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Effects of Immunocastration on Growth Performance, Body Composition, Meat Quality, and Boar Taint

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ABSTRACT

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The study objective was to evaluate the effect of immunocastration in the period between the first and second vaccinations and subsequently between the second vaccination and slaughter on growth performance, carcass composition, meat quality, and boar taint, and compare results in immunocastrated males (IC), uncastrated boars (UCM), surgically castrated barrows (CM), and gilts (FE). The study included 70 pigs of the Duroc × (Large White × Landrace) crossbreed. Upon the overall assessment of the selected fattening indicators (average daily gain, feed intake), significant differences between CM and the other groups were demonstrated. Meanwhile, no significant differences were found between the IC, UCM, and FE groups. In this test, immunocastrates showed no negative effect from the second vaccination in relation to those carcass value indicators evaluated in comparison with UCM and FE. CM showed adversely lower carcass value parameters compared the other groups. No significant differences in pH, meat colour, drip loss, shear force, and intramuscular fat were found. The values of these indicators obtained for IC converged with those measured in UCM and FE. It was demonstrated that immunocastration prevented the occurrence of undesired boar taint. Androstenone decreased by 77% and skatole by 71% in IC as compared to UCM.

Keywords: pig; castration; carcass value; androstenone; skatole

The requirement that good living conditions be ensured for farmed animals is gaining in importance across Europe. There is a discussion among the EU member states about the possibility to introduce a ban on surgical castration of pigs. Regulation No. 2008/120/EC determining the minimum standards for pig farming has been adopted on the basis of which the EU countries voluntarily undertake to stop the practice of boar surgical castration in 2018.

According to a number of experts, surgical castration, even if performed during the first week of a boar's life, is not only a stressful experience (Marsalek et al. 2015), but also constitutes a possible risk for infection. Surgical castration of males (boars) is routine and widely practiced on pig farms.

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Conventional castration, which is performed several days after birth and has been used for many years, is intended to prevent the development of boar gonads, minimize an aggressive behaviour, and subsequently eliminate the occurrence of boar taint which damages the sensory quality of pork meat (Bonneau and Squires 2004). Conventional castration can currently be replaced by castration under anaesthesia, fattening boars without castration, or immunological castration.

Immunological castration consists in vaccinating the animals using gonadotropin-releasing hormone (GnRH) in a modified form conjugated to protein which induces the creation of anti-GnRH (Thun et al. 2006; Zamaratskaia et al. 2008). The dosage used is 2 ml of the vaccine in the muscle behind the ear twice within a period of 4 weeks. The first dose is administered 8 weeks and the second 4 weeks before the anticipated slaughter. This method prevents the occurrence of boar taint while preserving the positive effects of testicular steroids and anabolic hormones occurring in males. Boars have greater genetic potential for protein and feed utilization storage and better feed utilization than barrows (Pauly et al. 2009). Immunological castration allows the requirements for meat production to be fulfilled while avoiding the occurrence of boar taint (Cronin et al. 2003), although the meat characteristics performance can differ between boars and immunocastrates. Differences in growth performance, carcass value, and meat quality have been confirmed (Lundstrom et al. 2009). The results obtained differ very much in relation to the breed or hybrid combination (D'Souza and Mullan 2002), feeding strategy (*ad libitum* or restricted), time of the second vaccination (4 and more weeks before slaughter), or housing type (group or individual) (Skrlep et al. 2010).

Although studies have recently been published addressing the effect of immunocastration in pigs on the development and elimination of boar taint (Millet et al. 2011; Batorek et al. 2012), the qualitative and quantitative parameters of the carcass value are also important. It has been documented that the carcass value of immunologically castrated boars can be significantly affected by the time interval between the 1st vaccination (V1) and the 2nd vaccination (V2), and especially by the time interval between V2 and slaughter. Some studies have found that until administering V2 the results achieved are similar to those for fattened boars (Pauly et al. 2009) but that the meat performance subsequently worsens. The differences between the results achieved in boars and immunocastrates can diminish, however, due to physical and sexual activity and thus poorer food consumption by fattened boars (Cronin et al. 2003).

Despite the described favourable effect of immunocastration on the level of boar taint, some authors describe an adverse post vaccination effect on growth performance and carcass value. The aim of this study, therefore, was to evaluate the effect of immunocastration in the period between V1 and V2, and subsequently between V2 and slaughter on the growth performance, carcass composition, meat quality, and occurrence of boar taint.

