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Effects of Surgical and Immunological Castration on Pork Quality and Composition: A Meta-Analysis

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Abstract

This systematic review and meta-analysis, conducted in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses, quantified the effects of surgical and immunological castration on pork quality, chemical composition, and fatty-acid profiles. A total of 18 studies published between 2010 and 2021 met the predefined inclusion and exclusion criteria. Treatments included surgical castration, immunocastration (standard or delayed), and uncastrated pigs (control). Outcomes were pH at 0 and 24 h postmortem; color (lightness, redness, and yellowness); backfat thickness; shear force; moisture; protein; intramuscular fat; and saturated, monounsaturated, and polyunsaturated fatty acids. Both surgical castration and immunocastration produced higher lightness ($p < .05$), greater backfat, and increased intramuscular fat relative to uncastrated pigs. Pork from immunocastrated pigs showed reduced redness, while surgical castration pork exhibited higher saturated fatty acids and monounsaturated fatty acids levels. Immunocastration produced lighter, less red meat, and increased saturated fatty acids, whereas surgical castration primarily increased intramuscular fat. Monounsaturated fatty acids responses were driven by secondary factors, and polyunsaturated fatty acids were unaffected.

Keywords: immunocastration; surgical castration; pork quality; intramuscular fat; fatty-acid profile.

Practical Application: These findings translate castration choices into predictable, market-relevant product attributes. Producers can align protocols with specification targets while also responding to consumer welfare concerns. The findings could also guide processors, retailers, and policymakers in refining quality standards, labeling claims, and welfare regulation.

1 INTRODUCTION

The sex odor (boar taint) of pork affects its sensorial acceptability. This odor results from concentrations of skatole in adipose tissues and the enzymatic and immunological components of this residue, which accumulate in the adipose tissue of uncastrated animals (Kumar & Umapathy, 2023). Castration has been used to mitigate the accumulation of skatole residues and thus has made pork acceptable to consumers (Bonneau & Weiler, 2019; Lervik et al., 2013).

Surgical castration should be performed within the first 7 days of life, when the animal's pain sensitivity is lower and its blood vessels still have a small diameter. However, it affects the piglet's well-being and physiological development, reducing the frequency of voluntary food consumption after surgery, lengthening the required recovery time, and increasing the possible occurrence of secondary infections (Llamas Moya et al., 2008). Since the end of the last century, immunization against the gonadotropin-releasing hormone (GnRH), or immunocastration (IC), has been used as a safe, effective castration protocol (CP) (Hennessy et al., 2009) that results in up to 70% shrinkage of the reproductive system and blockage of its endocrine activity (Thompson, 2000).

A census carried out in 24 European countries in 2018 has shown that 34% of all pigs produced were uncastrated animals, 63% were surgically castrated animals, and only 2.8% were immunocastrated animals (Backus et al., 2018). It is estimated that around 20 million piglets are castrated each year in Mexico (Morgado Cruz, 2020).

While surgical castration (SC) is 33 times cheaper than IC, it has been observed to result in up to 14% more deaths during lactation than the latter, which results in 5% less mortality. Based on these data, the cost of SC in 2019 was around USD $120 per head, while the cost of IC was USD $0.1375 per head (Morgan et al., 2019).

According to Grela et al. (2020), IC results in tougher pork (i.e., pork requiring a greater cutting force) and more

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intramuscular fat deposits than SC; moreover, they assert that it results in a lower percentage of protein than SC. Other studies find no differences in the physicochemical and technological characteristics of pork when using alternative IC protocols despite variations in the age when the latter takes place and the time expiring between doses (Gallegos-Lara et al., 2015). Škrlep et al. (2012b) show that both IC and SC have the same effect ($p > .05$) on pH, color traits (brightness, redness, and yellowness), and on water loss in pork.

It has also been observed that immunization against GnRH affects fatty-acid concentrations in pork, altering the distribution of adipocytes based on the latter's lipogenic enzyme activity and cellular histomorphology, as well as fatty-acid distribution concentration when the second dose is administered after the animal is over 16 weeks old (Poklukar et al., 2020).

