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ANIMAL SCIENCE

Carcass characteristics and meat quality of male pigs submitted to surgical or immunological castration

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Abstract: The objective of this study was to evaluate carcass characteristics and meat quality of surgically castrated and immunocastrated male pigs. Data were collected from 24 surgically castrated pigs and 24 immunocastrated male entire originating from the commercial line (Agroceres x Topigs), receiving isonutritive diets and were housed in the same experimental shed, slaughtered at 177 days old, with a slaughter weight of 127.8 (± 6.5) and 135.1 (± 7.8) kg, respectively. Carcass and meat quality characteristics such as carcass yield, lean meat yield, fat content, backfat thickness, muscle depth, pH, meat coloring and, drip, thawing and cooking loss, were evaluated. Immunocastrated pigs have heavier carcass, higher meat yield and lower fat thickness when compared to surgically castrated animals. Regarding meat quality, the immunocastrated presented a lighter meat, less reddness and less water holding capacity. In conclusion, this study confirmed that the carcass of male pigs, submitted immunocastration, has lower yield, however, more meat and less fat content, when compared to carcass of male pigs surgically castrated. Meat quality showed peculiar characteristics for immunocastrated pigs, and can be used more for sausage production, since it retains less water and have smaller redness color compared to surgically castrated pigs.

Key words: Castration methods, immunocastration, swine, surgically castrated, water holding capacity.

INTRODUCTION

Castration is a widespread procedure in pig farming recommended preventing pig meat from having an unpleasant taste and odor to the human palate, which may cause a reduction in your consumption (Pauly et al. 2010). Normally, castration is performed in the early days of life and without the use of analgesics and or anesthetics. However, with the growing concern in relation to animal welfare, new alternatives have been increasingly used.

The immunocastration is an alternative technique to surgical castration, without anesthesia and or analgesia, it has gained space and popularity in the pig production industry (Martins et al. 2013). It is a procedure, where induces the formation of specific antibodies that bind to and neutralize GnRH, reducing activity in the hypothalamic-pituitary-gonadal axis (Thun et al. 2006). It usually consists of applying two doses of the vaccine, the first dose prepares the immune system, while the second dose stimulates the animal to produce specific antibodies (Dunshea et al. 2001).

The immunocastration vaccine contributes to improving animal welfare during its productive life and performance in the fattening period (Weiler et al. 2013, Muniz et al. 2019). Characteristics that indicate meat quality as shear force and color are similar between castrated and immunocastrated pigs (Gispert et al. 2010, Batorek et al. 2012). The carcass yield in immunocastrated pigs can be up to 3.0% lower than that observed in castrated pigs (Dunshea et al. 2013). However, immunocastration increases the amount of meat compared to surgically castrated pigs (Caldara et al. 2012).

However, it is known that immunocastration generally results in ranging between studies, for variables such as meat yield and carcass fat content, color of meat samples and water holding capacity (Batorek et al. 2012, Aluwé et al. 2013). Thus, the objective of this study was to evaluate carcass characteristics and meat quality of surgically castrated and immunocastrated male pigs.

MATERIALS AND METHODS

The experiment was carried out at the Setor de Suínos linked to the Zootechnics Department of the Federal University of Santa Maria, Rio Grande do Sul state, Brazil. The procedures adopted in the study was approved by the Ethics Committee on the Use of Animals (protocol number 2874110618), from the same institution.

Animals and feeding

Data were collected from 24 surgically castrated pigs, on the third day of life, and 24 immunocastrated male entire originating pigs from the commercial line (Agroceres x Topigs), receiving isonutritive diets and were housed in 24 pens separated according to sex and weight, in the same experimental shed, slaughtered at 177 days old, with a slaughter weight (SW) of 127.8 (± 6.5) and 135.1 (± 7.8) kg, respectively. The experimental design was in completely randomised, having two treatments, castrated surgically and immunologically. The animals received a diet plan consisting of four diets balanced according to (NRC 2012; Table I).

Castration's management

The piglets, which underwent surgical castration, were sedated with administration of 4 $mg.kg^{-1}$ of tramadol and 1 $mg.kg^{-1}$ of midazolam, intramuscularly. After 10 minutes, the skin of the scrotal sac was cleaned and local anesthesia in each spermatic cord, using 0.5 ml of 2% lidocaine without epinephrine. The surgical procedure was performed 5 minutes after the application of the anesthetic, with the cleaning and disinfection of the skin of the scrotum with an iodine-based antiseptic solution, with a longitudinal cut and removal of the testicles. After surgical castration, no piglet had any complications, and it was not necessary to use anti-inflammatory or anti-biotic

The male pigs destined of the immunocastration, were vaccinated by a technical team (Vivax®, Zoetis, Brazil). The vaccination protocol consisted of the subcutaneous application of 2 ml (200 µh GnRH conjugated to protein per milliliter) of the vaccine, the first and second doses were performed eight and four weeks before slaughter, respectively. According to Dunshea et al. (2013), the first dose is of a sensitizing nature, where the animal will have contact with the anti-GnRH antigen, and the second dose will cause it to produce anti-GnRH antibodies.

