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RESEARCH ARTICLE

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Effect of Immunocastration Vaccine Administration At Different Doses on Performance of Feedlot Holstein Bulls

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ABSTRACT

The aim of the study is to determine the effect of immunocastration vaccine administration at different doses on fattening performance of feedlot Holstein bulls. In this research, 94 Holstein male calves assigned to the 4 treatments. Control group; 1 mL of 0.9% saline solution was subcutaneously injected to intact bulls on 1st and 60th days of the feedlot as placebo. On the same days of the feedlot, Immunocastration vaccine (Bopriva®) at two doses of 1 mL and 1 mL for Trial-1 group, 1.5 mL and 1.5 mL for Trial-2 group, 1.5 mL and 1 mL for Trial-3 group were subcutaneously injected to bulls. The feedlot lasted 180 days. Immunocastration vaccine administration at different doses did not affect the live weights (LWs) and cold carcass yields of feedlot Holstein bulls (P>0.05). However, it reduced fattening performance between 61-120 days (P<0.05) and 1-180 days (P<0.01). As a result, it was decreased the fattening performance that administration of Bopriva® at different doses as a GnRH vaccine in Holstein male bulls; whereas it was determined that numerically increase in average daily live weight gain was found in the Trial-2 group than the other groups to which the immunocastration vaccine was applied.

Keywords: GnRH, fattening, immunocastration

Farklı Dozlarda İmmunokostrasyon Aşı Uygulamasının Entansif Koşullarda Yetiştirilen Holstein Erkek Danalarının Besi Performansı Üzerine Etkisi

ÖZ

Bu çalışmanın amacı, farklı dozlarda GnRH aşısının Holştayn erkek buzağılarında besi performansı ve karkas randımanı üzerine etkisinin belirlenmesidir. Araştırmada, 94 baş Holştayn ırkı erkek buzağı kullanılmış ve rastgele 4 gruba ayrılmıştır. Besinin 1. ve 60. gününde kontrol grubuna plasebo olarak 1 mL %0.9'luk tuzlu su çözeltisi derialtı yolla enjeksiyon yöntemi ile uygulanmıştır. Besinin aynı günlerinde, Deneme-1 grubundaki buzağılara 1 mL ve 1 mL, Deneme-2 grubundaki buzağılara 1.5 mL ve 1.5 mL ve Deneme-3 grubundaki buzağılara ise 1.5 mL and 1 mL olmak üzere iki doz immunokastrasyon aşısı (Bopriva®) derialtı yolla enjeksiyon yöntemi ile uygulanmıştır. Besi 180 gün sürüştür. Farklı dozlarda immunokastrasyon aşısı uygulamasının entansif koşullarda yetiştirilen Holştayn erkek danalarında, canlı ağırlık ve karkas randımanı üzerine etkisinin olmadığı belirlenmiştir (P>0.05). Buna karşın immunokastrasyon aşısı uygulamasının besinin 61-120 (P<0.05) ile 1-180. gün (P<0.01) arası dönemde besi performansını azalttığı belirlenmiştir. Sonuç olarak, Holştayn erkek danalarında GnRH aşısı olarak Bopriva®'nın farklı dozlarda uygulamasının; besi performansını düşürdüğü buna karşın immunokastrasyon aşısı uygulanan gruplar içinde rakamsal olarak en yüksek canlı ağırlık artışının Deneme-2 grubunda olduğu tespit edilmiştir.

Anahtar Kelimeler: GnRH, besi, immunokastrasyon

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INTRODUCTION

Castration of male animals is a widespread farming method reported in the literature for more than 50 years and is used world-wide in controlling fertility. Castration has been commonly conducted to enhance growth, metabolism, carcass, and meat quality through decreased pH in the carcasses. It has also been used to improve body fat deposition, reduce aggressive and sexual behaviour for handling the animals in an easier manner, to obtain less carcass damage and to improve animal welfare for animal producers, consumers and owners. Unless the animals are not castrated, they may become dangerous because of aggressive behaviours among themselves and to the people who handle them (Wierbicki et al. 1955, Field 1971, Lofthouse and Kemp 2002, Duff and McMurphy 2007, Freitas et al. 2008, Amatayakul-Chantler et al. 2012, Miesner and Anderson 2015).