MATERIAL AND METHODS

Animals and management. The study included 70 pigs of the Duroc × (Large White × Landrace) crossbreed. The experiment was approved by the Ethics Committee of the Central Commission for Animal Welfare of the Ministry of Agriculture of the Czech Republic. The pigs were 66 days old at the start of the experiment and their mean weight was 28.7 kg. The test continued for 74 days up to the age of 140 days. The pigs were identified by means of electronic ear chips. The following four groups were created: group 1: boars (UCM, uncastrated males, n = 18); group 2: immunocastrates (IC, n = 16); group 3: barrows (CM, castrated males, n = 18); and group 4: gilts (FE, females, n = 18). The male pigs in group 3 were surgically castrated on the 5th day after birth. The boars in group 2 were treated with Improvac® containing 200 µg of GnRH-protein conjugate/ml in water adjuvant solution. Using a syringe, a dosage of 2 ml was administered subcutaneously at the base of the ear in accordance with the technical manual in two dates: when the pigs were 94 and 115 days old. All groups were housed in a single testing barn. Two pigs of the same sex were housed in each pen. The micro-climate, temperature, gas concentration, and humidity were controlled automatically and monitored at hourly intervals so as to correspond to the animals' needs. The animals were fed according to standard nutrient requirements (Simecek et al. 2000) using completed feed mixes identified as P1, P2, and P3 (Table 1). All pigs were fed by the same commercial diets. Feeding was *ad libitum* by means of self-feeders for the two pigs in each

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pen. The animals also had *ad libitum* access to water during the test fattening period.

Growth performance. In order to obtain the data describing the growth characteristics of the tested animals, the following measurements were regularly (at the same hour in weekly intervals) monitored in each animal: live weight in kg (LW), daily feed intake in kg (FI), feed conversion ratio in kg per each kg gained (FCR), and average daily gain in g (ADG).

Carcass value. Since V2 on day 115 of age till slaughter, the *musculus longissimus lumborum et thoracis* (MLLT) depth and area as well as backfat depths were measured using an ALOKA SSD 500 – MICRUS ultrasound probe (Hitachi Aloka Medical Ltd., Japan). The measurements were taken along the central back line as described by Sprysl et al. (2010). The fat depth (FAT1) in the lumbar back region, the fat depth (FAT2) in the chest region, and the loin depth (MUSCLE2) were measured (all in mm). On the basis of repeated measurements in the same regions before slaughter, the development of the monitored dimensions of FAT1, FAT2, and MUSCLE2 (Difference: Final – V2) were calculated. After termination of the test at the age of 140 days and the average LW of 105.8 kg, all pigs were slaughtered at the same day in order to assess the quantitative and qualitative carcass value. The pigs were fasted 24 h before slaughtering. All carcasses were then subjected to analysis according to Walstra and Merkus (1995). Immediately after slaughtering, the following indicators were measured in the individual pigs: carcass weight CW (kg), carcass lean meat ZP (i.e. using a two-point method ZP) (%), muscle depth ZP (mm), fat thickness ZP (mm), and loin eye area of MLLT (mm^2) as described by Citek et al. (2015). To assess the quantitative carcass value, regular slaughter analysis was performed 24 h *post mortem* on all 70 pigs from the study groups (IC, UCM, CM, FE). The following indicators were determined in the carcasses: ham subcutaneous fat (kg), ham intramuscular fat IMF (%), ham meat + bone (kg and %), shoulder subcutaneous fat (kg), shoulder IMF (%), shoulder meat + bone (kg and %), loin subcutaneous fat (kg), loin IMF (%), loin meat + bone (kg and %), neck subcutaneous fat (kg), neck IMF (%), and neck meat + bone (kg and %), weights of testicles and bulbourethral glands (g and %).

Table 1. Ingredients and nutrient composition of diets according to pig live weight

Item	Diets		
	P1	P2	P3
Average live weight (kg)	28.7–34.9	35.0–64.9	65.0–106.0
Components (g/kg)			
Barley	353	432	500
Wheat	440	400	378
Soybean meal	177	140	95
Fattening premix[1]	30	28	27
Chemical composition			
Dry matter (%)	88.79	88.68	88.59
Crude protein (%)	18.00	16.51	14.74
Fat (%)	1.75	1.75	1.76
Crude fibre (%)	3.59	3.68	3.72
Metabolizable energy (MJ/kg)	12.92	12.84	12.75
Amino acids (g/kg)			
Lysine	10.7	9.6	8.3
Methionine	3.1	2.9	2.7
Threonine	6.7	6.1	5.4

