



Effects of surgical and chemical castration on growth performance and meat quality of boars

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Growing animal welfare concerns have intensified the need for effective and humane alternatives to surgical castration for the control of boar taint in pig production. The study investigated the effects of different castration methods on growth performance, physiological status, and meat quality of boars. Surgical castration and chemical sterilization using intratesticular administration of Canophen-B were compared with intact males. Experiments were conducted on Large White boars under controlled feeding and housing conditions in accordance with animal welfare and bioethical standards. In the first experiment, chemically sterilized and intact sexually mature boars showed similar live body weight and average daily gain. Chemical sterilization resulted in a significant reduction in serum testosterone concentration, while hematological parameters remained within physiological reference ranges, indicating no adverse effects on animal health. Sensory evaluation demonstrated that meat and broth obtained from chemically sterilized boars were free of specific odor, whereas samples from intact males exhibited a characteristic odor, particularly in broth. In the second experiment, surgically castrated boars had lower final live body weight compared with chemically sterilized and intact males. Meat yield was higher and fat yield was lower in intact and chemically sterilized boars than in surgically castrated animals. Serum testosterone levels at the end of the fattening period were highest in intact males, intermediate in chemically sterilized boars, and lowest in surgically castrated animals. Hematological indicators in all groups remained within normal physiological limits. Sensory evaluation of cooked meat revealed no statistically significant differences among experimental groups for odor, color, tenderness, taste, texture, or fibrousness. However, broth prepared from chemically sterilized boars showed significantly higher scores for transparency compared with intact males, while other sensory attributes did not differ significantly. The results indicate that chemical sterilization effectively suppresses testosterone synthesis without negatively affecting growth performance, health status, or sensory quality of meat. The absence of boar taint in products obtained from chemically sterilized males suggests that this method can be considered a viable alternative to surgical castration in pig production, combining acceptable meat quality with improved animal welfare.

Keywords: male pigs; chemical sterilization; testosterone levels; hematological parameters; boar taint; organoleptic properties.

Introduction

Pig production is a key component of agricultural systems in many countries worldwide, and its efficient development contributes to progress toward the Sustainable Development Goals, particularly Goal 2: “Zero Hunger” (Visetnoi & Nelles, 2023; Sorooshian, 2024). However, sustainability achieved within a single production sector does not necessarily ensure sustainability at the system level. Therefore, the swine industry must simultaneously improve environmental and economic efficiency, safeguard animal health and welfare, and align scientifically grounded production practices with societal expectations, as social acceptance is crucial for its long-term development (Goncharov et al., 2013; Bilan et al., 2017; Vonderohe et al., 2022).

One of the major challenges in pig production concerns the fattening of male pigs and the quality of products derived from their slaughter (Xia et al., 2023; Pereira-Pinto et al., 2025). It has been well established that intact male pigs, compared with surgically castrated counterparts, exhibit superior growth performance and feed efficiency, resulting in the production of lean pork with reduced fat content (Bonneau & Weiler, 2019; Aluwe et al., 2022; Botelho-Fontela et al., 2024). However, the most frequently reported drawback associated with pork obtained from intact males is the occurrence of a characteristic off-odor, primarily caused by the accumulation of androstenone, particularly in adipose tissue. This steroid hormone, together with skatole – a product of bacterial degradation of the amino acid tryptophan in the large intestine – contributes to the unpleasant odor commonly referred to as boar taint (Wauters et al., 2017; Aluwe et al., 2020; Duarte et al., 2021). To mitigate this issue, several research strategies have been explored, including the rearing of male pigs to

market weight under intensive feeding conditions prior to the onset of puberty (Borell et al., 2020); selective breeding based on genetic studies aimed at reducing or eliminating 5 α -androstenone secretion (Mote & Rothschild, 2020; Squires et al., 2020; Larzul, 2021); immunization using steroid hormones such as testosterone, testosterone-protein conjugates, and 5 α -androstenone (Williamson & Patterson, 1982; Wauters et al., 2015); as well as immunocastration with commercial vaccines including Improvac[®], Improvest[®], Vivax[®], and Innosure[®] (Nautrup et al., 2018; Skrllep et al., 2019; Skrllep et al., 2020; Djurkin Kušec et al., 2021). Although these approaches have demonstrated scientific and practical value, the problem remains unresolved, providing a strong rationale for further investigation in this field.

