= surgical castration, sI= standard immunocastration, aI= alternative immunocastration; W=whole pigs.

The groups for analysis were the following:

Whole: pigs that remained without any type of intervention during the production period.

Surgical castration: pigs that had their testicles surgically removed before 7 d of age.

Standard immunocastration: pigs that underwent the immunization protocol as indicated by the manufacturer, two doses subcutaneously, at approximately 12 and 16 wk of age.

Alternative immunocastration: pigs that received the immunization protocol at ages other than the standard or with a longer interval between doses.

Categories of analysis

The analysis of the information was divided into two stages:

- a) Production period: described by indicators of feed intake, feed conversion ratio, and daily weight gain.
- b) Carcass measurement process: described by the indicators slaughter weight, hot carcass weight, and carcass yield.

From the identification and description of the categories of analysis, the following comparisons were established for the analysis of the information in each of the aforementioned indicators:

C1: surgical castration

C2: standard immunocastration vs whole.

C3: standard immunocastration vs surgical castration.

C4: alternative immunocastration vs whole.

C5: alternative immunocastration vs surgical castration.

C6: alternative immunocastration vs standard immunocastration.

Statistical analysis

The statistical analysis used to synthesize the results of various studies on the effect of castration protocols on the indicators of the productive period and the carcass measurement process was carried out with the NCSS[®] software (NCSS Statistical System for Windows, Kaysville, UT: Number Cruncher Statistical Systems, 2021). Dispersion averages were estimated based on the values of the mean, standard deviation, and number of observations for each indicator under study. A random effects model was utilized to test the hypothesis of

heterogeneity, the average standard difference of the effect, and its confidence interval ($\alpha=0.05$); this decision was supported by Chi-square tests⁽¹⁸⁾.

Results

Table 2 shows the comparisons, the result of the differences between the means points to the first analysis protocol for each of them.

Production period indicators

For the feed intake indicator, the alternate immunocastration (C4 and C5), surgical castration (C1 and C3) and standard immunization (C2 and C6) protocols obtained the highest feed intake (Table 2). Animals within the two immunization protocols had a higher intake than castrated animals (C3 and C5). Finally, among the immunization protocols, the standard protocol was the one that had the highest intake.

For feed conversion (Table 2), the whole pig protocol obtained the best value (C1, C2, and C4), followed by the standard immunocastration (C3 and C6) and surgical castration protocols (C5).

For daily weight gain (Table 2), the standard immunization protocol exhibited the best results (C2, C3 and C6), followed by the alternate immunization (C4 and C5) and whole pigs (C1) protocols.

Indicators of the carcass measurement process

Table 2: Results of the analysis of the indicators for each comparison

C1 Surgical castration vs whole					C4 Alternative immunocastration vs whole				
Variable	n	Difference between means ± SW	Coefficient limits (95%)	P	Variable	n	Difference between means ± SW	Coefficient limits (95%)	P
Feed intake, kg	16	0.23 ± 0.03	(0.16; 0.29)	0.01	Feed intake, kg	8	0.32 ± 0.09	(0.13; 0.51)	0.01
Feed conversion, kg:kg	13	0.27 ± 0.04	(0.20; 0.34)	0.01	Feed conversion, kg:kg	5	0.11 ± 0.15	(-0.18; 0.40)	0.01
Daily weight gain, g	15	-9.54 ± 16.62	(-42.12; 23.03)	0.01	Daily weight gain, g	8	107.63 ± 58.75	(-7.52; 222.78)	0.01
Slaughter weight, kg	14	4.11 ± 3.35	(-2.45; 10.68)	0.01	Slaughter weight, kg	5	0.09 ± 1.36	(-2.56; 2.76)	0.01
Hot carcass weight, kg	17	1.23 ± 0.51	(0.22; 2.24)	0.01	Hot carcass weight, kg	6	1.03 ± 0.86	(-0.66; 2.72)	0.01
Carcass yield, %	9	0.33 ± 0.52	(-0.69; 1.35)	0.97	Carcass yield %	6	-0.22 ± 0.63	(-1.46; 1.01)	0.94
C2 Standard immunocastration vs whole					C5 Alternative immunocastration vs surgical castration				
Feed intake, kg	17	0.23 ± 0.08	(0.08; 0.38)	0.01	Feed intake, kg	5	0.11 ± 0.12	(-0.13; 0.34)	0.01
Feed conversion, kg:kg	15	0.05 ± 0.04	(-0.0; 0.13)	0.01	Feed conversion, kg:kg	5	-0.19 ± 0.14	(-0.56; 0.08)	0.01
Daily weight gain, g	21	39.08 ± 11.37	(16.79; 61.34)	0.01	Daily weight gain, g	6	69.14 ± 32.67	(5.10; 133.18)	0.01
Slaughter weight, kg	21	1.24 ± 0.59	(0.07; 2.42)	0.01	Slaughter weight, kg	7	1.28 ± 0.50	(0.29; 2.27)	0.01
Hot carcass weight, kg	25	0.85 ± 0.47	(-0.06; 1.76)	0.01	Hot carcass weight, kg	7	-0.42 ± 0.44	(-1.28; 0.44)	0.01
Carcass yield, %	12	-0.68 ± 0.46	(-1.58; 0.22)	0.99	Carcass yield, %	4	-0.10 ± 0.75	(-1.58, 1.37)	0.89
C3 Standard immunocastration vs surgical castration					C6 Alternative immunocastration vs standard immunocastration				
Feed intake, kg	12	-0.05 ± 0.07	(-0.19; 0.09)	0.01	Feed intake, kg	6	-0.09 ± 0.11	(-0.31; 0.12)	0.01
Feed conversion, kg:kg	10	-0.16 ± 0.03	(-0.23; -0.09)	0.01	Feed conversion, kg:kg	7	0.11 ± 0.07	(-0.03; 0.24)	0.01