The meta-analysis of the results published on the effects of castration protocols (CPs) on pork shows the impact of IC on traits such as intramuscular fat (IMF) and cutting force, comparing the effects of immunization against GnRH on uncastrated pigs (UP) and surgically castrated pigs with restricted diets (Batorek et al., 2012). Pauly et al. (2012) observed significant differences ($p < .05$) in pork traits influenced by IC, including pH, lightness, cutting force, and concentrations of saturated, monounsaturated, and polyunsaturated fatty acids (SFA, MUFA, and PUFA). Although Kress et al. (2019) stress the benefits, in terms of behavior, well-being, and productive traits, of producing immunocastrated pigs, their review contains no quantitative analysis determining the comparative effects of different CPs.

The methodology of the abovementioned studies focused on IC without taking into account whether the procedure was carried out before puberty as part of a standard immunization protocol, after puberty as part of a late immunization protocol, or close to the slaughtering age, which can alter the response to this castration method in terms of the quality, and nutritional composition of the pork (Poklukar et al., 2021; Zoels et al., 2020). This meta-analysis examined the impact of surgical and immunological castration and compared with intact (uncastrated) pigs, on pork quality, chemical composition, and fatty-acid profiles.

1.1 Relevance of the work

This work consolidates a decade of evidence to clarify how castration protocol measurably shifts pork quality and composition relative to intact (uncastrated) males. By quantifying these effects across the literature via meta-analysis, it gives producers, processors, and regulators a clear, evidence-based map to balance product attributes with welfare considerations. Relevant findings of the study were: immunocastration yields lighter, less red meat with higher saturated-fat levels, whereas surgical castration increases intramuscular fat and monounsaturated fat content.

2 MATERIAL AND METHODS

The study adhered to the guidelines for Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and includes a bibliographical review of publications relating to the different CPs (SC, immunization against GnRH, and UP).

The methodological procedures included: (1) search for information; (2) systematic review; (3) quantitative synthesis; (4) analysis categories; and (5) statistical analysis.

2.1 Search for information

A literature search (January 1994–August 2022) in PubMed, Scopus, Web of Science, ScienceDirect, Meat Science, and Google Scholar identified studies assessing how surgical and immunological castration affects pork quality, chemical composition, and fatty-acid profiles.

Electronic searches used keywords related to pork quality, IC, and nutrient composition, combined with species terms such as "pig" and "pork" (Figure 1). Only peer-reviewed articles published in indexed journals in biological sciences, animal production, and meat-pork science, and technology were included.

2.2 Systematic review

A total of 299 articles were retrieved; 79 employed similar methodologies to assess CPs and their effects on pork quality and nutritional composition. Predefined inclusion and exclusion criteria were then applied to these 79 articles during the full-text review as part of the study-selection process before statistical analysis (Figure 2).

The studies included were ones that:

- Mainly dealt with surgical and immunological CPs and the use of UP;
- Used pigs devoted to supply and consumption as research subjects;
- Included pigs with a terminal genetic base or habitually consumed breeds among their subjects;
- Presented results pertaining to pork quality, chemical composition, and fatty-acid concentrations;
- Came from different countries;
- Came from different educational institutions or government entities.

Also excluded were studies:

- That used a treatment other than surgical and immunological castration;
- That used research subjects not destined for consumption, or supply or production processes;
- That dealt with social aspects or animal well-being;
- Whose results lacked parametric data or measures of dispersion;
- That reported qualitative nonparametric results.

2.3 Quantitative synthesis

Of the 79 articles reviewed, 18, published between 2010 and 2021, were chosen for analysis (Table 1); moreover, after reviewing the data, the following four study groups were identified:

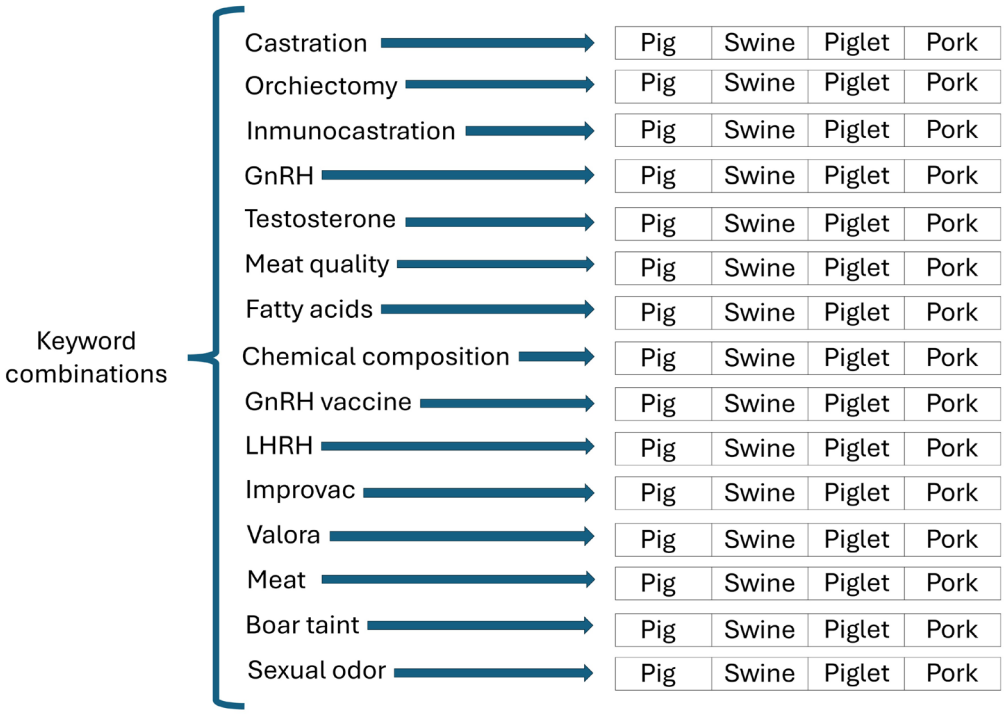


Figure 1. Initial literature search across electronic databases and meta-search engines.

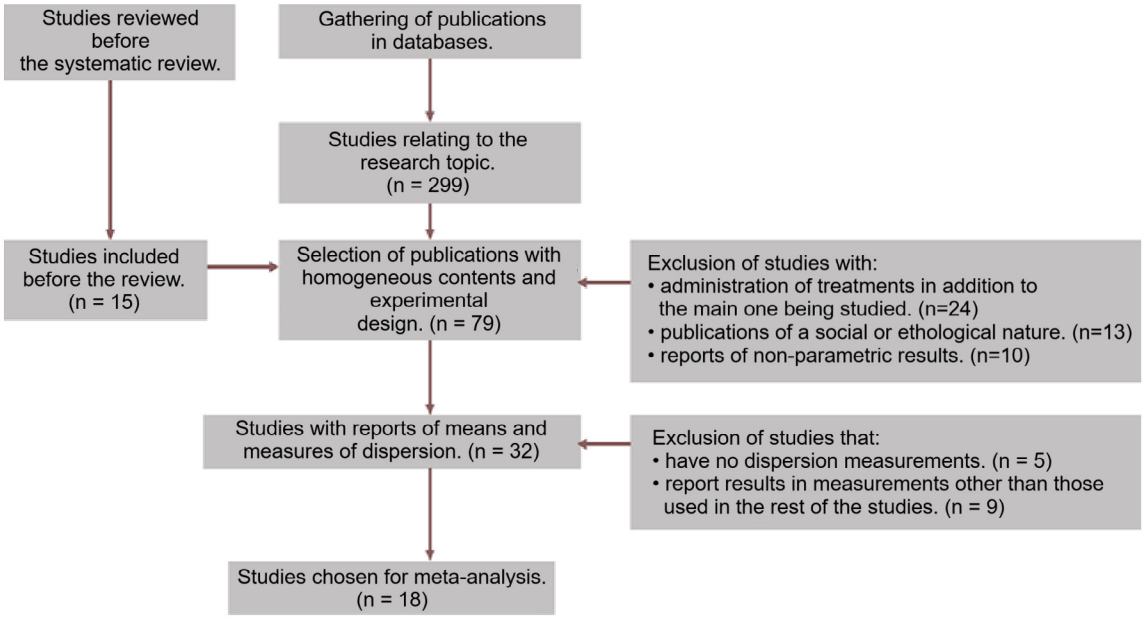


Figure 2. Process for choosing the analyzed studies.

- CPs: pigs that had been subjected to surgical or immunological castration.
- SC: pigs whose testicles had been surgically removed before they were 7 days old.
- IC: pigs treated with the manufacturer's immunization protocol, administered in two subcutaneous doses. The following two IC protocols were considered: (a) standard immunocastration (SIC), with the first dose having been administered when the pigs were 8 weeks old and the second one 4 weeks before slaughter and (b) late immunocastration (LIC), with the first dose having been administered when the pigs were between 12 and 16 weeks old and the second dose 4 weeks or less before slaughter.

Table 1. Details of publications chosen for the statistical analysis of the effects of different castration protocols on pork quality.