Surgical castration is commonly applied, although different castration methods are applied in animals. However, surgical castration (i.e. gonadectomy) usually comes with complications (stress, pain, discomfort etc..) and consequent reductions in post-castration performance (decrease in feed efficiency and rate of growth, and elongated deterioration in productivity etc.) (Marti et al. 2015, Ison et al. 2016).

Vaccination for gonadotropin-releasing hormone (GnRH), which is also called as immunocastration, is considered to be an animal-friendly alternative for surgical castration has received particular attention in male and female mammals. Both for males and females, GnRH, a hypothalamic hormone, has an important role in the regulation of reproductive functions. For this reason, immunization for GnRH (GnRH vaccine) ends up in the neutralization of endogenous GnRH with the subsequence suppression of the gonadotropin-luteinizing hormone (LH) and follicle-stimulating hormone (FSH) expression by anterior pituitary. As a result of this, testicular testosterone and androsterone production is reduced (Bonneau and Enright 1995, Thompson 2000).

GnRH secretion have marked increases after 4 months of age (happening at the same time with the increase in the secretion of LH) in Bull calves, at which time prepubertal transition and testicular development begins (Rodriguez and Wise 1989, 1991). However, benefits on carcass enhancement and testicular growth resulted with one immunization in 4 - 12 months of age (Adams et al. 1996).

The potential to use GnRH vaccine has caused specific attention in major livestock including cattle (Robertson et al. 1979, Finnerty et al. 1998, Huxsoll et al. 1998), goats (Godfrey et al. 1996), pigs (Caraty and Bonneau 1986, Molenaar et al. 1993, Meloen et al. 1994) and sheep (Clarke et al. 1978, Brown et al. 1995, Clarke et al. 1998).

A cattle-specific GnRH vaccine (for immunocastration) (Bopriva®, Zoetis Australia Ltd., West Ryde, Australia) was approved to be used in heifers and bulls in New Zealand, Australia, Mexico, Brazil, Argentina, Turkey, and Peru (Balet et al. 2014). The immunocastration vaccine is applied in 2 doses. With the 1st dose, the bovine immune system is prepared; and the immune response is activated with the 2nd dose. The animal is deemed immunocastrated only when the second dosage (i.e. the booster) is applied (Hennessy 2008). Suppression of GnRH in the hypothalamic axis through antibody induction by GnRH vaccine, reduced the testosterone concentration released, and as a result, the function of the gonads (Sherwood et al. 1993).

It has been reported in several studies conducted before that immunological castration may be very effective to prevent aggressive and sexual behaviour in bulls (Jago et al. 1997a, Marti et al. 2015, Price et al. 2003), but, literature data show that there is no clear effect of immunocastration on performance. The growth of immunocastrated animals was reported to be equal to castrates and less in intact bulls (Cook et al. 2000; Ribeiro et al. 2004, Hernández et al. 2005), intermediate between those that are intact and castrates (Adams et al. 1996, Aïssat et al. 2002) or equal to bulls that are intact (Adams and Adams 1992, Finnerty et al. 1994, Adams et al. 1996, Huxsoll et al. 1998, D'Occhio et al. 2001, Amatayakul-Chantler et al. 2012, Pérez-Linares et al. 2017).

In order to cover the increasing red meat demands of the ever-increasing population of the world, different strategies have been developed and different husbandry methods are used as well as castration. Although those who deal with livestock for meat have used high meat yield cattle bred as Angus and Charolais, they thought of fattening Holstein bull calves as an option, provided that they yield certain advantages to cattle producers like obtaining high-quality carcass (Duff and McMurphy 2007).

When it is considered that the studies in which the effects of immunocastration on growth performance are investigated are limited in number, and the fact that Holstein male calves are used to produce red meat by producers of livestock for meat are considered together, the purpose of the present study is to define the immunocastration dose that ensures the best breeding performance and to investigate the effects of immunization against gonadotropin-releasing hormone at different doses on feeding performance in Holstein male calves.

MATERIAL and METHODS

All animal-use protocols were carried out in accordance with Directive 2010/63/EU of the European Parliament and Council of 22 September 2010 on the protection of animals used for scientific purposes (EUD 2010). Research was conducted according to the institutional committee on animal use (protocol/file number 2016/16).