At present, researchers from many countries are actively working in this field. Although surgical castration remains the most reliable method for ensuring high-quality pork from male pigs during subsequent fattening, its use has been steadily declining due to increasing animal welfare requirements and concerns regarding humane treatment (Weiler et al., 2021).

One alternative approach to surgical castration involves rearing male pigs and slaughtering them before the onset of sexual maturity, or applying specific housing and management conditions to obtain the desired production outcomes (Bonneau et al., 2018; Bonneau & Weiler, 2019). Fattening and slaughtering intact males prior to puberty represents a strategy to prevent boar taint and puberty-related aggressive behavior. This practice eliminates the need for surgical castration, thereby improving animal welfare, but requires strict management to prevent premature accumulation of odor-causing compounds such as androstenone and skatole. Slaughter before sexu-

al maturity, typically at a body weight of approximately 85–100 kg, has been shown to be an effective method for producing high-quality pork free from unpleasant odors associated with male sex hormones (Bee et al., 2020; Borell et al., 2020; Pereira-Pinto et al., 2025).

At the same time, immunocastration of male pigs has gained increasing attention as a promising alternative strategy. Zamaratskaia et al. (2008), conducted a study on pigs of a Swedish population and consisting of two experimental trials, the effect of gonadotropin-releasing hormone (modified Improvac®, Pfizer Ltd.) on the content of testosterone levels in plasma and androstenedione, skatole and indole in the fat of surgically castrated, immunovaccinated and intact male pigs. Immunization resulted in a marked reduction in testicular weight and bulbourethral gland length, as well as significantly decreased concentrations of testosterone and estrone sulfate (E1S) in plasma and androstenedione, skatole (below 0.2 µg/g), and indole in fat tissue. In contrast, intact boars exhibited skatole concentrations exceeding acceptable thresholds. The lean meat content of immunocastrated males was slightly higher than that of surgically castrated pigs but lower than that observed in intact males (Zamaratskaia et al., 2008).

Moreover, Grell et al. (2020) emphasized that immunocastration represents a significant technological advancement, as it is nearly painless, easy to perform, and effectively addresses increasingly important animal welfare concerns. Their study demonstrated that, compared with surgical castration, immunocastration improved growth performance and feed conversion efficiency, while maintaining meat quality parameters within acceptable standards. These findings are further supported by other studies confirming that pork obtained from immunocastrated males meets established quality requirements (Čanek-Potokar et al., 2017).

According to Kress et al. (2019), immunocastration represents a method with the potential to replace surgical castration of piglets. The authors propose a two-step vaccination protocol designed to induce the production of antibodies that temporarily suppress testicular function and prevent the development of boar taint. Following the second vaccination, immunocastrated males are considered to transition from a boar-like physiological status to a state comparable to that of surgically castrated pigs.

In a study by Aluwe et al. (2016), a total of 180 pigs were used, including 60 gilts, 60 male pigs vaccinated six weeks before slaughter (IM-6), and 60 male pigs vaccinated four weeks before slaughter (IM-4). The average slaughter weight did not differ substantially among the experimental groups. The results demonstrated that daily feed intake, average daily gain, and feed conversion ratio did not differ significantly between the IM-6 and IM-4 groups. Gilts exhibited a higher lean meat content compared with both immunocastrated groups. Meat quality and sensory characteristics did not differ significantly between the IM-6 and IM-4 groups, and carcass traits met established quality requirements.

In a survey conducted between April and June 2020 using an online questionnaire in 16 countries (with more than 175 respondents per country), consumer (n = 3251) and stakeholder (n = 1027) attitudes toward surgical castration without pain relief, surgical castration with anesthesia, immunocastration, and the production of intact male pigs were assessed (Aluwe et al., 2020). Surgical castration without pain relief was immediately rejected due to its severe violation of animal welfare principles and showed the lowest level of acceptance (32%). The acceptance rates for alternative strategies aimed at controlling boar taint were as follows: surgical castration with anesthesia was accepted by 85% of respondents, immunocastration by 71%, and early slaughter of intact males by 49%.

