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Original scientific paper

The effects of immunocastration on male pig yield parameters and meat quality

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A b s t r a c t: The aim of this study was to evaluate the effects of immunocastration on pork meat and carcass quality, compared to meat from surgically castrated males and entire males. Ninety (Duroc x Pietrain) x (Landrace x Yorkshire) crossbred pigs were assigned to three experimental groups: surgically castrated males (barrows; castrated up to the seventh day of age), entire males (males), and vaccinated males (immunocastrates). Carcass and meat quality characteristics such as weight of hot and chilled carcass, meat yield, chilling loss and chemical parameters were examined. Surgically castrated pigs had significantly lower ($p<0.01$; $p<0.05$) weight before slaughter, than males and immunocastrates, and also lower ($p<0.01$) warm carcass weight than males. The average carcass meatiness of castrates was significantly lower ($p<0.01$) than the average meatiness of males and immunocastrates. Chilling loss of barrows was significantly lower ($p<0.01$) than chilling loss of males or immunocastrates. It was also found that the chilling loss of immunocastrates was significantly lower ($p<0.05$) than chilling loss of males. According to the results obtained, it can be concluded that immunocastration could be a good alternative to surgical castration considering meat and carcass quality characteristics.
Keywords: *immunocastration, yield, quality, pork.*

Introduction

The continual growth of the human population world-wide requires innovative solutions in order to significantly increase food production, in particular for foods of animal origin. The production of high quality pork meat has been an ultimate goal of the pig industry for many decades (*Dokmanovic et al.,* 2014; *Dokmanovic et al.,* 2015). One of the options to increase pork production is *via* fattening uncastrated male pigs, which are known to produce more meaty carcasses than surgically castrated males (barrows) and young female pigs (gilts). However, not castrating male pigs can cause the occurrence of the meat defect known as boar taint, due to the presence of androstenone or skatole in adipose tissue. Negative consumer perception of meat from entire male pigs has been reported by many authors, not only in fresh pork but also in processed products such as bacon and dry cured ham (*Matthews et al.,* 2000; *Font-i-Furnols et al.,* 2008; *Font-i-Furnols et al.,* 2012).

Surgical castration of male pigs at an early age is carried out in most countries to prevent boar taint, increase intramuscular and subcutaneous fat content for certain quality products and prevent aggressive behavior. Males and barrows have been shown to differ in carcass and meat quality traits (*Lundstrom et al.,* 2009). However, consumers concerns for animal welfare are increasing pressure on the pig industry to abandon surgical castration (*Fàbrega et al.,* 2010).

Immunological castration of pigs is an attractive alternative to surgical castration, and nowadays, is increasingly used in many countries to reduce boar taint and improve pork quality. Moreover, immunocastrated pigs showed reduced sexual and aggressive behavior compared to entire male pigs, thus improving animal welfare (*Zamaratskaia and Krøyer Rasmussen*, 2015). A vaccine for the immunocastration of male pigs (Improvac®, against GnRH) to avoid boar taint has been recently accepted for use in the European Union (*European Medicines Agency*, 2013). While vaccination has been shown to be effective against boar taint, performances can differ between entire males and males vaccinated against GnRH (*Aluwé et al.,* 2015). Many scientists have examined the effects of immunocastration on meat quality parameters (*Zamaratskaia et al.,* 2008; *Pauly et al.,* 2009; *Gispert et al.,* 2010; *Aleksic*, 2012). In fact, immunocastration is likely to result in

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carcasses which do not diverge a lot from the normal meatiness of boar carcasses (*Aleksic*, 2012).

The aim of this study was to evaluate the effect of immunocastration on meat quality by comparing three groups of pigs: surgically castrated males, entire males and immunocastrated males, slaughtered at the same age.

Materials and Methods

The study was conducted using three groups of 30 pigs each. The groups comprised surgically castrated males (castrated at up to seven days old), entire males, and immunocastrated males. All pigs were descendants of a one single boar (a crossbred of Duroc and Pietrain) and sows of the same line (crossbreds of Landrace and Yorkshire). At eight weeks of age they were transferred to the experimental barn, individually housed and fed a commercial diet *ad libitum*. At that time, the first vaccination against GnRH (2 ml of Improvac® vaccine per animal, Pfizer Animal Health) was applied by a veterinarian. Thereafter, pigs were assigned to three treatment groups: surgically castrated males (n=30, weight 18.26±2.19 kg), entire male boars (n=30, weight 18.76±2.86 kg), and immunocastrated males (n=30, weight 18.54±2.33 kg). The second vaccination of immunocastrated males (2 ml of vaccine) was performed at 5 weeks prior to slaughter. At the end of the study (178 days), surgically castrated males weighed 102.50±9.55 kg, male boars 111.40±6.22 kg, and immunocastrated males 107.70±7.92 kg.

After fattening and transport to the slaughterhouse, pigs were slaughtered and carcass processing was performed in the same way for all animals. Meat yield parameters were determined after slaughtering, processing and cooling. For chemical analyses, ten samples of meat (*m. longissimus dorsi pars lumbalis*) were taken from each group of pigs.