A total of 94 Holstein male calves (309.5 ± 2.58 kg LW and 267 days old) were distributed to one of the 4 treatment groups: intact bulls (Control), animals vaccinated with first and second (60 days after the first vaccination and starter of the feedlot) dose of with GnRH (vaccinated) which dose are 1.0 mL and 1.0 mL (Trial-1), 1.5 mL and 1.5 mL (Trial-2), 1.5 mL and 1.0 mL (Trial-3), respectively. The study was conducted in a private farm in Sirvan County of the Siirt province.

Between the arrival and the time when the trial started, the animals were handled in an equal manner. During the trial, animals were blocked based on BW. The animals were fed with the same feed (50.0% corn, 15.0% barley, 10.0% soybean meal, 12.2% sunflower meal, 1.75% limestone, 0.50% salt, 0.25% DCP, 0.3% premix; 16.1% CP, 5.2% ash, 11.2 Mcal MJ/kg; DM basis) and barley straw (4.1% CP, 6.3% ash; DM basis) ad libitum throughout the experiment. On day 0 and 60 of the feedlot, different dozes of GnRH vaccine (Bopriva®, Zoetis, Turkey) was given subcutaneously to animals in treatment group on neck's left side with a 12.5-mm 16-gauge needle in one dose with a safety vaccinator. On the same days of the feedlot, 1.0 mL of 0.9% saline solution was injected subcutaneously to control group as placebo.

In order to adopt the calves to the feed that will be used in breeding in 14 days, the feed was increased slowly before the study started. The animals were weighed with a scale in every 15-day period to determine their LWs. The feeding lasted for 180 days. With the help of the LWs taken initially, at the end of the feeding period, and in 15-day periods, the LW and average daily live weight gain (ADG) were determined in various periods. In addition, 12 animals were slaughtered from each group after the feeding period, and the hot and cold carcass yields were determined.

The statistical analysis for normal distribution data of the treatment groups was carried out with the general linear model procedure of SPSS software 20.0 (SPSS Inc., Chicago, IL, USA). The results are given as mean ± standard deviation. Duncan's multiple range test was employed for multiple comparisons in important groups. Data points with different letters were considered to be different at a significant level ($P \leq 0.05$).

The data were statistically analyzed using general linear model procedure adopted by SPSS 20.0 for Windows (SPSS Inc., Chicago, IL, USA) statistics software with One-way ANOVA. The results are given as mean ± standard deviation. Data points with different letters were considered to be different at a significant level ($P \leq 0.05$). Statistical significant effects were further analyzed and means were compared using Duncan's multiple range test.

RESULTS

In different periods of the feeding, it was determined that the immunocastration application at different doses did not have any effects on LW of the Holstein male calves ($P<0.05$). However, applying immunocastration at different doses reduced the ADG in the period between days 61 and 120 ($P<0.01$) and throughout the feeding period (days 1-180) ($P<0.05$) and also reduced the ADG. In other words, it was determined that the ADG of the calves in the Control Group were higher than the ADG of the calves throughout the feeding and between the days 61-120 when compared with the trial groups. In addition to this, it was determined that there were no statistically significant differences between the trial groups in terms of ADG ($P>0.05$) (Table 1).

It was also determined that applying immunocastration at different doses did not affect the hot carcass weight, hot carcass yield, cold carcass weight, and cold carcass yield of Holstein male calves ($P>0.05$) (Table 2).

Table 1. Effect of Immunocastration Vaccine Administration at Different Doses on live weight and daily live weight gain in various periods in Feedlot Holstein Bulls
Tablo 1. Holştayn Erkek Danalarında Farklı Dozlarda İmmunokastrasyonun çeşitli dönemlerdeki canlı ağırlık ve günlük canlı ağırlık artışı üzerine etkisi