[1]vitamin–mineral premix provided per kg diet: 400 000 IU retinol, 66 000 IU cholecalciferol, 3600 mg α-tocopherol, 100 mg menadione, 60 mg thiamine, 150 mg riboflavin, 800 mg niacin, 375 mg Ca pantothenate, 100 mg vitamin B_6, 1 mg vitamin B_{12}, 15 000 mg choline chloride, 15 mg folic acid, 3500 mg Fe as $FeSO_4 \cdot H_2O$, 3600 mg Zn as ZnO, 3100 mg Mn as MnO, 330 mg Cu as $CuSO_4 \cdot 5H_2O$, 175 mg I as $Ca(IO_3)_2$, 15 mg Co as $2CoCO_3 \cdot 3Co(OH)_2 \cdot H_2O$, 13 mg Se as Na_2SeO_3, 25 000 FTU 6-phytase (EC 3.1.3.26), 220 g Ca, 20 g P, 50 g Na, 10 g Mg, 85 g lysine, 15 g methionine, and 15 g threonine

Meat quality. The physical qualitative carcass value characteristics were evaluated at the cut between the 13th and 14th ribs in the loin (i.e. MLLT) and ham (i.e. *musculus semimembranosus,* MS). The pH_{45} was measured using a model 330i pH meter equipped with a SenTix Sp pH electrode (both WTW, Weilheim, Germany) 45 min *post mortem*. Electrical conductivity was determined 50 min *post mortem* (EC_{50}) using a conductometer/pigmeter (Czech Technical University in Prague, Czech Republic). Meat and fat colour values (L* = lightness, a* = redness, b* = yellowness) were measured by CM-2500d spectrophotometer (Minolta, Japan), shear force by Instron 3342 (Instron, USA), and drip loss 24 h *post mortem* according to the method of VanLaack and Smulders (1992). The samples were stored at 5°C for 24 h. Representative MLLT samples were taken from the

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right half-carcass, stored in plastic bags at –80°C for maximally 3 weeks, homogenized, and then analyzed chemically. The contents of water (difference of the sample weight before and after drying with sea sand) and IMF (gravimetric determination following extraction using petrol ether in a solvent extractor (SER 148; VELP Scientifica, Italy)) were measured. Androstenone and skatole levels in boars, immunocastrates, barrows, and gilts were analyzed. Fat samples from the neck region between the 1st and the 3rd cervical vertebrae were collected for the androstenone and skatole content analysis 24 h after slaughter and frozen without skin and muscles in a vacuum package at –80°C until the follow-up analysis. Contents of androstenone and skatole in the fatty tissue were determined according to the methodology of high-performance liquid chromatography modified by Hansen-Moller (1994). To determine the androstenone level, an Agilent Eclipse XDB C18 (5 µm, 150 × 4.60 mm ID) column tempered at 40°C was used. The mobile stage parameters were as follows: A – tetrahydrofuran : acetonitrile : sodium phosphate buffer (25 mM) : acetic acid (34 : 23.8 : 41.4 : 0.8), and B – methanol. The gradient profile program was as follows: 0–3.0 min, 90% A; 3.0–3.5 min, 90–45% A; 3.5–15.0 min, 45–5% A; 15.0–16.1 min, 5% A; 16.1–17.0 min, 5–90% A; 17.0–19.0 min, 90% A. The column flow rate was set at 1.2 ml/min with an injection volume of 40 µl. Fluorescence detection was performed with excitation at 346 nm and emission at 521 nm. We used the standard calibration curve to determine androstenone content in the actual sample. To determine the skatole level, a Kinetex C18 100A (5 µm, 50 × 4.60 mm ID) column tempered at 40°C was used. The mobile stage parameters were as follows: A – sodium phosphate buffer (10 mM) and B – methanol. The gradient profile program was as follows: 0–0.2 min, 90% A; 0.2–6.0 min, 90–55% A; 6.0–7.0 min, 55–0% A. The column flow rate was set at 1.2 ml/min with an injection volume of 30 µl. Fluorescence detection was performed with excitation at 285 nm and emission at 340 nm. We used the standard calibration curve to determine skatole content in the actual sample.