Pigs were weighed before slaughter after they were unloaded from the transport vehicle, on a walk-through balance located in the corridor (measurement accuracy was ±0.5 kg). The weight of hot or chilled carcasses was measured on a balance with accuracy of ±0.1 kg. Dressing percentage was calculated from the weight of live animals and warm carcass weight. Meat yield was expressed in percentages and kilograms, and was determined according to local Regulation on the quality of pigs for slaughter (*Serbia, SFRJ,* 2/85, 12/85, 24/86). According to this Regulation, meat yield is determined by the sum of the thickness of loin fat and backfat in millimeters, and warm carcass weight is expressed in kilograms. Based on these measures, meat yield was determined from the tabular values in kilograms or as a percentage. Chilling loss was determined based on the difference between warm carcass weight and weight of carcass after 24 h cooling, and was expressed as a percentage. For chemical analyses, standard AOAC methods (*AOAC*, 1990) were used.

Statistical analysis

Statistical analysis of the results was elaborated using software GraphPad Prism version 7.00 for Windows, GraphPad Software, San Diego California USA, www.graphpad.com. All parameters were described by mean and standard deviation (SD). The significance of differences between mean values of two groups was measured using the t-test. To test the significance of differences among three or more groups, ANOVA and Tukey's test were used. Significance levels of 0.01 and 0.05 were applied.

Results and Discussion

Vaccination very strongly reduced the size of testes in immunocastrates compared to the male boars (Figure 1). Numerous studies showed reduction of testes (16% to over 60%) in immunocastrates when compared to male boars (*Metz et al.,* 2002; *Jaros et al.,* 2005; *Zamaratskaia et al.,* 2008), as found in this study. In addition to macroscopic changes, this (Figure 2) and other studies (*Jaros et al.,* 2005; *Gökdal et al.,* 2010) showed histological differences between the testes of immunocastrates and entire male boars.

Surgically castrated pigs had significantly lower ($p<0.01$; $p<0.05$) weight before slaughter than males and immunocastrates, and also lower ($p<0.01$) warm carcass weight than males (Figure 3). Live weight in all groups increased as the day of fattening period progressed (data not shown), although the entire males seemed to be superior to the other groups (surgically castrated and immunocastrates). Gonadal steroids play a critical role in animal growth and development (*Ribeiro et al.,* 2004). Also, *Ribeiro et al.* (2004) reported that residual levels of testosterone secreted in immunocastrates have anabolic effects that, possibly, are sufficient to sustain a high rate of growth and development. In other studies (*Skrlep et al.* 2010; 2012), barrows were heavier than boars, while in our study, male boars were heavier than barrows ($p<0.01$). Several studies have pointed to a higher body weight in barrows and immunocastrates

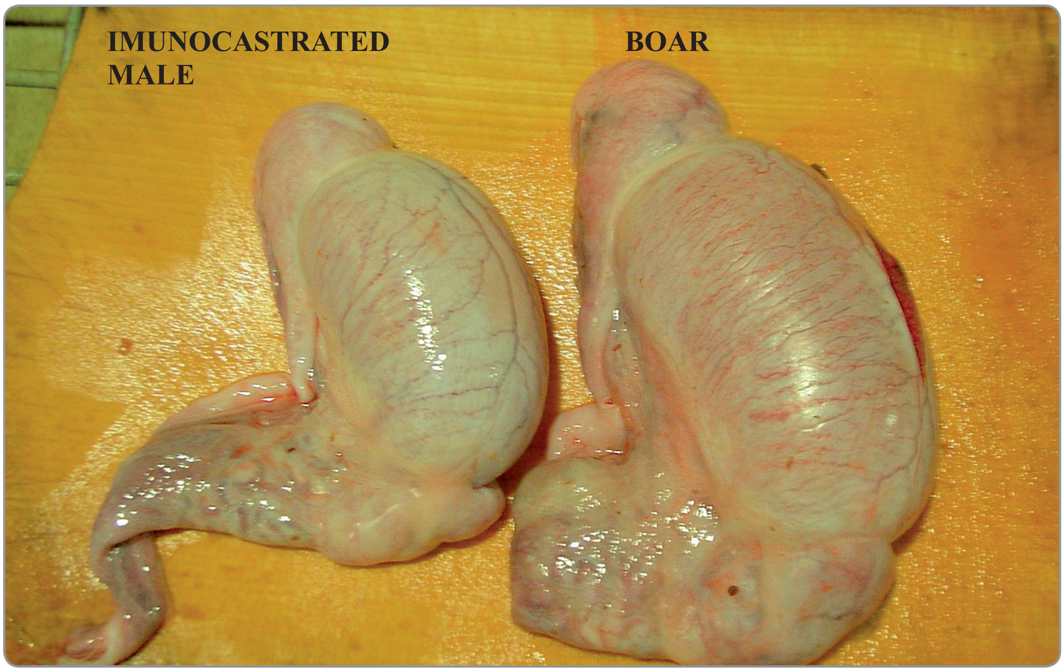


Figure 1. Representative image of testes belonging to an immunocastrated male and an entire male boar.

compared to entire male boars (*Dunshea et al.,* 2001; *Oliver et al.,* 2003; *Gispert et al*., 2010). In the study of *Fuchs et al.* (2009), there were no significant differences between immunocastrates and barrows in average body weight and weight of carcasses after slaughter. In our study there were no significant differences between the average warm carcass weight of immunocastrates and barrows, or between immunocastrates and entire males (Figure 3), which is consistent with the results of *Fuchs et al*. (2009).