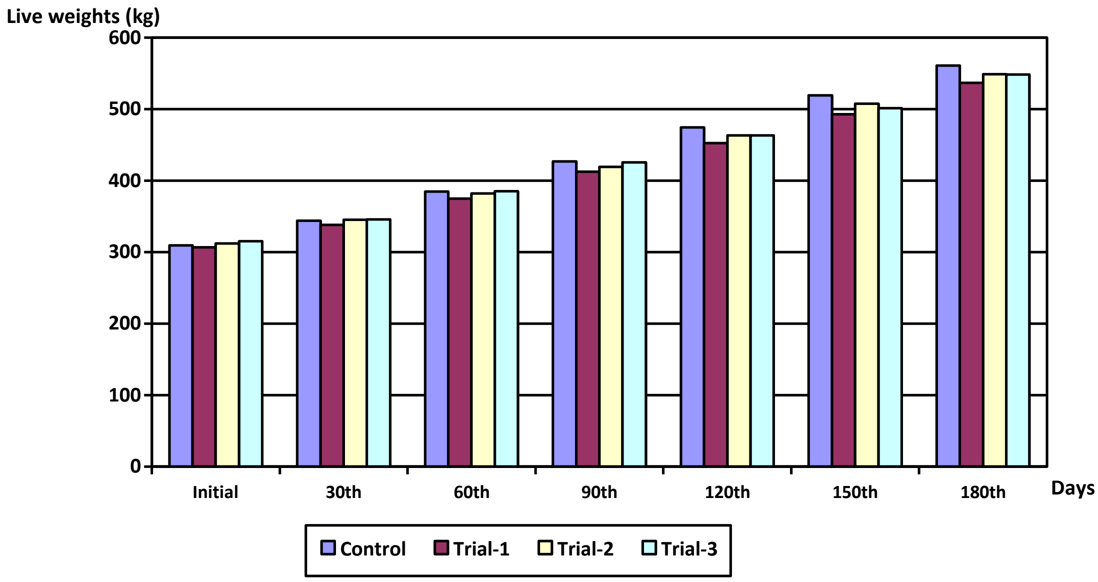
	Control	Trial-1	Trial-2	Trial-3	P-Value
			Live Weight		
Initial	309.21±5.49	306.62±4.22	312.11±5.45	315.39±5.23	0.652^{ns}
30th	343.72±5.29	338.30±4.28	345.41±6.39	345.70±7.06	0.693^{ns}
60th	384.72±5.46	374.95±4.40	381.96±6.77	385.05±8.59	0.501^{ns}
90th	426.93±6.28	412.39±4.70	419.13±7.74	425.44±10.21	0.325^{ns}
120th	474.32±6.48	452.53±4.83	463.18±7.81	462.95±10.7	0.137^{ns}
150th	518.98±6.68	492.62±4.94	507.31±7.25	501.19±11.43	0.053^{ns}
180th	560.88±8.27	536.67±5.35	548.56±8.36	548.25±11.95	0.144^{ns}
			Average Daily Live Weight Gain		
1-60th	1.26±0.05	1.14±0.02	1.16±0.06	1.16±0.07	0.210^{ns}
61-120th	$1.49±0.05^{a}$	$1.29±0.02^{b}$	$1.35±0.05^{b}$	$1.30±0.05^{b}$	0.001**
121-180th	1.44±0.08	1.40±0.03	1.42±0.06	1.42±0.04	0.938^{ns}
1-180th	$1.40±0.04^{a}$	$1.28±0.02^{b}$	$1.31±0.03^{b}$	$1.29±0.04^{b}$	0.016*

$^{a, b}$: Means with different superscripts in the same column differ significantly (P<0.05).
^{ns}: non-significant (P>0.05); *: P<0.05; **: P<0.01.

Table 2. Effect of immunocastration vaccine administration at different doses on carcass weight and percentage in feedlot Holstein bulls
Tablo 2. Holştayn Erkek Danalarında Farklı Dozlarda Bopriva ile İmmunokastrasyonun karkas ağırlığı ve oranı üzerine etkisi

	Control	Trial-1	Trial-2	Trial-3	P-Value
Hot carcass weight	291.86±10.55	279.21±4.94	282.96±5.01	289.93±6.28	0.451^{ns}
Hot carcass percentage	52.87±0.62	51.45±0.40	52.02±0.49	51.97±0.44	0.308^{ns}
Cold carcass weight	284.81±10.34	273.07±4.87	278.99±5.52	283.26±6.23	0.517^{ns}
Cold carcass percentage	51.59±0.61	50.32±0.40	50.85±0.46	50.77±0.45	0.398^{ns}

^{ns}: non-significant (P>0.05).