According to Lin-Schilstra et al. (2021), surgical castration of male piglets for the prevention of boar taint can be replaced by three more ethically acceptable approaches: the use of analgesia and anesthesia during and after castration, the fattening and early slaughter of intact males, and vaccination-based strategies. However, to date, only six countries have enacted legislation banning castration, and pork producers in these countries have adopted different alternative practices. Consequently, the search for new and more effective methods to reduce the characteristic odor of male pigs in slaughter products remains a highly relevant and pressing issue.

The aim of the study was to determine the effects of different castration methods in boars – namely surgical castration and chemical sterilization using Canophen-B administered by intratesticular injection into the testicular parenchyma – on growth performance and the quality of slaughter products, in comparison with intact males.

Materials and methods

The experiments were conducted on male pigs of the Large White breed at the Research Institute of Pig Breeding and Agro-Industrial Production of the National Academy of Agrarian Sciences of Ukraine. All experimental procedures were carried out in accordance with the ethical guidelines for animal research established by the First National Congress on Bioethics (Kyiv, 2001). Particular emphasis was placed on ensuring animal welfare throughout the study. Boars were housed in groups in pens providing adequate space in accordance with veterinary and zoohygienic requirements: animals with a live weight of 30–50 kg were allocated 0.6–0.8 m² per head, those weighing 50–85 kg were provided with 0.8–1.0 m², and animals weighing 85–110 kg were allotted 1.0–1.2 m² per head, ensuring sufficient space for movement and resting. Adequate access to feed was provided for all experimental animals. In addition, suckling piglets were supplied with a comfortable resting area equipped with infrared heating lamps.

During the experiment, blood samples for genetic analysis were collected using procedures specifically designed to minimize discomfort and stress. The health status and general condition of the animals were carefully monitored throughout the entire experimental period to ensure compliance with animal welfare standards. Furthermore, the research team adhered to the principles of the 3Rs (Replacement, Reduction, and Refinement) as established in the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (Strasbourg, 1985). This approach minimized potential stress, improved sampling accuracy, and prevented unnecessary procedures.

The first experiment was conducted on 12 sexually mature male pigs with a body weight of 90–91 kg, which were divided into two groups of six animals each. To assess clinical status and serum testosterone levels, blood samples were collected from all animals prior to treatment. In order to suppress testosterone secretion by Leydig cells, six males were chemically sterilized by intratesticular injection of Canophen-B at a dose of 10 mL per testis. Repeated blood sampling was performed seven days after treatment. The preparation used in the study, Canophen-B, contains sodium hydroxide, potassium hydroxide, and phenolphthalein (at an appropriate titration) and is approved for veterinary use by the relevant veterinary pharmaceutical authority.

The second experiment was conducted in accordance with generally accepted pig fattening methodologies to evaluate the productive and slaughter characteristics of surgically castrated, chemically sterilized, and intact male pigs. For this purpose, analogous animals aged five months with an initial body weight of 57–59 kg were selected and allocated into three groups of 11 animals each. Chemical sterilization was performed at the beginning of the experiment when the boars reached 5.5–6.0 months of age.

Blood samples for biochemical analysis were collected in the fasted state from the marginal ear vein at the beginning and at the end of the experimental period to determine clinical blood parameters and serum testosterone concentration. Testosterone levels were measured using a radioimmunoassay with a double-isotope labeling technique, employing a commercial immunoassay reagent kit for testosterone determination in serum/plasma (Hema, Ukraine). Clinical blood parameters, including erythrocyte count, hemoglobin concentration, and leukocyte differential (neutrophils, lymphocytes, monocytes, eosinophils, and basophils), were determined using a multifunctional hematology analyzer AI-100VET (Awalife, China).