Statistical analysis. Data were analyzed using the GLM procedure of the SAS software (Statistical Analysis System, Version 9.4, 2012). All means presented herein are the Least Squares Means of each group along with standard errors of the mean (SEM), together with the significance levels for the main effects of sex. Treatment mean differences were tested using Tukey's test. Significance was declared at $P < 0.05$. Final body weight (BW) was used as a covariate in the carcass data analysis. Sex effect was included in the growth data analysis. Because no interaction was found between sex and dietary treatments, these interactions were removed from the final statistical growth model.

RESULTS AND DISCUSSION

Growth performance. Table 2 shows the values of growth performance from the beginning of the fattening test until V1 and V2 and subsequently until the test completion for all test groups of pigs. No significant differences in LW were found.

Regarding ADG, and with the exception of CM, there was no effect in relation to vaccination dates on change in growth intensity as compared to the other monitored groups. The CM group exhibited the highest ADG for the testing period as a whole (1193 g), followed by IC and FE (both 1181 g). The lowest ADG was measured in the UCM group (1169 g), and the difference between CM and UCM was 2.05%. Similar results had been obtained by D'Souza and Mullan (2002) and by Pauly et al. (2008). On the other hand, other authors (Skrlep et al. 2012) have recorded more favourable results in boars as compared to other groups. This inconsistency may be caused by a number of factors, such as (among others) a lower FI in boars due to sexual activity and their behaviour, which even can cause social stress (Pauly et al. 2008) and thus a reduced grow ability.

A comparison of the results obtained for FI and FCR between IC and UCM at each tested stage clearly indicates that higher values were reached in the IC group. Nevertheless, the recorded differences were not significant. The CM group reached the highest values. Lower FI in boars and higher FI in immunocastrates at the end of the finishing period were recorded by Weiler et al. (2013). Similar results of FI and FCR had been obtained by Fabrega et al. (2010). It is also clear that after V2 the levels of testosterone, aggressiveness, and sexual behaviour decrease in IC (Mackinnon and Pearce 2007). As a consequence of this fact, there is an increase in FI and simultaneously in FCR (Cronin et al. 2003). Based on overall assessment

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Table 2. Growth performance parameters of immunocastrated males (IC), castrated males (CM), uncastrated males (UCM), and females (FE)

Variable	IC	CM	UCM	FE	Significance
Body weight (kg)					
Initial BW	34.72 ± 3.62	33.28 ± 7.38	33.75 ± 3.67	36.39 ± 3.46	0.2387
V1 BW	56.28 ± 5.80	53.52 ± 10.57	55.12 ± 6.29	56.98 ± 4.93	0.9729
V2 BW	82.22 ± 9.87	80.75 ± 13.02	80.97 ± 7.32	81.22 ± 6.99	0.6411
Final BW	106.99 ± 10.29	105.95 ± 12.21	106.20 ± 8.49	104.17 ± 7.94	0.8588
ADG (g/day)					
Start to V1	1026 ± 129	964 ± 184	1017 ± 155	981 ± 137	0.5859
V1 to V2	1235 ± 223	1297 ± 161	1231 ± 171	1154 ± 158	0.1365
V2 to slaughter	1282 ± 197^{ab}	1319 ± 197^{a}	1260 ± 198^{ab}	1129 ± 120^{b}	0.0153
Overall	1181 ± 130^{ab}	1193 ± 115^{a}	1169 ± 88^{ab}	1181 ± 130^{b}	0.0243
Feed intake (kg/day)					
Start to V1	1.95 ± 0.21	1.84 ± 0.33	1.95 ± 0.29	1.99 ± 0.20	0.3619
V1 to V2	2.79 ± 0.24^{b}	3.04 ± 0.35^{a}	2.71 ± 0.22^{b}	2.77 ± 0.30^{b}	0.0045
V2 to slaughter	3.31 ± 0.30^{ab}	3.59 ± 0.26^{a}	3.19 ± 0.52^{cd}	2.98 ± 0.21^{bc}	< 0.0001
Overall	2.68 ± 0.19	2.83 ± 0.24^{a}	2.62 ± 0.29^{b}	2.58 ± 0.19^{b}	0.0127
Feed conversion ratio					
Start to V1	1.92 ± 0.28	1.94 ± 0.32	1.92 ± 0.12	2.06 ± 0.29	0.3693
V1 to V2	2.12 ± 0.27	2.18 ± 0.25	2.08 ± 0.15	2.25 ± 0.29	0.2995
V2 to slaughter	2.63 ± 0.37	2.78 ± 0.39	2.54 ± 0.25	2.67 ± 0.32	0.2196
Overall	2.29 ± 0.20	2.38 ± 0.24	2.23 ± 0.14	2.39 ± 0.28	0.1008

ADG = average daily gain, BW = body weight, V1 = first vaccination 1, V2 = second vaccination

$^{a–d}$means within the same row with different superscripts differ significantly at $P < 0.05$

of growth performance (ADG, FI, and FCR), it may be stated that no significant differences were found among the IC, UCM, and FE groups. On the other hand, significant differences between CM and other tested groups were observed. There was no significant effect of vaccination date on the monitored indicators (ADG, FI, and FCR) observed in comparing IC with UCM.