Graphic 1. The live weights at different periods in feedlot Holstein bulls
Grafik 1. Holştayn erkek danalarda besinin farklı dönemlerdeki canlı ağırlıklar

DISCUSSION

The LW, ADG, and carcass weight and yield are significant properties for farmers, livestock producers and industry. As well as providing heavier commercial cuts, heavier carcasses allow to diffuse costs by optimizing the industrial process. They are also payment to producers. In addition to these, it is significant to have a pattern as carcasses of different weights make it compulsory to have similar labour and process time; however, they have clear industrial profitability (Pazdiora et al. 2013).

It was determined that the GnRH vaccine at different doses did not have any effects on the LW of the animals in different periods of the trial in Holstein bulls vaccinated on days 0 and 60. These results were similar to those reported by Adams and Adams 1992, Freudenberger et al. 1993, Finnerty et al. 1994, Huxsoll et al. 1998, D'Occhio et al. 2001, Amatayakul-Chantler et al. 2012, Marti et al. 2013, Pérez-Linares et al. 2017, and different from those reported by Adams and Adams 1992 and Amatayakul-Chantler et al. 2013.

The results of previous studies show that the magnitude of the response in immunocastration has different effects for bulls. The heterogeneity in the results reported previously stems from the use of different vaccine formulation in previous studies, applying different vaccine programs (one, two or three booster doses, different duration of effect from booster-slaughter date), using different race, using implant or not, the difference in husbandry or management practice and from the different types of feed.

Steroid hormones stimulate hypertrophy of the neck, chest and rump muscles, and provide a more forequarter yield (Pazdiora et al. 2013). The impact of testosterone on intact males that develop muscles throughout life occur because of increased nitrogen retention (Galbraith et al. 1978). Prior et al. 1983 claimed that testosterone had an effect that inhibits lipogenic enzyme activities in adipose tissue and induces higher basal lipolytic rates. GnRH-vaccinated cattle, other factors, such as modified sexual or aggressive behaviour may assist in maintaining growth compensating for the decreased natural anabolic hormone testosterone concentrations (Jago et al. 1997b, Price et al. 2003, Amatayakul-Chantler et al. 2012).

In the present study, it was determined that the LW of the calves to which immunocastration was applied were lower than the calves that were included in the Control Group in terms of numbers. In addition, this situation may be referred to the fact that the LW of the calves to which immunocastration is applied may be lower than the calves included in the Control Group in terms of numbers depending on the longer duration for fat deposition in the calves to which immunocastration is applied when compared with the intact calves and with the foresight claiming that testosterone has a lipogenic inhibitory effect on the enzymatic activity of the fat tissue that increases the basal level of the lipolytic activity because of the anabolic effect of testosterone explained above (Coutinho et al. 2006, De Freitas et al. 2015, Andreo et al. 2016).

In the present study, the result showing that applying immunocastration at different doses on days 61-120 ($P<0.01$) and throughout the feeding period (days 1-180) ($P<0.05$) reduces ADG was similar to the result reported by Marti et al. 2017 and Moreira et al. 2017; and different from the result reported by Adams et al. 1993, Huxsoll et al. 1998, Cook et al. 2000, Amatayakul-Chantler et al. 2012, Pérez-Linares et al. 2017.

It was determined that applying immunocastration at different doses did not affect the carcass weight and yield in Holstein male calves; however, this application reduced the carcass weight and yield in terms of numbers when compared with the Control Group. It was verified in previous studies that there are no differences in carcass dressing % between intact bulls and the animals that were vaccinated (Adams and Adams 1992, Adams et al. 1993, Freudenberger et al. 1993, Ribeiro et al. 2004, Amatayakul-Chantler et al. 2012, Marti et al. 2013. On the other hand, unlike our study, some previous studies reported that carcass percentage of bulls was higher compared to that of vaccinated animals (Huxsoll et al. 1998, Cook et al. 2000). The reduced carcass percentage in vaccinated animals compared to bulls may be explained by the taking away of the excessive fat around the kidneys and heart, and from the pelvis of the carcasses.

CONCLUSIONS

Physical castration causes stres and reduces performance in animals, on the other hand active immunization against GnRH maintains (or with slight reduce) performance by maximizing welfare in bulls, and controls unwanted sexual and aggressive behavior. Considering these facts about physical- and immunocastration, it was decreased the fattening performance that administration of Bopriva® at different doses as a GnRH vaccine in Holstein male bulls; whereas it was determined that numerically increase in average daily live weight gain was found in the Trial-2 group than the other groups to which the immunocastration vaccine was applied.