Feeding of pigs during the fattening period was carried out in accordance with the norms (Ibatullin et al., 2016). The diet of fattening male pigs was adjusted according to their live body weight. Boars with a body weight of 60–70 kg received 35.5 MJ of metabolizable energy, 435 g of crude protein, 20.8 g of lysine, 12.8 g of methionine

+ cystine, 21.0 g of calcium, and 17.5 g of phosphorus per day. Boars weighing 70–80 kg were provided daily with 38.2 MJ of metabolizable energy, 438 g of crude protein, 21.0 g of lysine, 12.4 g of methionine + cystine, 21.8 g of calcium, and 18.0 g of phosphorus. Animals with a body weight of 80–90 kg received 40.3 MJ of metabolizable energy, 463 g of crude protein, 22.2 g of lysine, 13.1 g of methionine + cystine, 23.0 g of calcium, and 19.0 g of phosphorus per day. Boars weighing 90–100 kg were fed diets containing 43.5 MJ of metabolizable energy, 499 g of crude protein, 23.9 g of lysine, 14.1 g of methionine + cystine, 24.8 g of calcium, and 20.5 g of phosphorus. Animals with a body weight of 100–120 kg received 46.6 MJ of metabolizable energy, 535 g of crude protein, 25.6 g of lysine, 15.2 g of methionine + cystine, 26.6 g of calcium, and 22.0 g of phosphorus.

Control slaughter of the experimental animals followed by sensory evaluation of meat and broth was carried out at the Poltava Meat Processing Plant (Ukraine). Fattening performance parameters recorded during the experiment included live body weight (kg) and average daily gain (g). Meat productivity traits were evaluated after slaughter and included carcass meat yield (%), carcass fat yield (%), and loin eye area (cross-sectional area of the longissimus dorsi muscle, cm²). A sensory evaluation panel from a meat-processing plant, consisting of nine women and two men, conducted sensory analysis of meat and broth obtained from the experimental animals using a five-point scoring scale, following the methodology described by Font-i-Furnols et al. (2020, 2021) and Heyman et al. (2020). In cooked meat samples, the panelists evaluated the following organoleptic attributes: odor, color, tenderness after cooking, taste, texture, and fibrousness; for broth samples, the evaluated attributes included color, clarity, odor, and taste. In the first experiment, to ensure greater objectivity of the sensory assessment, meat samples from chemically sterilized boars were collected from two different muscles (m. longissimus dorsi and m. semimembranosus).

Statistical processing of productive and morphological traits was performed using SAS/STAT[®] 15.1 (SAS Institute Inc., USA, 2018). The tables present the arithmetic means and their standard errors ($\bar{x} \pm SE$). The obtained data were analyzed using analysis of variance (ANOVA) followed by Tukey's post hoc test. Differences were considered statistically significant at $P < 0.05$.

Results

In the first experiment, animals in the experimental and control groups had nearly identical live body weights at both the beginning and the end of the study, as well as almost identical average daily gains (Table 1). A slight transient swelling of the testes was observed in boars following the intratesticular injection; however, this did not affect their general physiological condition. At the beginning of the experiment, serum testosterone concentrations were nearly identical in all 12 animals, whereas after 49 days the level in sterilized males decreased by 8.426 nmol/L, corresponding to a 1.62-fold reduction compared with intact boars.

No significant differences were detected between the groups in hematological parameters (Table 2). Chemical sterilization did not adversely affect animal health or productive performance. All blood pa-

rameters remained within physiological reference ranges, indicating that the animals were clinically healthy both before and after sterilization.

Table 1

Live body weight, growth performance, and serum testosterone levels in experimental Large White boars ($n = 6$, $\bar{x} \pm SE$)

Parameter	Intact boars	Sterilized boars
Live body weight at the beginning of the experiment, kg	91.3 ± 1.1	88.8 ± 2.5
Live body weight at the end of the experiment, kg	123.3 ± 1.2	121.1 ± 2.8
Average daily gain, kg/day	0.660 ± 0.031	0.659 ± 0.069
Serum testosterone level at the beginning of the experiment, nmol/L	7.67 ± 4.33	9.29 ± 2.34
Serum testosterone level at the end of the experiment, nmol/L	22.1 ± 4.7	13.6 ± 4.3

Note: ANOVA revealed no significant differences among experimental groups ($P > 0.05$).

The sensory evaluation of coded samples of cooked meat and broth revealed differences in odor perception between intact and sterilized boars. According to female panelists, cooked meat from intact males did not exhibit a specific odor, whereas male panelists detected a characteristic odor in meat from intact animals. In contrast, meat obtained from sterilized boars was evaluated by all panelists as free of any specific odor. Similarly, the organoleptic assessment of broth demonstrated that broth prepared from meat of intact males exhibited a pronounced specific odor, whereas broth obtained from sterilized males was assessed as acceptable and free of off-odors (Table 3).