Daily weight gain, g	14	40.70 ± 12.18	(17.03; 64.77)	0.01	Daily weight gain, g	1	-53.00 ±	(-100.66; -	0.01
Slaughter weight, kg	14	1.21 ± 0.53	(0.16; 2.25)	0.01	Slaughter weight, kg	2	24.32	5.34)	
Hot carcass weight, kg	17	0.46 ± 0.69	(-0.90; 1.81)	0.01	Hot carcass weight, kg	9	0.47 ± 2.07	(-3.58; 4.53)	0.01
Carcass yield, %	9	-0.66 ± 0.52	(-1.68; 0.35)	0.45	Carcass yield, %	9	1.02 ± 1.67	(-2.25; 4.30)	0.01
						9	0.29 ± 0.52	(-0.72; 1.31)	0.76

Final weight showed favorable indicators for alternative immunization at C4, C5, and C6 (Table 2), followed by standard immunization at C2 and C3, and surgical castration (C1). When analyzing the hot carcass weight, the highest value was obtained with the standard immunization protocol (C2 and C3), followed by the alternative immunization protocol (C4 and C6), and surgical castration (C1 and C5).

Contrary to the final weight and the hot carcass weight, the response observed in the carcass yield analysis showed that the surgical castration protocol obtained higher percentages in C1, C3, and C5. On the other hand, whole pigs show higher performance at C2 and C4, leaving only the alternative immunization protocol with a favorable indicator at C6.

Figures 4 and 5 represent the heterogeneous behavior ($P < 0.05$) in the analysis of the alternative immunocastration protocol at C4, C5, and C6. In both cases, an increase in favorable results was observed with the application of the alternative immunization.

Discussion

The response of the analyzed indicators is explained on the basis of the results of a whole animal, considered as the ideal productive animal for its metabolic qualities and their effect on the carcass⁽³⁷⁾.

Production-period indicators

Feed intake

The amount of food consumed is regulated by the satiety center, which responds to serum concentrations of leptins, produced by adipocytes. Several factors can modify feed intake such as: the presentation and formulation of the food, the physical and physiological state of the individual, and the physical and social activity within the group⁽³⁸⁾.

The physical and physiological state of the animal modifies the feed intake; therefore, surgical castration or immunocastration are protocols that alter this indicator. Surgical castration increases feed intake due to the increase in the serum concentration of leptins, 2.97 ng/ml — as a consequence of the redistribution and increase of adipose tissue after the removal of the gonads^(39,40)—, saturating and inhibiting the satiety center located in the central nervous system⁽⁴¹⁾. In immunocastrated pigs, serum leptin concentrations remain similar to those of whole pigs (2.68 ng/ml); therefore, satiety is not altered⁽¹⁵⁾.

Likewise, the interruption of the hypothalamic-pituitary-gonadal axis when the gonads are removed affects the consumption and satiety habits, also influenced by sex hormones, especially by estrogens, which when the testes are removed are not aromatized; this causes the estrogen to be produced by the adipose tissue in low concentrations, of 0.34 pg/ml, and, therefore, the pig exhibits resistance to glucose and a higher feed intake⁽⁴²⁾. Estradiol concentration decreases in immunized pigs, 0.37 pg/ml; however, its effect may vary depending on the age at which the second dose is applied⁽⁴³⁾.

Another element that modifies the intake is the physical and social activity within the group. While whole pigs show greater sexual activity, dominance and competitiveness for food, whereby their feed intake diminishes⁽³⁷⁾, immunocastration and surgical castration reduce the presence of androgens and, therefore, the pigs' sexual activity and dominance, increasing their feed intake⁽¹⁵⁾.

With respect to immunization protocols, studies report no differences, contrary to the findings of this study, where variability in the timing of alternative immunizations may alter the feed intake response⁽²³⁾.

Feed conversion

The best feed conversion is established as the one with the lowest feed intake in relation to the production of one kilogram of meat; among the factors that can modify it are the physical and physiological state of the pig.