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REFERENCES

Adams TE, Adams BM. Feedlot performance of steers and bulls actively immunized against gonadotropin-releasing hormone. Journal of Animal Science. 1992; 70: 1691-1698.

Adams TE, Daley CA, Adams BM, Sakurai H. Testis function and feedlot performance of bulls actively immunized against gonadotropin-releasing hormone: effect of implants containing progesterone and estradiol benzoate. Journal of Animal Science. 1993: 71(4); 811–817.

Adams TE, Daley CA, Adams BM, Sakurai H. Testes function and feedlot performance of bulls actively immunized against gonadotropin-releasing hormone: effect of age at immunization. J. Anim. Sci. 1996: 74; 950-954.

Aïssat D, Sosa JM, de Avila DM, Bertrand KP, Reeves JJ. Endocrine, growth, and carcass characteristics of bulls immunized against luteinizing hormone- releasing hormone fusion proteins. Journal of Animal Science. 2002: 80; 2209–2213.

Amatayakul-Chantler S, Hoe F, Jackson JA, Roça RDO, Stegner JE, King V, Howard R, Lopez E, Walker J. Effects on performance and carcass and meat quality attributes following immunocastration with the gonadotropin releasing factor vaccine Bopriva or surgical castration of Bos indicus bulls raised on pasture in Brazil. Meat Science. 2013: 95(1); 78-84.

Amatayakul-Chantler S, Jackson JA, Stegner J, King V, Rubio LMS, Howard R, Lopez E, Walker J. Immunocastration of Bos indicus × Brown Swiss bulls in a feedlot with the gonadotropin-releasing hormone vaccine Bopriva provides improved performance and meat quality. Journal of animal science. 2012: 90(11); 3718-3728.

Andreo N, Bridi AM, Soares AL, Prohmann PEF, Peres LM, Tarsitano MA, Giangareli BL, Takabayashi AA. Fatty acid profile of beef from immunocastrated (BOPRIVA®) Nellore bulls. Meat Science. 2016: 117; 12–17.

Balet L, Janett F, Hüsler J, Piechotta M, Howard R, Amatayakul-Chantler S, Steiner A, Hirsbrunner G. Immunization against gonadotropin-releasing hormone in dairy cattle: Antibody titers, ovarian function, hormonal levels, and reversibility. Journal of dairy science. 2014: 97(4); 2193-2203.

Bonneau M, Enright W. Immunocastration in cattle and pigs. Livest. Prod. Sci. 1995: 42;193–200.

Brown BW, Mattner PE, Carroll PA, Hoskinson RM, Rigby RDG. Immunization of sheep against GnRH early in life: effects on reproductive function and hormones in ewes. J. Reprod. Fert. 1995: 103; 131–135.

Caraty A, Bonneau M. Immunisation active du porc mPle contre la gonadoliberine: Effets sur la secretion d'hormones gonadotropes et sur la teneur en 5a-androst-16-ene- %one du tissu adipeux. C. R. Acad. Sci. Paris Ser. D 1986: 303:673

Clarke IJ, Brown BW, Tran VV, Scott CJ, Fry R, Millar RP, Rao A. Neonatal immunization against gonadotropin-releasing hormone (GnRH) results in diminished GnRH secretion in adulthood. Endocrinology. 1998: 139; 2007–2014.

Clarke IJ, Fraser HM, McNeilly AS. Active immunization of ewes against luteinizing hormone releasing hormone, and its effects on ovulation and gonadotrophin, prolactin and ovarian steroid secretion. J. Endocrinol. 1978: 78; 39–47.

Cook RB, Popp JD, Kastelic JP, Robbins S, Harland R. The effects of active immunization against GnRH on testicular development, feedlot performance, and carcass characteristics of beef bulls. Journal of Animal Science. 2000: 78(11); 2778–2783.

Coutinho JLV, Peres RM, Justo CL. Produção de carne de bovinos contemporâneos, machos e fêmeas, terminados em confinamento. Revista Brasileira de Zootecnia. 2006: 35(5); 2043–2049.