Sensory evaluation of meat broth revealed statistically significant differences between broths obtained from chemically sterilized and intact male pigs for all assessed organoleptic traits. For color, broth prepared from the longissimus dorsi muscle of sterilized was estimated by 0.95 points (26.4%) higher than that of intact males. A similar advantage was observed for the semimembranosus muscle, exceeding the intact group by 1.00 point (27.8%). The broth transparency showed similar trends: broth samples from sterilized male meat received higher scores compared to broth from intact male meat by 0.85 points (23.3%). Significant differences were also established for odor and taste. Odor ratings for broth from sterilized males exceeded those of intact males by 0.80 points (22.2%) for longissimus dorsi and by 0.95 points (26.4%) for semimembranosus. The most pronounced differences were recorded for taste: broth from the longissimus dorsi and semimembranosus muscles of sterilized males was scored higher by 1.15 points (33.8%) and by 1.40 points (41.2%) respectively than that of intact males. No statistically significant differences were observed between the two muscles within the group of sterilized males for any of the evaluated sensory attributes. Overall, these results indicate a clear improvement in sensory quality of meat broth derived from chemically sterilized males compared with intact males.

In the second experiment, the evaluation of growth and carcass performance indicators showed that, at the end of the experimental period, surgically castrated boars had a lower live body weight compared with chemically sterilized and intact males by 9.9 and 10.0 kg, corresponding to decreases of 10.3% and 10.4%, respectively (Table 4).

Table 2

Hematological parameters of experimental boars before and after sterilization and of age-matched intact control animals ($n = 6$, $\bar{x} \pm SE$)

Parameter	First period		Second period	
	intact males (control group)	males before sterilization (experimental group)	intact males (control group)	males after sterilization (experimental group)
Erythrocytes, $\times 10^6/\text{mm}^3$	5.46 ± 0.14	5.53 ± 0.08	5.78 ± 0.18	5.83 ± 0.15
Hemoglobin, g/dL	11.68 ± 0.37	11.89 ± 0.64	11.50 ± 0.23	12.29 ± 0.33
Leukocytes, $\times 10^3/\text{mm}^3$	15.33 ± 1.92	13.67 ± 1.24	13.36 ± 0.88	15.11 ± 1.97
Leukocyte differential:				
basophils, $\times 10^3/\text{mm}^3$	0.3333 ± 0.0015	0.1667 ± 0.0011	0.5022 ± 0.3012	0.3333 ± 0.0015
monocytes, $\times 10^3/\text{mm}^3$	5.50 ± 1.22	7.66 ± 0.88	5.83 ± 0.82	4.83 ± 0.67
eosinophils, $\times 10^3/\text{mm}^3$	3.49 ± 0.79	4.99 ± 1.23	5.19 ± 0.59	6.33 ± 0.87
band neutrophils, $\times 10^3/\text{mm}^3$	6.02 ± 1.77	6.01 ± 0.44	3.69 ± 0.59	3.16 ± 0.34
segmented neutrophils, $\times 10^3/\text{mm}^3$	35.45 ± 3.57	42.16 ± 5.13	45.45 ± 3.93	36.66 ± 2.89
lymphocytes, $\times 10^3/\text{mm}^3$	48.67 ± 4.55	39.00 ± 5.50	39.02 ± 3.84	48.66 ± 6.83

Note: see Table 1.

Table 3

Sensory scores of meat and broth samples obtained from experimental animals based on panel evaluation (n = 10, x ± SE)