Chilling losses of barrows, entire males and immunocastrates are shown in Figure 4. Chilling loss of barrows was significantly lower ($p<0.01$)

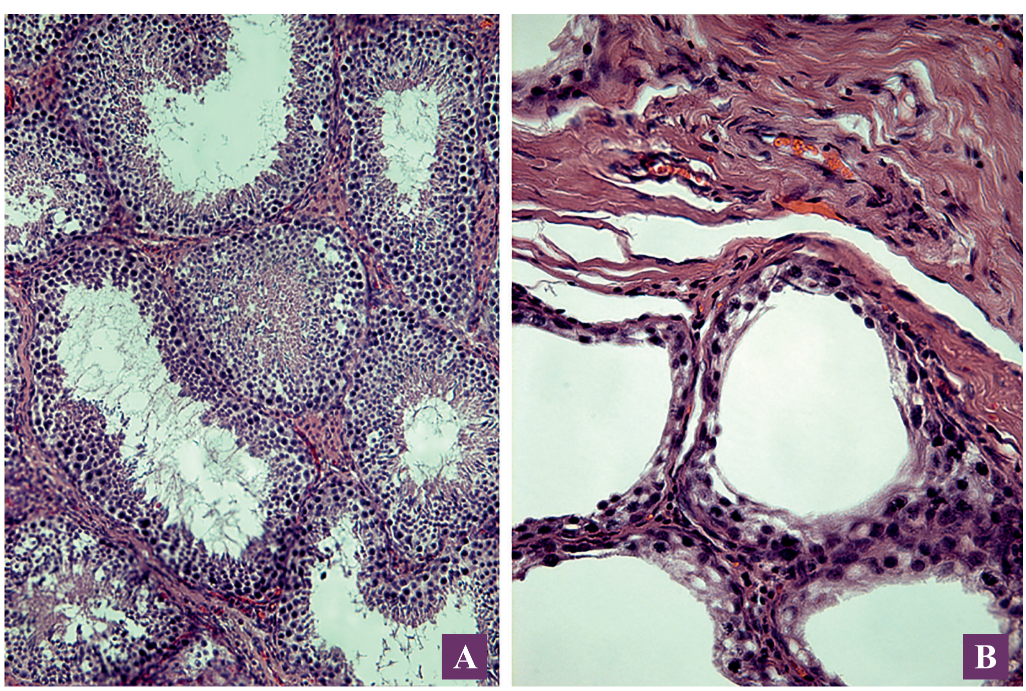
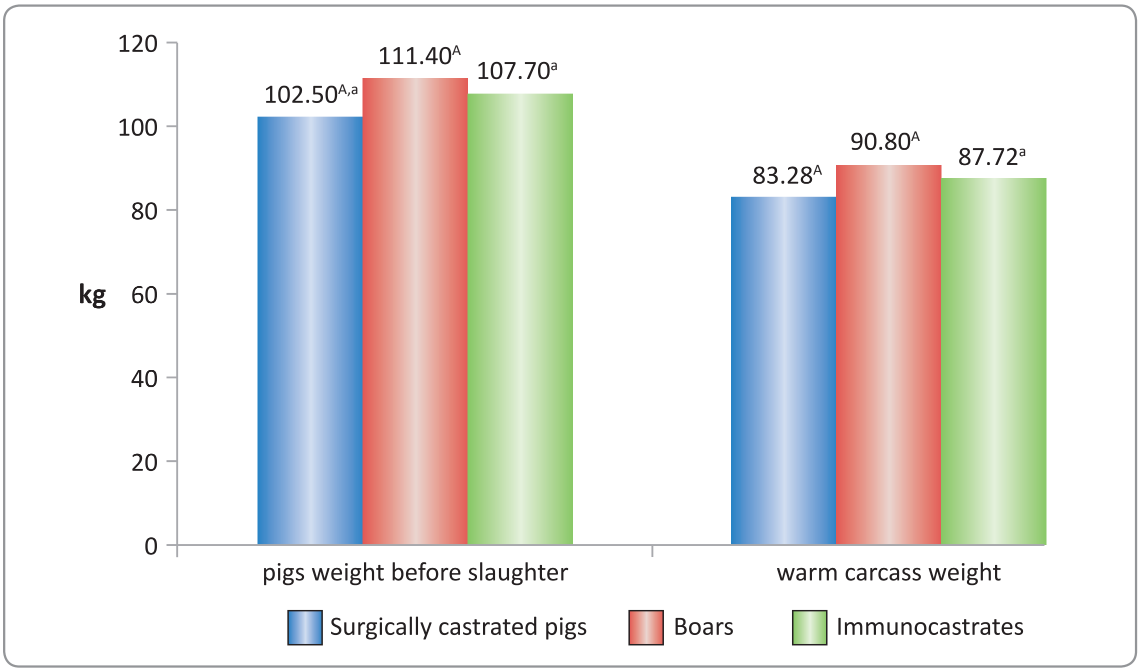


Figure 2. Typical testicular histology of an entire male boar (A) and an immunocastrated male (B).