Author	*n*	Genetic line	Sex	Age at slaughter (weeks)	Group	Age when IC was carried out
Grela et al. (2020)	120	Polish Pulawska; Polish Zloynika	M	22	UP, SC, IC	LIC
Zoels et al. (2020)	25	Commercial	M	26	UP, SC, IC	SIC, LIC
Kyle et al. (2014)	120	Commercial	F, M	24	UP, SC, IC	LIC
Yuan et al. (2012)	40	Duroc·(Landrace x·LargeWhite)	M	25	SC, IC	LIC
Poklukar et al. (2021)	36	Landrace x pietrain	M	26	UP, SC, IC	LIC
Seiquer et al. (2019)	54	Iberian	F, M	31	UP, SC, IC	LIC
Lowe et al. (2014)	352	Commercial	M	25	SC, IC	LIC
Cai et al. (2010)	18	Large White	M	21	UP, SC	LIC
Morales et al. (2010)	69	Commercial	M	23	UP, SC, IC	LIC
Gamero-Negrón et al. (2015)	36	Commercial	F	33	UP, SC, IC	LIC
Lealiifano et al. (2011)	110	Large white x Landrace	M	22	UP, SC, IC	SIC, LIC
Škrlep et al. (2012a)	75	Large white x Landrace x Duroc	M	25	UP, SC, IC	LIC
Van den Broeke et al. (2016)	120	Commercial	M, F	20	UP, SC, IC	SIC
Oliviero et al. (2016)	50	Landrace x Large white, F2	M	25	UP, IC	LIC
Daza et al. (2016)	96	Duroc x (Landrace x Large white)	M, F	24	UP, SC, IC	SIC
Stupka et al. (2017)	80	Durocx (large white x Landrace)	M, F	20	UP, SC, IC	SIC
Škrlep et al. (2012b)	72	Fat Slovakian pigs x Duroc	M	24	UP, SC, IC	LIC
Andreo et al. (2018)	46	Commercial	M	23	UP, IC	LIC

F: female; M: male; IC: immunocastration; LIC: late immunocastration; SC: surgical castration; SIC: standard immunocastration; UP: uncastrated pigs.

- UP: pigs that have not been subjected to any kind of intervention during the production period and are used for control purposes (Silva-Santos et al., 2024).

Moreover, other relevant data, such as the age when castration was carried out and the animal's age at the moment when it was slaughtered, were gathered as part of the methodological approach pertaining to each study.

2.4 Analysis categories

The following three categories were established as reference points for the gathering and subsequent analysis of results when evaluating pork:

(a) Evaluation of the attributes of the carcass and the quality of the pork, concentrating on pork quality traits such as backfat thickness (mm), initial pH and, at 24 h, on color (L, a, b), lightness (0 to 100), redness (–60 a 60), yellowness (–60 to 60), and cutting force (kg).

(b) Chemical composition, taking into account the following traits when evaluating % of humidity, % of protein, and % of IMF.

(c) Concentrations (%) of fatty acids in the pork, differentiating between SFA, MUFA, and PUFA.

The analyses are based on comparisons focused on the effects of applying both CP to UP, as well as comparing SC to UP, and IC to UP, analyzing the mean and standard deviation for each studied trait.

To compile the database, each of the mean values per selected article was captured, with their respective standard deviations. Table 2 shows the weighted mean values for each trait described in the analysis categories.

Table 2. Reference values of the weighted mean values of the data obtained from the chosen articles, for each trait described in the analysis categories.

Trait	Treatment	*n*	Weighted average ± SD
Backfat thickness (mm)	uncastrated	687	13.56 ± 0.84
	surgically castrated	338	24.99 ± 3.86
	Immunocastrated	960	17.40 ± 1.04
Initial pH	uncastrated	164	6.17 ± 0.07
	surgically castrated	200	6.18 ± 0.05
	Immunocastrated	222	6.24 ± 0.04
pH at 24 h	uncastrated	524	5.52 ± 0.77
	surgically castrated	468	5.57 ± 0.54
	Immunocastrated	738	5.56 ± 0.51
L*	uncastrated	612	53.07 ± 5.62
	surgically castrated	498	48.83 ± 3.94
	Immunocastrated	730	61.89 ± 4.59
a*	uncastrated	612	10.52 ± 0.77
	surgically castrated	498	8.27 ± 0.67
	Immunocastrated	859	9.19 ± 0.51
b*	uncastrated	612	6.68 ± 0.51
	surgically castrated	518	6.33 ± 0.33
	Immunocastrated	839	5.67 ± 0.34
Cutting force (kg)	uncastrated	155	3.52 ± 0.13
	surgically castrated	354	3.14 ± 0.37
	Immunocastrated	315	3.07 ± 0.49
% humidity	uncastrated	73	71.52 ± 4.63
	surgically castrated	285	72.64 ± 14.72
	Immunocastrated	276	73.30 ± 16.3
% protein	uncastrated	73	24.81 ± 1.82
	surgically castrated	109	23.57 ± 0.93
	Immunocastrated	100	24.04 ± 0.91

Continue...