Parameter	Sample type	Sensory scores of meat and broth samples obtained from			
		sterilized males (m. longissimus dorsi)	sterilized males (m. semimembranosus)	intact males (m. longissimus dorsi)	intact males (m. semimembranosus)
Odor, score	cooked meat	4.45 ± 0.16	4.60 ± 0.16	3.81 ± 0.32	3.76 ± 0.29
Color, score	cooked meat	4.59 ± 0.22	4.49 ± 0.22	4.19 ± 0.21	4.24 ± 0.37
Tenderness after cooking, score	cooked meat	4.35 ± 0.24	4.29 ± 0.15	4.41 ± 0.22	4.39 ± 0.28
Taste, score	cooked meat	4.42 ± 0.21	4.35 ± 0.14	4.05 ± 0.36	4.12 ± 0.11
Texture, score	cooked meat	4.05 ± 0.24	4.22 ± 0.13	4.39 ± 0.16	4.46 ± 0.17
Fibrousness, score	cooked meat	4.01 ± 0.23	3.90 ± 0.18	4.35 ± 0.15	4.36 ± 0.23
Color, score	broth	4.56 ± 0.22 ^a	4.59 ± 0.16 ^a	3.62 ± 0.16 ^b	3.61 ± 0.14 ^b
Clarity, score	broth	4.50 ± 0.17 ^a	4.54 ± 0.17 ^a	3.65 ± 0.17 ^b	3.64 ± 0.13 ^b
Odor, score	broth	4.41 ± 0.22 ^a	4.55 ± 0.16 ^a	3.56 ± 0.34 ^b	3.56 ± 0.29 ^b
Taste, score	broth	4.55 ± 0.28 ^a	4.80 ± 0.13 ^a	3.41 ± 0.27 ^b	3.46 ± 0.19 ^b

Note: different letters within a row indicate statistically significant differences between groups according to Tukey's HSD test ($P < 0.05$); absence of letters within a row indicates no statistically significant differences.

Table 4

Growth performance, carcass traits, and serum testosterone levels in experimental boars (n = 11, x ± SE)

Parameter	Surgically castrated boars	Chemically sterilized boars	Intact boars
Live body weight at the beginning of the experiment, kg	57.2 ± 3.3	58.9 ± 3.2	56.9 ± 3.2
Live body weight at the end of the experiment, kg	96.2 ± 2.3 ^a	106.1 ± 2.8 ^b	106.2 ± 3.8 ^{ab}
Meat yield, %	57.9 ± 5.2	59.3 ± 1.3	60.5 ± 3.2
Fat yield, %	29.1 ± 2.3	26.2 ± 1.0	24.2 ± 1.4
Loin eye area (longissimus dorsi muscle), cm ²	34.4 ± 1.1	36.3 ± 2.1	36.6 ± 2.8
Serum testosterone level at the beginning of the experiment, nmol/L	1.502 ± 0.859	2.032 ± 0.663	1.245 ± 0.012
Serum testosterone level at the end of the experiment, nmol/L	3.7 ± 1.2 ^a	11.1 ± 4.4 ^{ab}	21.6 ± 1.3 ^b

Note: see Table 3.

It was determined that intact and chemically sterilized boars exhibited higher meat yields than surgically castrated animals, by 2.5% and 1.3%, respectively, while fat yield was lower by 4.2% and 2.9%. The results of serum testosterone analysis indicated that hormone levels at the beginning of the experiment were nearly identical across all groups, with no statistically significant differences detected. After 114 days, serum testosterone concentrations were lower in surgically castrated boars by 17.97 nmol/L, corresponding to a 5.92-fold reduction, and in chemically sterilized boars by 7.45 nmol/L, or a 3.04-fold reduction, compared with intact males.

Hematological parameters remained within physiological reference ranges, indicating that animals in all experimental groups were clinically healthy (Table 5).

It was established that cooked meat from chemically sterilized and surgically castrated animals did not exhibit a specific odor. In contrast, both meat and broth from intact males were perceived as having a characteristic odor by male panelists and by four female panelists. However, despite the presence of this specific odor, female panelists assigned higher taste scores to the meat obtained from intact males (Table 6).

Table 5

Hematological parameters and leukocyte differential of experimental boars (n = 11, x ± SE)