Somatotropin is one of the elements required for muscle development, which is altered if the physical state changes⁽⁴¹⁾ as a consequence of the reduction of the blood IGF-1 concentration in castrated pigs to 256 ng/ml, related to the reduction of estradiol, whereby the mechanisms of muscle growth and development become altered⁽⁴³⁾. In immunized pigs the concentration of IGF-1 reaches 332 ng/ml, compared to its value in whole pigs, which is 459 ng/ml⁽⁴³⁾.

In late alternative immunization protocol, the feed conversion value increases with the second dose; therefore, the age of application is a relevant factor in allowing the physiological mechanisms to remain for a longer period of time^(15,44).

Daily weight gain

The physiological mechanisms and state, and the physical and social activity of the pigs are some of the factors that influence weight gain. The utilization of nutrients in the diet promotes the growth and development of tissues. An example of this is the response of the muscle masses to the presence of lysine, which causes a retention of nitrogen in muscle of 31.24 g/d^(45,46). Surgical castration allows a retention of 25.51 g/d of nitrogen, while immunocastrated pigs retain only 22.95 g/d^(45,47,48).

The physical activity of whole pigs is more dynamic due to the hierarchy within groups, as well as the competition in feed intake, also considering that, as the age of puberty approaches, the incidence of aggressions increases⁽³⁷⁾.

In the case of surgically castrated pigs, physical activity and energy demand are lower; however, competition for feed intake prevails and, in some cases, increases because of alterations in the satiety centers. In immunized pigs, the increase in this indicator responds to the reduction of aggressions and dominance attitudes among pigs, which allows a homogeneous feed consumption and reduces the need to heal wounds and injuries⁽⁴¹⁾.

Indicators of the carcass measurement process

Slaughter weight

At the end of the production cycle, the final weight of the animals will depend on the physical condition and age at slaughter; it should be noted that the result is related to the feed conversion rate and daily weight gain, as well as to the metabolic mechanisms of these indicators. The production cycle of pigs for slaughter usually lasts approximately 20 to 22 wk, during which time the whole pig reaches an average weight of 110 kg, attributed to its metabolic efficiency, considering that a large part of this value corresponds to muscle mass⁽³⁸⁾.

Surgically castrated pigs eventually gain weight due to the redistribution and growth of adipose tissue, especially subcutaneous fat⁽⁴⁹⁾. The weight of immunocastrated pigs involves a similar muscle development to that of whole pigs, a thicker fat cover —without reaching those of the surgical castration protocol—, homogeneous feed consumption, metabolic utilization, and a higher weight gain due to docile behavior⁽⁴¹⁾.

Hot carcass weight

After slaughtering and the process of removing the head and viscera, the carcass is obtained; its weight is determined by the morphology of the pig, as well as the amount of fat it contains and its relation to the muscles. The carcass of whole pigs is leaner because it has little fat cover and intermuscular fat, in addition to the 1.4 % reduction in weight corresponding to the testicles⁽⁵⁰⁾, which coincides with the results of the meta-analysis performed in 2012⁽¹⁵⁾.

In surgically castrated pig carcasses, the amount of fat cover and intermuscular fat increases the weight, and the difference in final weight is not affected by the removal of the reproductive tract⁽⁴¹⁾.

In immunized pigs, the fat cover is thicker than that of whole pigs and thinner than that of surgically castrated pigs; they have a better metabolic response after the second dose and allow similar muscle growth and development to those of a whole pig⁽⁵¹⁾. Alternative immunization protocols have a better response, especially in late immunization or with a longer interval between the first and second dose⁽¹⁹⁾.

Carcass yield

The ratio between live weight and carcass weight, as well as the number of cuts that can be obtained and their weight, determine the carcass yield, which is influenced by the amount of inter- and intramuscular fat, as well as the ratio between the volume of the meat pieces and the covering fat⁽⁵²⁾. It is important to consider that certain external factors may influence the percentage expression of yield, such as fasting prior to slaughter, transportation, and travel time.

In the case of surgically castrated pigs, there is a greater content of intermuscular adipose tissue, giving more weight to the cuts, despite the fact that the number of cuts in whole pigs is larger due to the length of the carcass⁽⁵³⁾.

The volume of meat of pigs immunized with either one of the application protocols is lower than that of whole pigs, as well as of the meat and intermuscular fat developed by surgically castrated pigs, and, therefore, their performance is lower^(15,16).

Conclusions and implications

In conclusion, the meta-analysis of various castration protocols in pigs under experimental conditions shows that immunocastrated pigs, with both the standard and alternative application protocols, are more efficient in terms of the indicators of consumption and weight gain, as well as of live weight and hot carcass weight. A higher carcass yield is observed in surgically castrated pigs. Whole pigs have better feed conversion. There are differences in production indicators and carcass measurement between the standard and the alternative immunization protocols.

It is important to consider that the age of immunocastration modifies the results in the production indicators. Castration protocols exhibit different effects on pig production, depending on the type and age at which they are applied. Absence of gonadotropin-releasing hormone and androgen concentration modifies the physiological response to productive performance. Standard immunocastration enhances the response of pig production process

traits. Alternative immunocastration enhances carcass trait response; further research on the age of application of this protocol and its potential effects is required.

Acknowledgments and conflict of interest

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