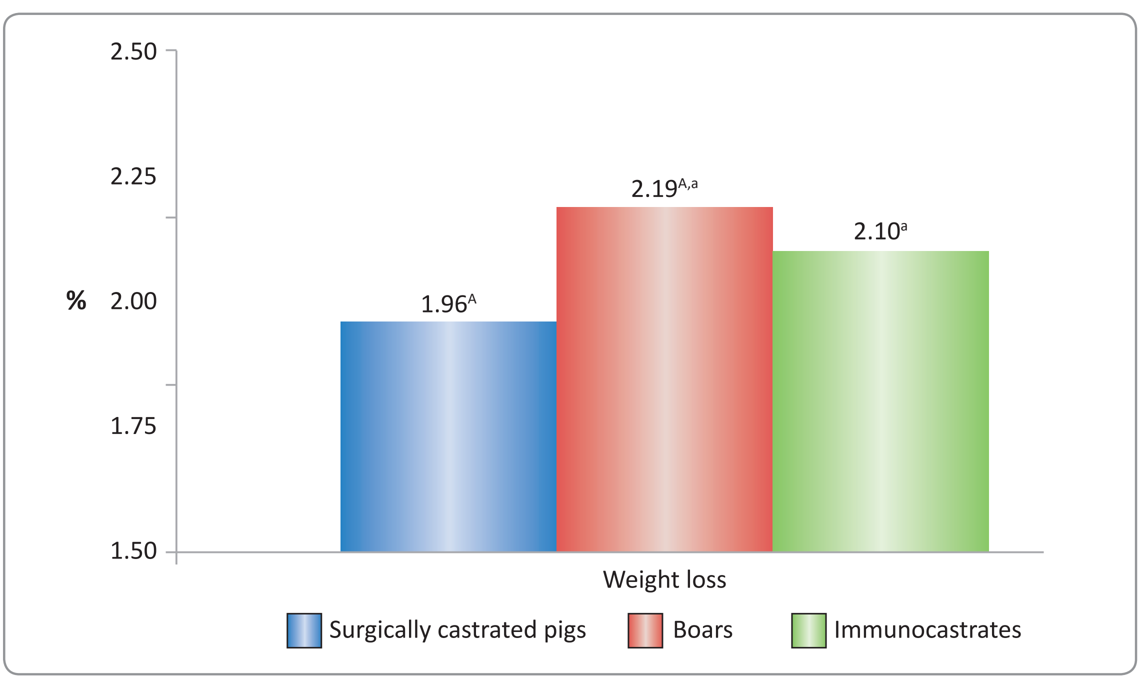
Legend: Means with a common superscript letter are significantly different: [A] – p<0.01; [a] – p<0.05.

Figure 3. Pig weight before slaughter and warm carcass weight ($\overline{X}$).

than chilling loss of males or immunocastrates. It was also found that the chilling loss of immunocastrates was significantly lower (p<0.05) than chilling loss of entire males.

Carcass yields for the three pig groups was calculated on the basis of chilled carcass weights and ranged from 79.06±2.03% to 79.77±2.30%. There were no significant differences between the average carcass yields of the three pig groups (Figure 5).

Numerous factors, such as breed, type, genotype, nutrition, weight and age at slaughter affect the quality of live and slaughtered pigs, and



Legend: Means with a common superscript letter are significantly different [A] - p<0.01; [a] – p<0.05.

Figure 4. Chilling loss ($\overline{X}$) of barrows, males and immunocastrates.