Table 2. Continuation.

Trait	Treatment	*n*	Weighted average ± SD
% intramuscular fat	uncastrated	61	2.31 ± 0.37
	surgically castrated	273	3.59 ± 0.63
	Immunocastrated	264	2.84 ± 0.53
% SFAs	uncastrated	139	35.86 ± 3.86
	surgically castrated	159	39.08 ± 2.35
	Immunocastrated	139	38.74 ± 2.73
% MUFAs	uncastrated	159	47.61 ± 4.37
	surgically castrated	139	49.72 ± 4.17
	Immunocastrated	139	49.28 ± 4.18
% PUFAs	uncastrated	159	14.37 ± 1.49
	surgically castrated	139	10.49 ± 1.13
	Immunocastrated	139	11.15 ± 1.19

MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; SD: standard deviation; SFA: saturated fatty acids.

2.5 Meta-analysis

The meta-analysis was carried out using R Studio software with the "meta" package (RStudio Team, 2020).

The standardized mean differences or treatment effect sizes (ES) were calculated based on the control groups (UP), using the dispersion measurements of the results (mean values, standard deviation, and number of observations) of each variable and trait studied in each publication. Subsequently, the combined effect sizes (CEs) from the various studies were analyzed, with a Hartung-Knapp random-effects adjustment being used as a truncation tool to adjust the standard error of the coefficients and the residual heterogeneity of the data (Pardo et al., 2009), considering: (a) the control groups and all the protocols (UP vs. CP), where, regardless of the CP, it was determined whether the CEs of the CP was different from zero; (b) the control group vs. the surgical-castration protocol (UP vs. SC), where it was determined whether the CEs of the SC was different from zero; and c) the control groups vs. the immunocastrated pigs (UP vs. IC), where it was determined whether the CEs of the IC was different from zero. The respective reliability intervals ($\alpha = 0.05$) for the CEs were calculated, and the heterogeneity of the test was calculated using the "Q" heterogeneity test and its heterogeneity indicators, heterogeneity coefficient (I2), and the combined variance of the CEs (T2) for both cases.

3 RESULTS

3.1 pH and color (L*a*b*)

The CEs of the pH, both initial and at 24 h, have shown no significant differences between the results for castrated pigs and those for UP ($p > .05$).

With regard to color traits, a significant CEs ($p < .05$) was observed in response of the CPs on pork lightness (L*), in UP vs. CP, and in UP vs. IC (Figure 3), indicating that castration produces paler meat ($p < .05$); in the a* value, the CEs were observed in PE vs. PC and in PE vs. IC, indicating that pork from UP is redder than pork from castrated animals ($p < .05$); for its part, the b* value had no significant CEs ($p > .05$), compared with pork from UP (Table 3 and Figure 4).

3.2 Cutting force and backfat thickness

No significant CEs ($p > .05$) were observed in any of the comparisons when analyzing cutting force, while the results regarding backfat thickness show a significant CEs ($p < .05$) in UP vs. CP and UP vs. IC, indicating a higher fat content in pork from castrates than in pork from UP (Table 3 and Figure 5).

3.3 Chemical composition

The results for chemical castration do not show any CEs stemming from the use of castration protocols on humidity or pork-protein percentages ($p > .05$). However, the intramuscular fat content had a significant CEs ($p < .05$) on UP vs. CP and UP vs. SC, which implies a greater intramuscular fat content due to these CPs.

3.4 Concentration of fatty acids

The CPs had a positive CEs on the concentrations of SFAs, which are greater in CP and IC than in UP ($p < .05$). A higher concentration of MUFAs was observed in CP than in UP ($p < .05$); moreover, the fact that PUFA concentrations showed no significant CEs ($p > .05$) due to the CPs on UP indicates that the concentrations of these fatty acids are not affected by the CPs (Table 3 and Figure 5).