Slaughter and data collection

The animals were fasted for eight hours before the transport. At the slaughterhouse, pigs were weighed individually, and housed in collective pens with free access to water. The time between transport and slaughter was approximately twelve hours. Using standard handling

Table I. **Composition and calculated nutritional values of the diets fed to pigs in the growing and finishing phases.**

Ingredients	Diets, %			
	G1	G2	F1	F2
Corn	64.48	68.13	69.74	75.14
Soyabean meal (46% CP)	30.41	27.03	25.46	21.83
Soya oil	1.94	1.79	1.73	0.40
L-Lysine	0.32	0.31	0.29	0.27
DL-Methionine	0.14	0.11	0.13	0.07
L-Threonine	0.11	0.09	0.10	0.07
Limestone	0.74	0.77	0.78	0.76
Dicalcium phosphate	1.33	1.20	1.19	0.92
Salt	0.43	0.48	0.48	0.45
Mineral premix[1]	0.05	0.05	0.05	0.05
Vitamin premix[2]	0.05	0.05	0.05	0.05
Composition nutritional and energy	G1	G2	F1	F2
Crude Protein, %	18.85	17.61	16.77	15.81
Metabolizable energy (ME), $MJ \cdot kg^{-1}$	13.82	13.82	13.82	13.60
SID lysine (Lys), %	1.00	0.92	0.88	0.79
Lys: ME, ($g \cdot MJ^{-1}$)	0.73	0.66	0.64	0.57
Calcium, %	0.70	0.67	0.64	0.59
Standardized phosphorus, %	0.35	0.33	0.32	0.28
Sodium, %	0.17	0.19	0.19	0.18

G1– 24 days (30-50kg); G2– 28 days (50-80kg); F1– 25 days (80-105kg); F2– 26 days (105-130kg); [1]Composition per kg of product: calcium: 98.800mg; cobalt: 185mg; copper: 15.750mg; iron: 26.250mg; iodine: 1.470mg; manganese: 41.850mg; zinc: 77.999mg; selenium: 105mg; [2] Composition per kg of product: folic acid: 116.55mg; pantothenic acid: 2.333mg; biotin: 5.28mg; niacin: 5.600mg; pyridoxine: 175mg; riboflavin: 933.3mg; thiamine: 175mg; Vit. A: 1.225.000 U.I.; Vit. D3: 315.000 U.I.; Vit. E: 1.400mg; Vit. K3: 700mg; Vit. B12: 6.825mg.

pre-slaughter to minimize stress, the pigs were stunned with electrical system, followed immediately by bleeding, scalding, mechanical depilation and evisceration. The carcass were weighed and divided lengthwise.

After were collected hot carcass weight (HCW) and cold carcass (CCW) (without head and feet); pH 45 minutes post-slaughter (pH-45) and pH 24 hours post-slaughter (pH-24), measured in the ham using the Testo-205® portable pH meter, this device compensates the temperature simultaneously due to an integrated sensor that allows accurate pH measurement.

The pH meter calibration was carried out by immersing his sensor in solutions with pH 4 and 7, according to the device manual. The gradient and displacement values were greater than 50 mV / pH and less than 60 mV, respectively, demonstrating that the electrode is functioning properly. Among the readings performed, the pH meter was packed in its cap, filled with KCl-based gel, to prevent disbalances.

In the region of the third and fourth ribs in the caudal-cranial direction, a cross section was performed, where the muscle depth (MD) of *Longissimus lumborum* and backfat thickness were measured, the entire area was drawn on butter paper for the calculation of loin eye area (LEA) and loin fat area (LFA). For the analysis of color, drip loss, thawing loss, cooking loss and shear force, samples of *Longissimus lumborum* muscle were collected from the left half-carcass. The carcass yield (CY) and carcass lean meat (CLM), were estimated through equations described by Irgang et al. (1998).