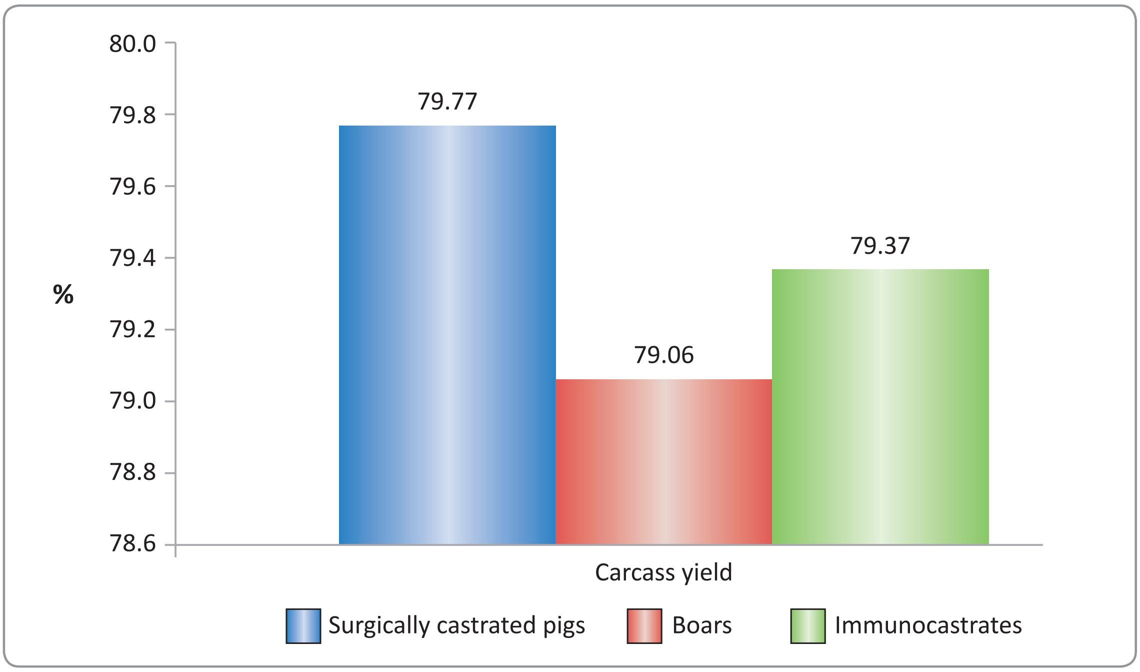
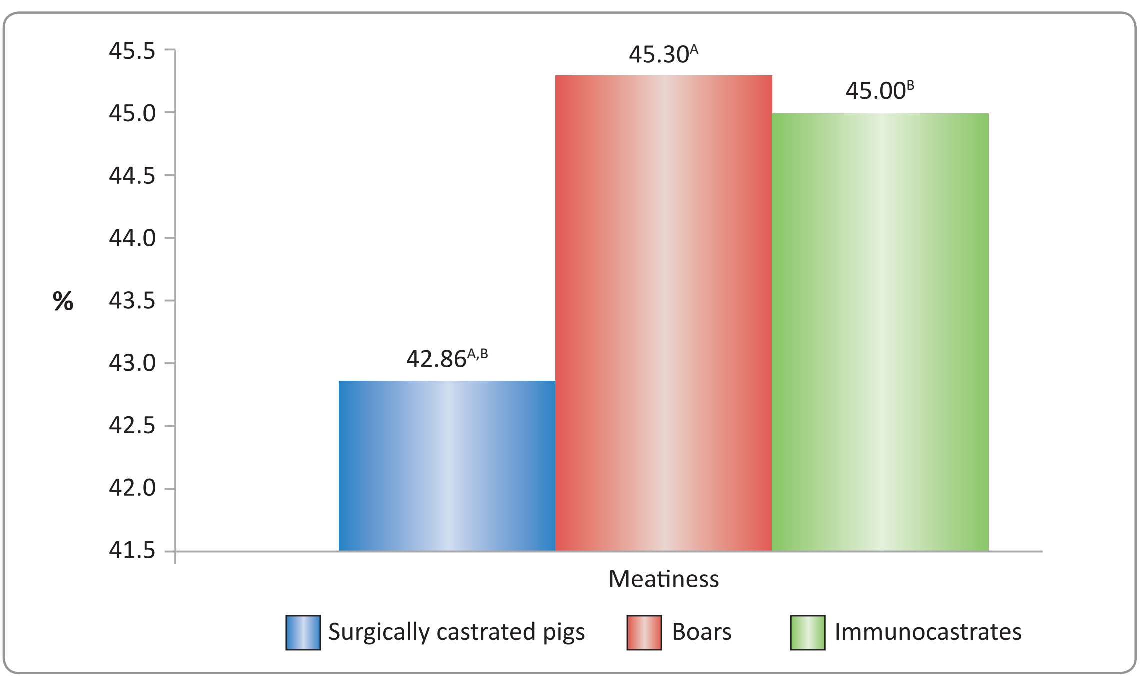


Figure 5. Carcass yield ($\overline{X}$) of the three pig categories.

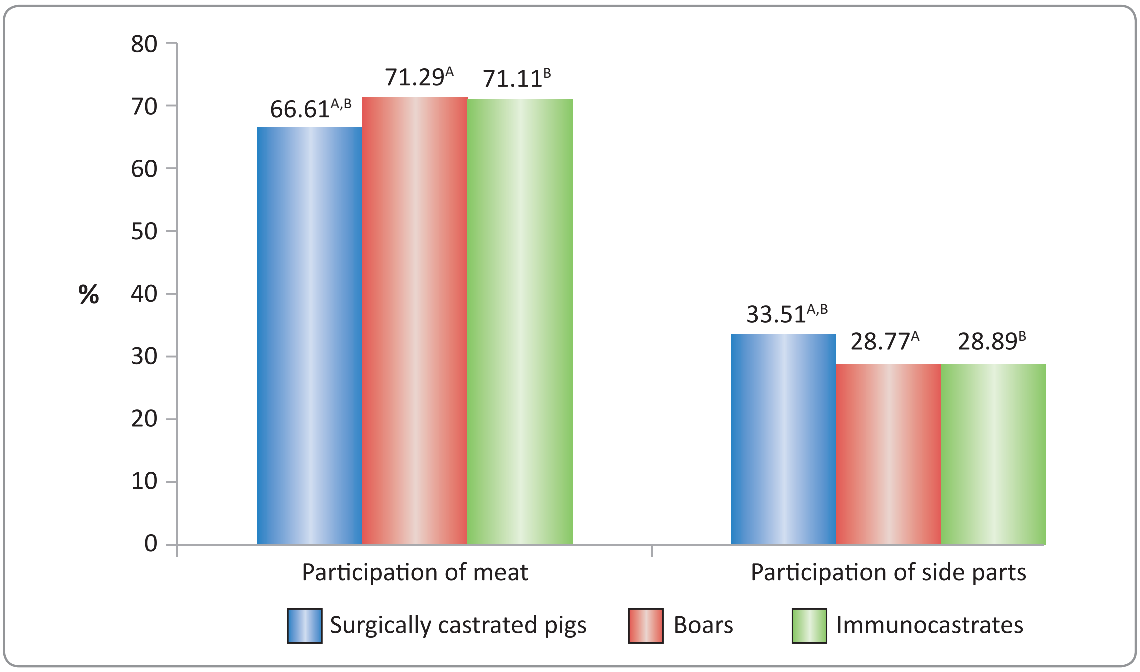
characteristics of the meat and fat. In fattening pigs kept in groups and fed with concentrated feed *ad libitum*, *Sencic et al.* (2005) indicated that increased body weight results in increased yield, although this also depended on the pig type. In fatty type pigs, carcass yield is about 82.6%, in half fat types it is around 81.5%, and in fleshy type pigs, carcass yield is around 80.9% (*Jaros et al.*, 2005). Most often, carcass yield varies from 78% to 82% (*Jaros et al.*, 2005).