Table 3. Effect of the second vaccination (V2) on the body composition of immunocastrated males (IC), castrated males (CM), uncastrated males (UCM), and females (FE) (in mm)

Variable	IC	CM	UCM	FE	Significance
MLLT depth, MUSCLE2					
Up to V2	37.52 ± 3.63	38.43 ± 4.80	36.00 ± 3.56	38.91 ± 3.39	0.1315
Final	46.43 ± 3.89	46.93 ± 5.81	43.58 ± 3.71	46.57 ± 3.10	0.0795
Difference: Final – V2	8.91 ± 2.32	8.51 ± 2.80	7.58 ± 2.03	7.66 ± 2.21	0.2833
Backfat thickness, FAT2					
Up to V2	11.21 ± 1.01^{a}	11.21 ± 1.04^{a}	10.60 ± 0.60	10.30 ± 0.84^{b}	0.0057
Final	15.15 ± 1.61	15.70 ± 1.93	14.56 ± 1.55	15.16 ± 1.76	0.2770
Difference: Final – V2	3.94 ± 0.88	4.50 ± 1.41	3.97 ± 1.40	4.86 ± 1.34	0.1102
Backfat thickness, FAT1					
Up to V2	11.58 ± 1.02^{a}	11.30 ± 0.81^{a}	11.35 ± 1.09^{a}	10.22 ± 1.02^{b}	0.0006
Final	13.55 ± 1.26^{a}	13.75 ± 1.35^{a}	13.50 ± 1.26^{a}	12.43 ± 0.82^{b}	0.0064
Difference: Final – V2	1.98 ± 0.71	2.45 ± 0.85	2.15 ± 0.79	2.21 ± 0.71	0.3513

MLLT = *musculus longissimus lumborum et thoracis*

$^{a–b}$means within the same row with different superscripts differ significantly at $P < 0.05$

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Table 3 describes the effect of V2 on backfat (FAT1, FAT2) and MLLT muscle creation. No significant difference in MLLT depth after V2 was observed between IC and the other groups (CM, UCM and FE). As concerns backfat, an equal growth trend was found across all groups at FAT1. The highest FAT1 was reached by the CM group (13.75 mm) compared to the groups UCM (13.50 mm) and IC (13.55 mm). The lowest value was measured in the FE group (12.43 mm), which was significantly lower than in all the other groups. There were differences between groups as measured by change in FAT1 between V2 and slaughter. The smallest difference was recorded for the IC group (1.98 mm). The same trend had been found by Pauly et al. (2009) and Fabrega et al. (2010). At the end of the fattening test, FAT2 showed no significant differences between the pig groups. It can be therefore stated that no negative effect of V2 on the final indicators (MLLT depth, FAT1, and FAT2) was observed. However, there was detected an effect on the MLLT depth and FAT2 indicators in the growth of IC and CM groups compared to UCM, but without significant differences. This can be explained by the V2 date before slaughter. When the V2 date was extended to 7–9 weeks before slaughter, Kantas et al. (2014) found significant differences in these indicators.

Carcass composition. Table 4 presents the obtained carcass parameters. The highest CW was

Table 4. Carcass value parameters of immunocastrated males (IC), castrated males (CM), uncastrated males (UCM), and females (FE)