Post-slaughter analysis

The water-holding capacity was measured according to the methodology of Honikel (1987), comprising the sum of the variables, drip loss, thawing loss and cooking loss. Drip loss was determined using a 150 g meat sample approximately, suspended and wrapped with a plastic bag, without contact, in a cold chamber, being weighed at the beginning and after forty-eight hours. Samples of proportion similar to those used for drip loss (150 g), were submitted to freezing after twenty-four hours of the slaughter, for thawing loss determination (frozen samples weight – thawed samples weight). The samples of 150 g in natura were then cooked in an oven, until the internal temperature reached 70 ºC, and weighed, for cooking loss quantification (in natura samples weight - cooked samples weight).

The Shear force was determined, with a Warner-Bratzler Shear machine, in six cores 12.5 x 25.0 mm diameter and width, respectively, were removed parallel to the longitudinal orientation of the muscle fibers, per meat sample. A boxplot was used to identify and exclude outliers, results within normality were used to obtain the mean of each sample.

The color intensities (L, a* and b*) were evaluated with 2.5 cm thick samples. Three measurements were taken at different sample points, using the Minolta Sensing Spectrophotometer CR-400, with 10 grade of standard observer, D65 illuminant and 11-mm aperture, calibrated with a background white.

Statistical analyses

All statistical analyzes were performed in Minitab® 2018 statistical software. The qualitative and quantitative data of carcasses of swine, were submitted to analysis of variance by the General Linear Model procedure. Were analyzed, with sexual categories as fixed factor, and carcass weight as co-variable for the following variables carcass yield, carcass lean meat, loin fat area, backfat thickness, loin eye area and muscle depth. The differences between means were compared by the Fisher test and considered significant if $P < 0.05$.

RESULTS

The carcass traits differed ($P < 0.05$) among the sexual categories. The swine immunocastrated (IM) showed superiority, for hot carcass weight (HCW), cold carcass weight (CCW), carcass lean meat (CLM), loin eye area (LEA) and muscle depth (MD). While swine male surgically castrated (SC), were higher for carcass yield (CY), loin fat area (LFA), backfat thickness (Table II).

The pH45, pH24 and shear force did not differ ($P > 0.05$) between the castration groups. However, for meat coloration, only the variable b* (yellowness) did not differ statistically; L (luminosity) and a* (redness) were significantly different ($P < 0.05$), indicating higher values for IM and SC, respectively (Table II). For the

Table II. Carcass characteristics, meat quality and water holding capacity determined in the Longissimus *lumborum* muscle from swine male surgically castrated and immunocastrated.

	SC	IM	SEM	*p*-value
Carcass Characteristics (n)	24	24		
Slaughter weight, Kg	127.80	135.10	1.475	0.001
Hot carcass weight, Kg	93.11	96.45	1.095	0.037
Cold carcass weight, Kg	88.51	92.01	1.065	0.025
Carcass yield, % ^{sw*}	72.88	71.38	0.240	0.001
Carcass lean meat, % ^{sw*}	57.88	59.93	0.413	0.001
Loin fat area, cm² ^{sw*}	24.13	20.23	0.792	0.001
Backfat thickness, mm ^{sw*}	16.18	12.89	0.651	0.001
Loin eye area, cm² ^{sw*}	56.52	60.63	1.190	0.019
Muscle depth, mm ^{sw*}	71.83	74.84	0.748	0.007
Meat Quality (n)	24	24		
pH-45	6.49	6.54	0.053	0.493
pH-24	6.02	5.95	0.044	0.270
L*	52.86	55.65	0.619	0.004
a*	7.75	6.72	0.352	0.049
b*	12.94	12.64	0.309	0.496
Shear Force (N)	33.94	36.07	2.460	0.547
Water holding capacity (n)	24	24		
Drip Loss (%)	2.21	2.92	0.203	0.019
Thawing loss (%)	5.06	7.28	0.544	0.008
Cooking loss (%)	23.22	25.91	0.903	0.044

SC: Male surgically castrated, IM: Male submitted to immunocastration; SEM: Standard error mean; Backfat thickness: was measured in the region of the third and fourth ribs in the caudal-cranial direction; L*: Luminosity, a*: redness, b*: yellowness; pH-45: forty-five minutes after slaughter; pH-24: twenty-four hours after slaughter. ^{SW*}: Variables in which the slaughter weight was utilized with co-variable for analysis of variance.

water-holding capacity variables, IM in relation to SC, obtained higher values ($P < 0.05$) for drip, thawing and cooking loss (Table II).

DISCUSSION

Quantitative and qualitative characteristics of pig carcasses are highly influenced by body weight, castration method and genetics (Kouba & Sellier 2011, Trefan et al. 2013). According to Pauly et al. (2009), the IM have higher intestine, kidney and liver weights. In addition, the total weight of the reproductive organs of the IM is greater, due to the presence of the testicles, and attached glands of the reproductive system, which have not yet reduced to the same proportion as in SC (Skrlep et al. 2010, Batorek et al. 2012). This accounts for the differences between sexual categories, for slaughter weight and hot carcass weight, resulting in as well the higher carcass yield for SC.