Meatiness of carcasses, expressed as a percentage, is shown in Figure 6. The average carcass meatiness of surgical castrates (42.86±1.12%) was significantly lower (p<0.01) than the average meatiness



Legend: Means with a common superscript letter are significantly different $^{A, B}$ – p<0.01.

Figure 6. Meatiness of carcasses ($\overline{X}$) from the three pig categories.



Legend: Means with a common superscript letter are significantly different A, B – $p<0.01$.

Figure 7. Percentage of meat and side parts in leg ($\overline{X}$) from the three pig categories.

of males (45.30±0.77%) and the average meatiness of immunocastrates (45.00±0.64%).

Elimination of puberty and production of carcasses without boar taint are the main reasons to apply Improvac vaccine (*Bonneau et al.,* 1994; *Dunshea et al.,* 2001; *Metz et al.,* 2002; *Turkstra et al.,* 2002; *Jaroš et al.,* 2005). The effects of this castration method are reflected in greater meatiness of immunocastrate carcasses, compared to those of surgical castrates. The study of *Jaros et al.* (2005) found that meat quality and proportion of muscle tissue are significantly better in immunocastrates compared to castrates. This is of special importance to producers, who thereby achieve better economic effects, as well as for the meat industry, which is always interested in more meaty carcasses.

Leg is the most valuable part of the pig carcass according to meat quality, and the amount of meat. The average percentages of meat and side parts of leg (knuckle, skin with subcutaneous fat tissue, bone) of barrows, entire males and immunocastrates obtained during processing are shown in Figure 7. The average percentages of meat in the leg from males and immunocastrates were significantly higher ($p<0.01$) compared to the average meat percentage from surgical castrates. Also, the average percentage of the side parts from barrows was significantly higher ($p<0.01$) than the side parts from males and immunocastrates.

There were no differences in the average weight of leg between the immunocastrate and males, which is in accordance with other results (*Fuchs et al.,* 2009; *Pauly et al.,* 2009; *Bonneau et al.,* 1994). In the study of *Skrlep et al.* (2010), immunocastrates had a higher proportion of muscle tissue in leg compared to castrates, while there was no different in the proportion of muscle tissue in legs of males and immunocastrates.

Table 1. Percentage of side parts in total leg weight of the three pig categories.

Pig category	Knuckle	Bones	Skin with subcutaneous fat tissue
Surgically castrated pigs	$12.34^{A}\pm0.36$	$5.73^{A}\pm0.32$	$15.32^{A,B}\pm2.34$
Entire males	$11.92^{B}\pm0.64$	$5.70^{B}\pm0.30$	$11.09^{A}\pm2.24$
Immunocastrates	$13.29^{A,B}\pm0.78$	$6.36^{A,B}\pm0.46$	$9.25^{B}\pm2.28$

Legend: Data are mean ± standard deviation. Within a column, means with a common superscript letter are significantly different A, B – $p<0.01$.

Table 2. Chemical composition (%) of meat from the three pig categories.

Pig category	Water	Proteins	Lipids	Ash
Surgically castrated pigs	72.61^{A}±0.46	21.83^{A}±0.27	4.27^{A,B}±0.19	1.40±0.02
Entire males	73.54^{A,a}±0.41	22.52^{A,B}±0.33	2.59^{A,C}±0.20	1.40±0.01
Immunocastrates	73.04^{a}±0.32	22.05^{B}±0.15	3.67^{B,C}±0.25	1.41±0.02

Legend: Data are mean ± standard deviation. Within a column, means with a common superscript letter are significantly different ^{A,B,C} – p<0.01; ^{a} – p<0.05.

The percentage of side parts (knuckle, bones, skin with subcutaneous fatty tissue) in the total leg weight of barrows, males and immunocastrates are shown in Table 1. The percentages of knuckles and bones in the total leg weight of immunocastrates were significantly higher (p<0.01) then percentages of these parts in the total leg weight of barrows and males. In contrast, the percentage of skin with subcutaneous fat tissue was significantly higher (p<0.01) in the total leg weight of surgically castrated pigs than it was in males and immunocastrates.

Entire male pig carcasses have a higher proportion of bones, while barrows have a lower proportion of bones and consequently produce fewer losses due to deboning. Entire males had a higher proportion of muscle tissue, and among other groups (castrates, immunocastrates) there were no differences (*Cruz-Bustillo et al.,* 1989; *Judge et al*., 1990). Additionally, a higher proportion of leg, loin and shoulder was found in entire males than in immunocastrates, and in immunocastrates compared to castrates (*Cruz-Bustillio et al.,* 1989; *Judge et al*., 1990). The carcasses of males have about 5% more muscle tissue compared to castrates (*Cruz-Bustillio et al.,* 1989; *Judge et al*., 1990).