4 DISCUSSION

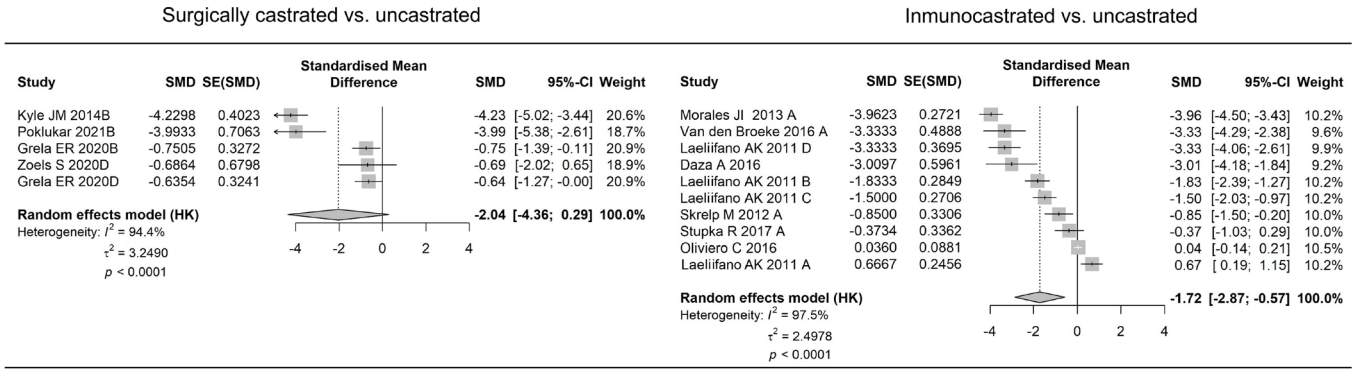
4.1 pH and color (L*a*b*)

The importance of pH as a pork quality trait lies in the variation of its values at 45 min and 24 h after slaughter. This study demonstrates that castration does not alter the pH of the pork, considering that the preslaughter conditions reported in the studies analyzed fostered the well-being of the animals (Botelho-Fontela et al., 2024; Faucitano & Nannoni, 2023).

As previously noted, preslaughter handling and resultant stress play an important role not only in lowering pH after the animal's death, but also in how this lowering of pH influences color due to the denaturation of the muscle proteins during the transition from muscle to pork, where a rapid decrease in pH, is more likely to result in paler pork (Terlouw et al., 2021).

The types of fiber that make up muscle mass play an important role in the color of meat. Yu et al. (2017) found that immunocastrated pigs had fewer oxidative (type I, red) muscle fibers than glycolytic (type II, white) fibers. The myoglobin concentration of these fibers impacts color measurements under the light spectrum, as highlighted in this study. However, surgically castrated pigs showed the lightest meat among CPs, but this was not a decisive factor for the trait. Thus, other factors influencing this outcome should be investigated in animal rearing and processing practices.

The impact of IC on the redness of pork may also depend on the type of fiber that makes up the muscle prior to slaughter.



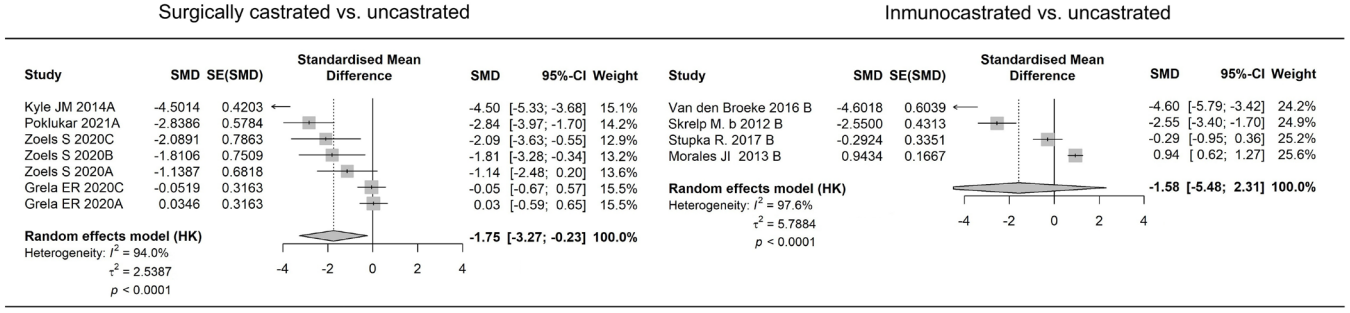
SMD: standardized mean difference; SE: standard error; HK: Hartung–Knapp adjustment.