Variable	IC	CM	UCM	FE	Significance
Live weight (kg)	107.0 ± 10.3	106.0 ± 12.2	106.2 ± 8.5	104.2 ± 7.9	0.8588
Carcass weight (kg)	80.70 ± 8.1	81.8 ± 10.5	79.2 ± 7.2	79.5 ± 6.5	0.7733
Lean meat ZP[1] (%)	59.9 ± 1.3[b]	58.5 ± 1.5[a]	60.3 ± 1.1[b]	60.1 ± 1.2[b]	0.0003
Muscle depth ZP[1] (mm)	65.0 ± 5.8[b]	70.4 ± 6.8[a]	63.4 ± 5.4[b]	68.0 ± 4.7	0.0027
Backfat thickness ZP[1] (mm)	12.6 ± 2.6[b]	17.1 ± 3.8[a]	11.5 ± 2.4[b]	12.8 ± 2.7[b]	< 0.0001
MLLT area (mm^2)	3727 ± 485[b]	4361 ± 416[a]	3975 ± 412	4409 ± 395[a]	0.0026
Ham					
Subcutaneous fat (kg)	1.75 ± 0.33[b]	2.26 ± 0.37[a]	1.80 ± 0.24[b]	2.04 ± 0.30	0.0028
IMF (%)	3.08 ± 0.54[b]	3.69 ± 1.04	3.07 ± 0.86[b]	4.59 ± 1.41[a]	0.0054
Meat + bone (kg)	8.27 ± 1.04	8.53 ± 0.86	8.15 ± 0.52	9.04 ± 0.81	0.0945
Meat + bone (%)	21.72 ± 0.75[b]	21.89 ± 0.97	21.15 ± 0.87[b]	22.85 ± 1.03[a]	0.0019
Shoulder					
Subcutaneous fat (kg)	1.43 ± 0.40	1.35 ± 0.12	1.36 ± 0.29	1.21 ± 0.23	0.3691
IMF (%)	2.18 ± 0.42[bc]	2.82 ± 0.61[a]	2.43 ± 0.54[ac]	1.85 ± 0.25[b]	0.0006
Meat + bone (kg)	4.27 ± 0.50	4.26 ± 0.36	4.12 ± 0.37	4.36 ± 0.37	0.6073
Meat + bone (%)	11.23 ± 0.64	10.95 ± 0.73	10.69 ± 0.76	11.03 ± 0.41	0.3243
Loin					
Subcutaneous fat (kg)	1.63 ± 0.39	1.73 ± 0.25	1.42 ± 0.21	1.50 ± 0.23	0.0884
IMF (%)	2.13 ± 0.28	2.31 ± 0.43	2.18 ± 0.33	1.96 ± 0.35	0.1647
Meat + bone (kg)	4.51 ± 0.69	4.60 ± 0.45	4.58 ± 0.66	4.87 ± 0.39	0.5048
Meat + bone (%)	11.82 ± 0.80	11.82 ± 0.69	11.80 ± 0.75	12.32 ± 0.43	0.2662
Neck					
Subcutaneous fat (kg)	0.45 ± 0.11	0.51 ± 0.11	0.54 ± 0.11	0.42 ± 0.11	0.0851
IMF (%)	5.18 ± 1.10	6.37 ± 2.44	6.26 ± 2.79	4.51 ± 1.18	0.1385
Meat + bone (kg)	2.68 ± 0.35	2.59 ± 0.31	2.73 ± 0.15	2.68 ± 0.19	0.6850
Meat + bone (%)	7.05 ± 0.56	6.65 ± 0.55	7.09 ± 0.33	6.78 ± 0.36	0.1168

IMF = intramuscular fat, MLLT = *musculus longissimus lumborum et thoracis*

[1]measured by a two-point method ZP

[a–d]means within the same row with different superscripts differ significantly at $P < 0.05$

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reached by the CM group (81.8 kg) and the lowest by UCM (79.2 kg). The recorded differences were not significant. On the other hand, significant differences were found in carcass lean meat ZP ($P = 0.0027$), where the lowest values were reached by the CM group (58.5%), which also exhibited the highest backfat thickness ZP (17.1 mm) as well as the highest muscle depth (70.4 mm) and the second highest MLLT area (4361 mm^2). Although comparison of the IC and UCM groups indicated more favourable values for the UCM group, these differences were nevertheless not significant.

Evaluation of the selected carcass parts revealed a significantly higher proportion of IMF and subcutaneous fat in CM as compared to the other monitored groups. No significant difference was found between the groups IC and UCM. The lowest levels in all monitored parts were in the FE group. As regards the absolute and relative meat ratio (ham, shoulder, loin, and neck – in kg and %), no significant differences were found in the individual categories of the carcass parts. Some authors have pointed to differing muscle composition between the sexes. Fortin et al. (1987) documented that in comparison with gilts, boars have heavier neck and chest muscles and lighter pelvic and limb muscles. Similar results were found as regards carcass hind legs and shoulders, wherein boars showed the lowest proportion among all pig groups. Uttaro et al. (1994) reached just the opposite conclusion, but they did not evaluate hybrid populations.