Chemical parameters of meat quality were studied in *m. longissimus dorsi pars lumbalis* of our three pig types (Table 2). Average water content in the meat from entire males was significantly higher (p<0.01) than the average water content in barrow meat. We also found that the average water content in immunocastrate meat was significantly lower (p<0.05) than the average water content in meat from entire males. There were no significant differences between the average water content in meat from barrows and immunocastrates. Ash content in the meat of males and surgical castrates was identical, and that in meat from immunocastrates was slightly higher; however, there were no statistically significant differences among the groups (Table 2). These results are similar to those reported by *Gokdal et al.* (2010).

Differences between the average fat content in meat of barrows, males and immunocastrates were significant. The main effects of immunocastration included a reduction of intramuscular fat in proportion to surgical castrates, but not to the average level we determined in meat from entire males (p<0.01; Table 2). It is expected that these differences would adversely affect the tenderness and juiciness of meat. In contrast, the force required for meat cutting is reduced, which should be beneficial for tenderness. Also, characteristics such as intramuscular fat, meat color and chilling loss were better for immunocastrates compared to castrates (*Hennessy et al.,* 2000).

An integral evaluation, incorporating the results of production (*Fàbrega et al.,* 2010), meat and carcass quality and sensory characteristics (*Font-i-Furnols et al.,* 2008; *Font-i-Furnols et al.,* 2012), suggests that vaccination with Improvac for boar taint control will provide a good alternative to surgical castration.

Conclusion

Regarding our results we can conclude that immunocastration, from the point of view of meat and carcass quality, could be a good alternative to surgical castration.

Conflict of Interest. The authors declare that they have no conflicts of interest.

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References

Aleksic, J., Dokmanovic, M., Aleksic, Z., Teodorovic, V., Stojic, V., Trbovic, D., Baltic & Z. M. (2012). Investigation of the efficacy of immunocastration aimed at the prevention of sex odour in boar meat. *Acta Veterinaria Beograd, 62*, 653-663.

AOAC. (1990). Official Methods of Analysis, 15th ed. Association of Analytical Chemists, Washington, DC.

Aluwé, M., Langendries, K. C. M., Bekaert, K. M., Tuyttens, F. A., De Brabander, D. L., De Smet, S. & Millet, S. (2015). Effect of surgical castration, immunocastration and chicory-diet on the meat quality and palatability of males. *Meat Science, 94*, 402–407.

Bonneau, M., Dufour, R., Chouvet, C., Roulet, C., Meadus, W. & Squires, E. J. (1994). The effects of immunization against luteinizing hormone-releasing hormone on performance, sexual development, and levels of boar taint-related compounds in intact male pigs. *Journal of Animal Science, 72*, 14–20.

Cruz-Bustillo, D., Steer, R., Barreto, B., Sanches, A., Rojas, J. R., Pacheco, G. & Varona, S. (1989). Animal behaviour, carcass composition and sensory evaluation of meat from entire male slaughter pigs raised in commercial conditions. In Proceedings of the International Congress of Meat Science and Technology, Copenhagen, pp. 103941.

Dokmanovic, M, Baltic, M., Djuric, J., Ivanovic, J., Popovic, Lj., Todorovic, M., Markovic, R. & Pantic, S. (2015). Correlations among different stress, meat and carcass quality parameters in pigs. *Asian-Australasian Journal of Animal Sciences, 23*, 435-441.

Dokmanovic, M., Velarde, A., Tomovic, V., Glamoclija, N., Markovic, R., Janjic, J. & Baltic, M. Z. (2014). The effects of lairage time and handling procedure prior to slaughter on stress and meat quality parameters in pigs. *Meat Science, 98*, 220-226.

Dunshea, F. R., Colantoni, C. & Howard, K. (2001). Vaccination of males with a GnRH vaccine (Improvac) eliminates boar taint and increases growth performance, *Journal of Animal Science, 79*, 2524–2535.

European Medicines Agency. (2013). European Public Assessment Report (EPAR): IMPROVAC (EMEA/V/C/136). Retrieved January 2017, from. http://www.ema.europa.eu/docs/en_GB/document_library/EPAR__Summary_for_the_public/veterinary/000136/WC500064055.pdf

Fàbrega, E., Velarde, A., Cros, J., Gispert, M., Suárez, P., Tibau, J. & Soler, J. (2010). Effect of vaccination against gonadotrophin-releasing hormone, using Improvac®, on growth performance, body composition, behaviour and acute phase proteins. *Livestock Science, 132*, 53–59.

Font-i-Furnols, M., Gispert, M., Guerrero, L., Velarde, A., Tibau, J., Soler, J., Hortós, M., García-Reguero, J.A., Pérez, J., Suárez, P. & Oliver, P. (2008). Consumers' sensory acceptability of pork from immunocastrated male pigs. *Meat Science, 80*, 1013–1018.

Font-i-Furnols, M., Gispert, M., Soler, J., Diaz, M., Garcia-Regueiro, J.A., Diaz, I. & Pearce, M.C. (2012). Effect of vaccination against gonadotrophin-releasing factor on growth performance, carcass, meat and fat quality of male Duroc pigs for dry-cured ham production. *Meat Science, 91*, 148-54.