Figure 3. Forest–plots in lightness analysis (L*).

Table 3. Summary of the meta-analysis results.

	Uncastrated vs. Castrated					Uncastrated vs. Surgically Castrated					Uncastrated vs. Immunocastrated				
Trait	***n***	**Standardized mean difference**	**Confidence intervals (95%)**	***I²***	***P (CEs)***	***n***	**Standardized mean difference**	**Confidence intervals (95%)**	***I²***	***P (CEs)***	***n***	**Standardized mean difference**	**Confidence intervals (95%)**	***I²***	***P (CEs)***
Initial pH	10	1.51	[−1.71; 4.72]	96	0.31	5	3.54	[−3.94; 11.03]	98	0.25	5	−0.40	[−0.93; 0.13]	45	0.10
pH at 24 h	16	−0.48	[−1.79; 0.83]	96	0.44	8	0.53	[−1.63; 2.69]	94	0.58	9	−1.22	[−2.78; 0.34]	97	0.10
Color L*	19	−8.31	[−15.90; −0.72]	98	0.03	7	−0.66	[−2.30; 0.98]	94	0.36	12	−13.26	[−24.97; −1.54]	99	0.03
a*	19	10.17	[2.37; 17.97]	98	0.01	8	2.4	[−2.98; 7.78]	97	0.32	12	14.73	[2.89; 26.57]	99	0.01
b*	19	−2.42	[−7.73; 2.89]	98	0.35	8	1.71	[−2.00; 5.42]	97	0.31	12	−5.2	[−13.42; 3.03]	99	0.19
Cutting force (kg.)	11	0.02	[−0.37; 0.42]	68	0.89	5	0.06	[−0.74; 0.86]	73	0.84	6	0.00	[−0.64; 0.63]	70	0.99
Backfat thickness (mm)	14	−1.67	[−2.70; −0.65]	97	0.003	4	−1.58	[−5.48; 2.31]	98	0.28	10	−1.72	[−2.87; −0.57]	98	0.008
Humidity (%)	9	1.99	[−0.49; 4.47]	92	0.10	5	2.52	[−2.04; 7.09]	94	0.19	4	1.37	[−3.39; 6.14]	92	0.42
Protein (%)	7	−1.33	[−3.18; 0.51]	92	0.12	4	−1.51	[−5.13; 2.10]	94	0.27	3	−1.13	[−6.20; 3.93]	92	0.43
Intramuscular fat (%)	7	−2.62	[−4.68; −0.57]	93	0.02	4	−4.00	[−6.90; −1.10]	79	0.02	3	−0.78	[−2.54; 0.97]	67	0.19
SFAs (%)	12	−1.87	[−2.92; −0.81]	94	0.002	5	−2.03	[−4.36; 0.30]	94	0.07	7	−1.75	[−3.27; −0.23]	94	0.03
MUFAs (%)	13	−1.18	[−2.36; −0.01]	89	0.04	6	−1.56	[−4.24; 1.11]	93	0.19	7	−0.9	[−2.30; 0.51]	82	0.16
PUFAs (%)	13	2.44	[−0.09; 4.96]	96	0.05	6	3.67	[−2.58; 9.93]	98	0.19	7	1.37	[−0.30; 3.03]	90	0.09

*I^2: Coefficient of heterogeneity; SFAs: saturated fatty acids; MUFAs: monounsaturated fatty acids; PUFAs: polyunsaturated fatty acids.



SMD: standardized mean difference; SE: standard error; HK: Hartung–Knapp adjustment.