Parameter	Surgically castrated boars	Chemically sterilized boars	Intact boars
Erythrocytes, ×10 ⁶ /mm ³	5.72 ± 0.18	5.72 ± 0.24	5.78 ± 0.11
Hemoglobin, g/dL	10.65 ± 0.08	10.54 ± 0.49	10.83 ± 0.37
Leukocytes, ×10 ³ /mm ³	18.2 ± 1.9	17.8 ± 2.8	18.2 ± 2.9
Erythrocyte sedimentation rate, mm/h	5.45 ± 1.19	4.75 ± 0.48	3.96 ± 0.41
Leukocyte differential:			
basophils, ×10 ³ /mm ³	1.245 ± 0.123	1.015 ± 0.019	1.333 ± 0.189
monocytes, ×10 ³ /mm ³	5.75 ± 0.12	5.02 ± 0.21	4.25 ± 0.55
eosinophils, ×10 ³ /mm ³	5.04 ± 1.47	4.03 ± 1.47	6.75 ± 1.25
band neutrophils, ×10 ³ /mm ³	6.75 ± 0.62	3.03 ± 0.40	4.03 ± 0.81
segmented neutrophils, ×10 ³ /mm ³	43.5 ± 3.8	39.5 ± 5.3	39.5 ± 2.9
lymphocytes, ×10 ³ /mm ³	38.0 ± 3.3	46.5 ± 6.7	44.2 ± 4.6

Note: see Table 1.

Table 6

Results of sensory evaluation of meat from experimental boars in the second experiment (n = 11, x ± SE)

Parameter	Sample type	Sensory scores of meat and broth samples obtained from		
		Intact boars	Chemically sterilized boars	Surgically castrated boars
Odor, score	cooked meat	4.63 ± 0.15	4.54 ± 0.15	4.11 ± 0.21
Color, score	cooked meat	4.62 ± 0.14	4.53 ± 0.16	4.63 ± 0.15
Tenderness after cooking, score	cooked meat	4.64 ± 0.15	4.54 ± 0.21	4.36 ± 0.24
Taste, score	cooked meat	4.73 ± 0.13	4.54 ± 0.16	4.36 ± 0.21
Texture, score	cooked meat	4.62 ± 0.16	4.27 ± 0.14	4.27 ± 0.14
Fibrousness, score	cooked meat	4.63 ± 0.21	4.28 ± 0.19	4.27 ± 0.14
Color, score	broth	4.18 ± 0.12	4.72 ± 0.14	4.11 ± 0.16
Clarity, score	broth	4.39 ± 0.01 ^a	4.72 ± 0.14 ^b	4.36 ± 0.15 ^{ab}
Odor, score	broth	4.54 ± 0.16	4.54 ± 0.16	4.45 ± 0.15
Taste, score	broth	4.17 ± 0.12	4.63 ± 0.15	4.54 ± 0.17

Note: see Table 3.

Sensory evaluation of boiled meat samples revealed no statistically significant differences among intact, chemically sterilized, and surgically castrated males for odor, color, degree of boiling, taste, con-

sistency, or fibrousness, indicating comparable sensory quality of cooked meat regardless of the applied treatment. In contrast, sensory assessment of meat broth identified a statistically significant differ-

ence for transparency. Broth prepared from meat of chemically sterilized males exceeded that of intact males by 0.32 points, corresponding to an increase of 7.4%. No significant differences were detected between chemically sterilized and surgically castrated males, nor between intact and surgically castrated males for this trait. Other broth characteristics, including color, odor, and taste, did not differ significantly among the experimental groups. Overall, these results indicate that the applied treatments had no adverse effects on the sensory properties of cooked meat and resulted in only minor differences in broth transparency.

Discussion

In the context of modern swine production, various alternatives to surgical castration have been proposed to address both animal welfare concerns and meat quality issues associated with boar taint. Among these approaches, chemical sterilization represents a compromise between maintaining productive performance and effectively reducing androgen-related effects. In comparison with surgical castration, chemical sterilization avoids invasive intervention and the associated pain and stress responses, while still achieving a significant suppression of testosterone synthesis (De Roest et al., 2009).

The results obtained in the present study indicate that chemical sterilization did not adversely affect the health status or productive performance of the experimental animals. All evaluated clinical and hematological parameters remained within physiological reference ranges throughout the experimental period, suggesting that the applied method was well tolerated and did not induce systemic disturbances. The absence of clinically relevant deviations both before and after sterilization confirms that the animals remained in a healthy physiological state during the study. These findings are consistent with previous reports demonstrating the safety of chemical sterilization in pigs, including studies conducted on Yorkshire (Large White) pigs of Indian selection (Vanlalmangaihsanga et al., 2019).