Fuchs, T., Nathues, H., Koehrmann, A., Andrews, S., Brock, F., Sudhaus, N., Klein, G. & Beilage, E. (2009). A comparison of the carcase characteristics of pigs immunized with a 'gonadotrophin-releasing factor (GnRF)' vaccine against boar taint with physically castrated pigs. *Meat Science, 83*, 702-705.

Gispert, M., Oliver, M. A., Velarde, A., Suarez, P., Perez, J. & Furnols, M. F. (2010). Carcass and meat quality characteristics of immunocastrated male, surgically castrated male, entire male and female pigs. *Meat Science, 85*, 664–670.

Gökdal, Ö., Atay, O., Ülker, H., Kayaardı, S., Kanter, M., De Avila, M. D. & Reeves, J. J. (2010). The effects of immunological castration against GnRH with recombinant OL protein (Ovalbumin-LHRH-7) on carcass and meat quality characteristics, histological appearance of testes and pituitary gland in Kıvırcık male lambs. *Meat Science, 86*, 692-698.

Hennessy, D. P., Dunshea, F. R., McCauley, I., Colantoni, C., Jackson, P., Long, K. A., Lopaticki, S., Nugent, E.A., Simons, J. A. & Walker, J. (2000). Immunocastration – world first boar taint vaccine, Proceedings of the 16th International Pig Veterinary Society Congress, Melbourne, Australia, 315–323.

Jaros, P., Burgi, E., Stark, K. D. C., Claus, R., Hennessy, D. & Thun, R. (2005). Effect of active immunization against GnRH onandrostenone concentration, growth performance and carcass quality in intact male pigs. *Livestock Science, 92*, 31-38.

Judge, M. D., Mills, E. W., Orcut, M.W., Forrest, J. C., Diekman, M., A., Harmon, B. G., Lin, R. S. & Nicholls, L. L. (1990). Utilization of boar meat: composition, quality and odour incidence in relation to androstenone and skatole. *Animal Science Journal, 68*, 1030-1033.

Lundstrom, K., Matthews, K. R. & Haugen, J. E. (2009). Pig meat quality from entire males. *Animal, 3*, 1497–1507.

Matthews, K. R., Homer, D. B., Punter, P., Beague, M. P., Gispert, M. & Kempster, A. J. (2000). An international study on the importance of androstenone and skatole for boar taint: III. Consumer survey in seven European countries. *Meat Science, 54*, 271-283.

Metz, C., Hohl, K., Waidelich, S., Drochner, W. & Claus, R. (2002). Active immunization of males against GnRH at an early age: consequences for testicular function, boar taint accumulation and N-retention. *Livestock Production Science, 74*, 147–157.

Oliver, W.T., McCauley, I., Harrell, R. J., Suster, D. J., Kerton, D. J. & Dunshea, F. R. (2003). A gonadotropin-releasing factor vaccine (Improvac) and porcine somatotropin have synergistic and additive effects on grow performance in group housed males and gilts. *Animal Science Journal, 81*, 1959–1966.

Pauly, C., Spring, P., O'Doherty, J. V., Ampuero Kragten, S. & Bee, G. (2009). Growth performance, carcass characteristics, and meat quality of group penned surgically castrated, immunocastrated (Improvac®) and entire male pigs and individually penned male pigs. *Animal, 3*, 1057–1066.

Regulation of the quality of slaughtered pigs and categorization of pork meat (Sl. list SFRJ, 2/85, 12/85 and 24/86). In Serbian.

Ribeiro, A., Hernandez, E. L., Zanella, J. A., Shimokomaki, E. L., Prudêncio-Ferreira, M., Youssef, S. H. & Reeves, J. J. (2004). Growth and carcass characteristics of pasture fed LHRH immunocastrated, castrated and intact *Bos indicus* bulls. *Meat Science, 68*, 285-290.

Sencic, Dj., Antunovic, Z., Kanisek, J. & Speranda, M. (2005). Fattening, meatness and economic efficiency of fattening pigs. *Acta Veterinaria Beograd, 55*, 327-334.

Skrlep, M., Segula, B., Prevolnik, M., Kirbis, A., Fazarinc, G. & Candek-Potokar, M. (2010). Effect of immunocastration (Improvac) in fattening pigs II: carcass traits and meat quality. *Slovenian Veterinary Research, 47*, 65-72.

Skrlep, M., Batorek, N., Bonneau, M., Prevolnik, M., Kubale, V. & Candek-Potokar, M. (2012). Effect of immunocastration in group-housed commercial fattening pigs on reproductive organs, malodorous compounds, carcass and meat quality. *Czech Journal of Animal Science, 57*, 290-299.

Turkstra, J. A., Zeng, X. Y., Van Diepen, J. T. M., Jongbloed, A. W., Oonk, H. B., Van de Wiel, D. F. M. & Meloen, R. H. (2002). Performance of male pigs immunized against GnRH is related to the time of onset of biological response. *Animal Science Journal, 80*, 2953-2959.

Zamaratskaia, G., Andersson, H.K., Chen, G., Andersson, K., Madej, A. & Lundström, K. (2008). Effect of a gonadotropin-releasing hormone vaccine ImprovacTM on steroid hormones, boar taint and performance in entire male pigs. *Reproduction in Domestic Animals, 43*, 351-359.

Zamaratskaia, G. & Krøyer Rasmussen, M. (2015). Immunocastration of male pigs – situation today. *Procedia Food Science, 5*, 324–327.

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