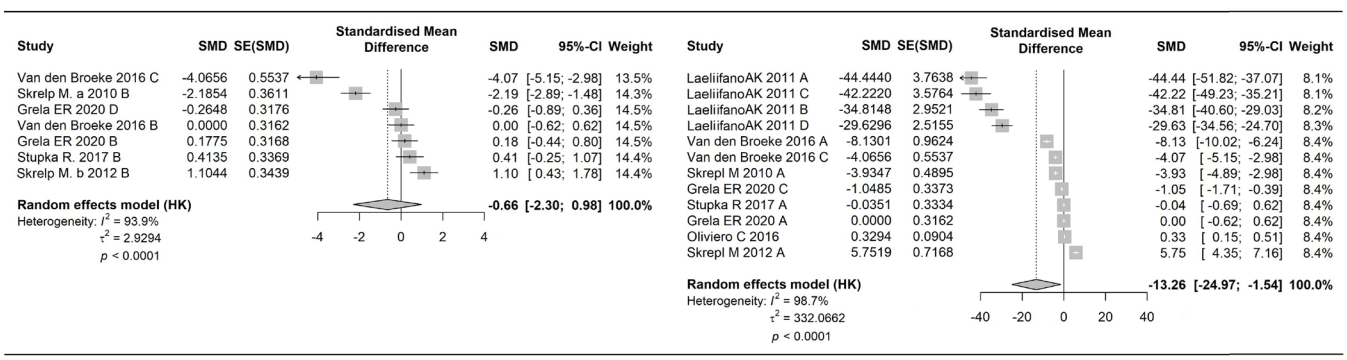
Figure 4. Forest plots in backfat thickness analysis.

The brightest-red pork is reported when the pig is between 5 and 25 weeks old, at which ages there is a greater proliferation of Type-1 fibers (Yu et al., 2017). However, the fact that the pork from surgically castrates is less red than that from UP is not directly related to the CP.

4.2 Cutting force and backfat thickness

These results show that CPs do not affect the toughness of pork, given that supply pigs are generally taken to the slaughterhouse at the relatively young age of 20 weeks, when they have more soluble collagen (Li et al., 2022).

Furthermore, although increased backfat thickness owing to castration is directly associated with such handling (Batorek et al., 2012; Pauly et al., 2012), this study shows that, while SC results in thicker backfat compared to uncastrated males, the said protocol does not play a decisive role in this trait as asserted by Shi-Zheng and Su-Mei (2009), being attributable to other factors such as diet or age at slaughter.



SMD: standardized mean difference; SE: standard error; HK: Hartung–Knapp adjustment.

Figure 5. Forest plots in the analysis of saturated fatty acids (SFAs).

4.3 Chemical composition

Despite the increase in the intramuscular fat content due to the CPs, since the time when IMF is deposited does not vary, the adipose tissue continues to be deposited after the animal is 20 weeks old, while, as also found in previous studies (Burnett et al., 2020), the muscles stop developing (Cicarelli et al., 2017).

Although the effects observed in the IC analysis cannot be directly attributed to that procedure, since it has no significant effect on the study described here, the smaller amounts of adipose tissues present in UP—as opposed to that occurring in surgically castrated animals, which become less physically active and are involved in less fights and aggressions in their pens after castration—can be attributed to behavioral changes during the rearing period, at the end of which less lesions can be seen at the end of the fattening phase (Bonneau & Wellier, 2019).

Since neither SC nor IC affects the amount of humidity in pork, the relationship between the amount of interstitial water and the amount of IMF is not prejudiced by these CPs (Xia et al., 2023), and likewise, the percentage of protein remains within acceptable limits.

4.4 Concentration of fatty acids

The observed effects of IC on SFA concentrations can be attributed to the changes in the physiological process of adipose-tissue deposition, as mentioned earlier (Poklukar et al., 2020), taking into account the fact that increased fatty-acid concentrations in the muscles of UP occur with the onset of puberty at an age of around 20 weeks (Cicarelli et al., 2017), when actual IC has been completed with the administration of a second dose of the immunogen against GnRH, which is why, in the analyzed studies that contemplate a slaughtering age of over 22 weeks, one can observe such changes in adipose-tissue metabolism caused by the mobilization and concentration of fatty acids upon castration, while a large proportion of the adipose tissue in surgically castrated pigs is to be found in the visceral fat, the increase in subcutaneous fat occurs towards the end of the fattening period, causing more SFAs to be concentrated in the subcutaneous fat than in the muscles (Poklukar et al., 2020).

Moreover, the results of this study show that the implementation of SC and IC protocols does not, per se, lead to an increase in the MUFA deposits (Koćwin-Podsiadła et al., 2006), since other factors such as diet—i.e., its nutritional components and their uptake—may have an influence on these fatty acids (Bonneau & Wellier, 2019), while the CPs did not affect the concentrations of PUFA in pork, given that the concentrations of these fatty acids are mainly due to natural causes (Suman & Joseph, 2013).

5 CONCLUSIONS

The castration type modulates pork quality and composition relative to intact males. IC yields lighter, less red meat and increases the proportion of SFA, whereas SC primarily elevates IMF. While both protocols affected MUFA, this effect is also mediated by additional factors. Neither protocol alters PUFA.

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