At the beginning of the experiment, serum testosterone concentrations were comparable among all experimental animals, indicating uniform endocrine status prior to treatment. However, a pronounced reduction in testosterone levels was observed in chemically sterilized males during the post-treatment period, with concentrations decreasing to nearly half of those recorded in intact males after 49 days. This decline reflects the effectiveness of the sterilization procedure in suppressing androgen production and is in line with findings reported in earlier studies (Zamaratskaia et al., 2008; Brunius et al., 2011).

The reduction in serum testosterone concentration observed in the present study plays a central role in improving meat quality, as testosterone is closely linked to the accumulation of boar taint compounds such as androstenedione and skatole. Lower androgen activity limits their synthesis and deposition in adipose tissue, which explains the improved sensory characteristics of meat and broth obtained from sterilized males. Similar relationships between androgen suppression and reduction of boar taint have been reported for both immunocastration and chemical castration approaches, supporting the physiological relevance of the observed effects (Squires et al., 2020; Fazarinc et al., 2023).

The observed hormonal changes can be explained by structural alterations in the testicular tissue, particularly in the Leydig cells, which are primarily responsible for testosterone synthesis. Histological examination of testicular parenchyma samples from sterilized males revealed degenerative and structural modifications of these cells, providing morphological evidence for the reduced endocrine activity. Similar histopathological changes following chemical or immunological castration have been described by other authors, supporting the proposed mechanism of action and confirming the biological plausibility of the obtained results (Sladek et al., 2018; Mitjana et al., 2020).

An important aspect of the present findings is the absence of negative effects on animal health and growth performance. Preservation of normal productive parameters indicates that chemical sterilization does not compromise metabolic processes or feed utilization, which is a critical consideration for commercial swine production. This distinguishes the method from traditional surgical castration, which is often

associated with reduced growth efficiency due to early suppression of anabolic hormones (Županjac et al., 2022; Hess et al., 2024).

From an animal welfare perspective, chemical sterilization aligns with current societal and regulatory trends aimed at minimizing painful procedures in livestock production. The high tolerability of the method, confirmed by stable clinical and hematological parameters, suggests that it can be considered a humane alternative capable of meeting both ethical expectations and production requirements (Garcia & McGlone, 2022; Dutt, 2025).

Taken together, these results indicate that chemical sterilization may represent a viable strategy for controlling boar taint while maintaining animal health, growth performance, and sensory quality of pork, thereby offering a potential alternative to surgical castration in modern swine production systems. Further studies focusing on optimization of dosage, timing, and long-term effects under commercial conditions are warranted to fully assess the practical applicability of this method in industrial swine production systems.

Conclusions

Chemical sterilization of male pigs at the age of 5.5–6.0 months can be considered a viable alternative to surgical castration, as it is consistent with contemporary principles of humane animal treatment and animal welfare. The procedure was well tolerated by the animals and did not negatively affect their general physiological condition, as confirmed by hematological parameters remaining within physiological reference ranges throughout the experimental period. Chemically sterilized boars maintained normal appetite, exhibited no signs of impaired health, and achieved final live body weights comparable to intact males (106.1 vs. 106.2 kg), while exceeding surgically castrated boars by approximately 10%.

Chemical sterilization resulted in a pronounced suppression of androgen activity. Serum testosterone concentrations in chemically sterilized boars were reduced by more than threefold compared with intact males by the end of the fattening period (11.10 vs. 21.62 nmol/L), indicating effective inhibition of testicular endocrine function. This hormonal suppression was sufficient to prevent the manifestation of boar taint in slaughter products.

Sensory evaluation conducted by trained tasting panels confirmed the absence of specific boar odor in both meat and broth obtained from chemically sterilized males. In contrast, products derived from intact males were more frequently associated with a characteristic odor, particularly in broth. Broth prepared from chemically sterilized boars received significantly higher scores for color, clarity, odor, and taste in the first experiment, exceeding those from intact males by 22–41%, depending on the evaluated attribute. In the second experiment, sensory properties of cooked meat did not differ significantly among treatment groups, while broth from chemically sterilized males demonstrated superior transparency.

Overall, the results indicate that chemical sterilization, when applied at the proposed age and followed by an appropriate interval before slaughter, effectively prevents boar taint without compromising growth performance, animal health, or sensory quality of pork, thereby representing a promising and welfare-friendly alternative to surgical castration in modern pig production systems.

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