According to our results, IM were superior to SC for CLM, MD and LEA measurements, these variables have a positive correlation (Rehfeldt & Kuhn 2006). The likely explanation for this would be, male pigs submitted to immunocastration have greater anabolic potential, a result of the presence of gonadal hormones during most of the fattening period. Causing higher protein deposition in the carcass, resulting in value higher CLM after slaughter in relation to SC, that because they do not have testicles, they perform greater lipid deposition. (Pauly et al. 2009, Boler et al. 2012, Muniz et al. 2019).

The amount of fat in pig carcasses is influenced by the castration method, due to changes in the animal's lipid metabolism (Kouba & Sellier 2011). Both forms of castration, surgical or vaccine-induced, reduce steroid hormones levels in the blood, resulting in increased lipid deposition (Schreurs et al. 2008, Fàbrega et al. 2010). However, in the IM increases the rate of lipid deposition after the second dose of the vaccine, 28 days before slaughter, (Lealiifano et al. 2011). Already SC, have this lipid metabolism from the third day of life, this may be the explanation for the presence the highest backfat thickness and loin fat area, resulting in a fatter carcass, for this sexual category.

Color is a subjective indication of meat quality for the consumer, although the color indicators described in the literature are inconsistent (Aluwé et al. 2013). The IM obtained lower pH-24 and higher drop in pH post-mortem, however, nothing statistically significant. The pH drop causes, electrostatic repulsion between myofilaments, increasing the distance between myofibrils, and with that the refraction of light (Swatland 2004), thus increasing the value for variable L, in samples this sexual category. For variable a*, the difference obtained can be explained by the slaughter weight. According to Tikk et al. (2008) the meat of heavier carcasses swines, tend to have a lower intensity of red, being confirmed by this study, where IM had higher slaughter weight and lower intensity of a* variable.

Batorek et al. (2012) demonstrated through meta-analytic study that entire male pigs have high values for shear force. The compensatory growth that occurs after the second dose of the vaccine in swines immunocastrated, produces a higher in vivo protein turnover, increasing post-mortem proteolysis which makes the meat from immunocastrated swine softer (Therkildsen et al. 2004, Lametsch et al. 2006). Generating similarity in the values found, for the variable shear force between IM and SC, as demonstrated in our study.

Unlike Boler et al. (2014), who state that immunocastration does not affect water-holding in the carcass. Our study found differences, in the variables that quantify water holding capacity between the sexual categories. The value found for CLM in our study, may be the explanation for the lower water holding capacity, obtained by IM. According to Schiavon & Emmans (2000), protein deposition retains more as, twice as much water as lipid deposition. With this, the IM has more water to be lost in industrial processes, such as cooling (drip loss), freezing followed by thawing (thawing loss) and cooking (cooking loss), validating the values found by our study.

The drop in pH post-mortem results in myofibrillar distancing, interfering with the loss of inter and intracellular water (Swatland 2004, Huff-Lonergan & Lonergan 2005). In a study by Bertram et al. (2002), the authors state that the water located outside the myofibrils, migrate towards the surface of the meat, contributing to the increase in water loss, during the storage and cooking processes. Caldara et al. (2012), submitted pork to cooking, finding higher losses of water by cooking in samples whose pH was less than 6.0. These higher losses found may be switched on to the acceleration of the denaturation process of myofibrillar proteins during cooking, due to pH and temperature, justifying for the values obtained for cooking loss in our study.

CONCLUSION

In conclusion, this study confirmed that the carcass of male pigs, submitted immunocastration, has a lower yield. However, immunocastrated pigs presented higher amounts of meat and less fat content when compared to carcass of male pigs surgically castrated. The meat of immunocastrated pigs retains less water and has smaller redness color compared to surgically castrated pigs, and therefore can be recommended for sausage production.

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Henrique da Costa Mendes Muniz, contributed to performed the experiment, analyzed the data, writing of the manuscript and edited, for the periodic; Vladimir de Oliveira acted as a master's advisor for Henrique da Costa Mendes Muniz, participating in the acquisition the financial resources of this project research, analysis the data and revised the manuscript for intellectual content; Eduarda S. de Lima, Luciane I. Schneider, Daniela R. Klein and Leonardo T. da Rocha assisted in performing the experiment and revised the manuscript; José L. Nörnberg and Arlei R.B. de Quadros revised the manuscript for intellectual content. All the authors have read and approved the final manuscript.