Meat quality. Table 5 describes the physical meat quality parameters recorded. No significant differences were found between the groups in relation to pH, meat colour, drip loss, and shear force. The values recorded for IC converged with those recorded for UCM and FE. As concerns meat colour, Lundstrom et al. (1987) and Boler et al. (2014) came to the same findings as did we. Wood et al. (1986) found a slightly lighter colour of MLLT in boars than in gilts. On the other hand, Sather et al. (1991, 1993) recorded a slightly darker meat colour in boars in comparison to that from females. When assessing the shear force, our results corresponded to those of Sather et al. (1991) and Boler et al. (2014) showing no differences between

Table 5. Selected parameters of pork meat quality of immunocastrated males (IC), castrated males (CM), uncastrated males (UCM), and females (FE)

Meat quality	IC	CM	UCM	FE	Significance
Carcass (*n*)	16	18	18	18	
Carcass weight (kg)	80.7 ± 8.1	81.8 ± 10.5	79.2 ± 7.2	79.5 ± 6.5	0.7733
MLLT pH_{45}	6.4 ± 0.3	6.4 ± 0.3	6.4 ± 0.3	6.4 ± 0.3	0.8738
MS pH_{45}	6.5 ± 0.3	6.5 ± 0.3	6.4 ± 0.3	6.4 ± 0.3	0.8918
MLLT colour					
L*	52.3 ± 2.9	51.0 ± 3.0	52.2 ± 2.8	52.1 ± 3.3	0.7305
a*	–1.3 ± 0.5	–1.2 ± 0.7	–1.1 ± 0.6	–1.6 ± 0.6	0.4100
b*	8.3 ± 0.9	8.0 ± 1.1	8.7 ± 0.7	8.4 ± 1.1	0.3828
Backfat colour					
L*	80.7 ± 2.2	79.5 ± 2.6	81.3 ± 1.3	80.4 ± 1.3	0.2196
a*	–0.5 ± 0.6	–0.4 ± 0.7	–0.5 ± 0.6	–0.6 ± 0.6	0.9511
b*	7.4 ± 1.1	7.6 ± 0.9	7.6 ± 0.6	7.3 ± 0.9	0.7791
MLLT IMF (%)	2.13 ± 0.28	2.31 ± 0.43	2.18 ± 0.33	1.96 ± 0.35	0.1647
Drip loss (%)	4.7 ± 2.8	4.1 ± 1.7	4.8 ± 2.4	5.5 ± 3.0	0.6768
Shear force (N)					
MLLT raw	51.8 ± 7.7	45.4 ± 6.6	51.6 ± 8.2	50.9 ± 5.8	0.1553
MLLT boiled	27.9 ± 3.3	30.3 ± 4.4	28.6 ± 3.9	29.6 ± 4.6	0.5547
Raw fat	93.0 ± 24.8	71.7 ± 30.3	90.7 ± 18.0	84.8 ± 27.6	0.2594

IMF = intramuscular fat, MLLT = *musculus longissimus lumborum et thoracis*, MS = *musculus semimembranosus*, L* = lightness, a* = redness, b* = yellowness, pH_{45} = pH measured 45 min *post mortem*

[a–d]means within the same row with different superscripts differ significantly at $P < 0.05$

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Table 6. Least Squares Means of androstenone and skatole levels and the testes and bulbourethral glands variables of immunocastrated males (IC), castrated males (CM), uncastrated males (UCM), and females (FE)

Variable	IC	CM	UCM	FE	Significance
Androstenone (μg/g)	0.53 ± 0.70[a]	0.18 ± 0.14[a]	2.38 ± 0.67[b]	0.19 ± 0.17[a]	< 0.0001
Skatole (μg/g)	0.06 ± 0.05[a]	0.05 ± 0.02[a]	0.22 ± 0.06[b]	0.05 ± 0.03[a]	< 0.0001
Testes weight (g)	255.0 ± 160.3[a]		415.8 ± 100.3[b]		0.0012
Testes weight/live weight (%)	0.24 ± 0.14[a]		0.40 ± 0.11b		0.0008
Bulbourethral glands weight (g)	78.2 ± 25.1[a]		130.0 ± 35.6[b]		< 0.0001
Bulbourethral glands weight/live weight (%)	0.07 ± 0.02[a]		0.12 ± 0.04[b]		< 0.0001

[a–b]means within the same row with different superscripts differ significantly at $P < 0.05$

sexes. Lower shear force values in boar meat were found by Lundstrom et al. (1987), but the opposite finding was published by Sather et al. (1993). In assessing the drip loss in MLLT, Lundstrom et al. (1987) found no differences between sexes. Similar results were obtained in this work. To the contrary, Sather et al. (1991) suggested lower drip losses for boars as compared to gilts and castrates. IMF content is an important meat quality indicator, and no significant differences among groups were found. Considering that low IMF content can cause undesirable changes in meat taste and texture, it should be noted that the lowest values were achieved in FE (1.96%) and the highest in CM (2.31%). IC and UCM reached almost the same values (2.13 and 2.18%, respectively). Gispert et al. (2010) reported that meat from CM reached the greatest extent of IMF, boars showed the least, and gilts and CM were in between. Dubois et al. (2012) came to the conclusion that boars have lower proportion of fat and therefore also a lesser extent of IMF due to the anabolic effects of androgynous steroids, such as testosterone. This can cause problems, as even in CM the IMF in some muscles is less than the 2–3% which is recommended for optimal sensory quality. Nevertheless, in studies where such characteristic was monitored, no extremely low IMF levels were found in boars. Levels ranging from 1.5 to 3.5% were recorded, and the differences between sexes were relatively small (Barton-Gade 1987; Fortin et al. 1987).

As concerns the content of androstenone (Table 6), the significantly highest levels were recorded in the UCM group (2.38 μg/g). The IC group ranked second (0.53 μg/g) and was followed by the groups CM and FE with almost identical values (0.18 μg/g and 0.19 μg/g, respectively). A similar trend can be noted in the skatole level. Similar results were obtained by Zamaratskaia et al. (2008).

In assessing the weights of testicles and bulbourethral glands between the IC and UCM groups, highly significant differences ($P < 0.001$) were observed in all indicators. Mean testicular weight in boars reached 415.8 g compared to 255.0 g in immunocastrates. A similar trend was recorded for bulbourethral glands, where the weights in boars and immunocastrates, respectively, reached 130.0 g and 78.2 g. The effect of immunocastration on gonad development in boars was therefore fully demonstrated. This was manifested, too, in the low levels of androstenone and skatole. Forland et al. (1980) reported similar findings, as well as

Table 7. Proportion of animals with high concentrations of androstenone and skatole in backfat in the experimental groups

Variable	IC (n = 16)	CM (n = 18)	UCM (n = 18)	FE (n = 18)
High androstenone (≥ 0.50 μg/g)				
Animals (%)	31.2	11.1	100.0	11.1
Androstenone (μg/g)	1.44	0.52	2.38	0.64
High skatole (≥ 0.20 μg/g)				
Animals (%)	0	0	61.1	0
Skatole (μg/g)	–	–	0.26	–

IC = immunocastrated males, CM = castrated males, UCM = uncastrated males, FE = females

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a relatively high correlation between the size and weight of gonads and the androstenone level in fat.

Table 7 presents the proportion of animals with high concentrations of androstenone and skatole in the experimental groups. In UCM, 100% of animals exhibited above limit concentrations of androstenone (≥ 0.50 μg/g; on average 2.38 μg/g), followed by IC with 31% of animals (on average 1.44 μg/g). Only 11% of animals exceeded the limit in the other groups (CM and FE). Conversely, no animals with above limit concentrations of skatole (≥ 0.20 μg/g) were observed in IC, CM, and FE, whereas in UCM 61% of animals exceeded this limit (on average 0.26 μg/g). It is evident that the economics of pork production will be negatively affected especially in UCM but also in the IC group due to penalization of carcasses with excessive concentrations of androstenone and skatole.

CONCLUSION

The overall assessment of growth performance shows that there have been no differences between the groups of IC, UCM, and FE. On the other hand, significant differences between CM and the other groups were observed. No significant effect of vaccination date on the evaluated features of IC occurred as compared to UCM. It is nevertheless clear that under group boar housing mutual attacks will occur, and, as a consequence, fattening parameters will be adversely affected. It can also be stated that IC group pigs showed no negative effects from the second vaccination as measured by the final carcass value indicators, and their fat accumulation was not greater in comparison with UCM and FE. In this regard, the CM group exhibited the highest fat accumulation compared to the other groups.

Regarding the indicators characterizing pork meat quality, no significant differences in pH, meat colour, drip loss, shear force, or IMF proportion were found. The values recorded for IC converged very much with those for UCM and FE. As a consequence of immunocastration, the testicular weight decreased significantly, the occurrence of undesired boar taint was prevented.

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