De Freitas VM, Leão KM, de Araujo Neto FR, Marques TC, Ferreira RM, Garcia LLF, de Oliveira EB. Effects of surgical castration, immunocastration and homeopathy on the performance, carcass characteristics and behaviour of feedlotfinished crossbred bulls. Semina: Ciências Agrárias. 2015: 36(3); 1725–1734.

D'Occhio MJ, Aspden WJ, Trigg TE. Sustained testicular atrophy in bulls actively immunized against GnRH: Potential to control carcase characteristics. Animal Reproduction Science. 2001: 66; 47–58.

Duff GC, McMurphy CP. Feeding Holstein steers from start to finish. The Veterinary Clinics of North America. Food Animal Practice 2007: 23(2); 281–297.

EUD. European Union Directive: Directive 2010/63/EU of the European Parliament and of the Council of 22 September 2010 on the protection of animals used for scientific purposes. Official Journal of the European Union. 2010: L276; 33-79.

Field RA. Effect of castration on meat quality and quantity. Journal of Animal Science. 1971: 32; 849–858.

Finnerty M, Enright WJ, Morrison CA, Roche JF. Immunization of bull calves with GnRH analogue-human serum albumin conjugate: Effect of conjugate dose, type of adjuvant and booster interval on immune, endocrine, testicular and growth responses. Journal of Reproduction and Fertility. 1994: 101;333–343.

Finnerty M, Enright WJ, Roche JF. Testosterone, LH and FSH episodic secretory patterns in GnRH-immunized bulls. J. Reprod. Fertil. 1998: 114; 85–94.

Freitas AK, Restle J, Pacheco PS, Pádua JT, Lage ME, Miyagi ES, Silva GFR. Características de carca¸cas de bovinos Nelore inteiros vs castrados em duas idades, terminados em confinamento. Brazilian Journal of Animal Science. 2008: 37; 1055–1062.

Freudenberger DO, Wilson PR, Barry TN, Sun YX, Purchas RW, Trigg TE. Effects of immunization against GnRH upon body growth, voluntary food intake and plasma hormone concentration in yearling red deer stags (Cervus elaphus). The Journal of Agricultural Science. 1993: 121(3); 381-388.

Galbraith H, Demspter DG, Miller TB. A note on the effect of castration on the growth performance and concentration of some bloodmetabolites and hormones in British Friesian male cattle. Animal Production. 1978: 26; 339–342.

Godfrey SI, Walkden-Brown SW, Martin GB, Speijers EJ. Immunisation of goat bucks GnRH to prevent seasonal reproductive and agonistic behaviours. Animal Reproduction Science. 1996: 44; 41–54.

Hennessy D. Improvac® mode of action. Technical bulletin, Pfizer Animal Health, Apr. 2008.

Hernandez JA, Zanella EL, Bogden R, de Avila DM, Gaskins CT, Reeves JJ. Reproductive characteristics of grass-fed, luteinizing hormone-releasing hormone-immunocastrated Bos indicus bulls. Journal of Animal Science. 2005: 83(12); 2901–2907.

Huxsoll CC, Price EO, Adams TE. Testis function, carcass traits, and aggressive behavior of beef bulls actively immunized against gonadotropin-releasing hormone. Journal of Animal Science. 1998: 76; 1760–1766.

Ison SH, Clutton RE, Di Giminiani P, Rutherford KMD. A review of pain assessment in pigs. Frontiers in Veterinary Science. 2016: 3; 1–16.

Jago JG, Bass JJ, Matthews LR. Evaluation of a vaccine to control bull behaviour. Proceedings of the New Zealand Society of Animal Production. 1997a: 57(Cv); 91–95.

Jago JG, Cox NR, Bass JJ, Matthews LR. The effect of prepubertal immunization against gonadotropin-releasing hormone on the development of sexual and social behavior of bulls. J. Anim. Sci. 1997b: 75; 2609-2619.

Lofthouse S, Kemp J. Manipulating the immune response; applications in livestock breeding. J Reprod Immunol. 2002: 57(1/2); 239–53.

Marti S, Devant M, Amatayakul-Chantler S, Jackson JA, López E, Janzen ED, Schwartkkopf-Genswein K S. Effect of anti-gonadotropin-releasing factor vaccine and band castration on indicators of welfare in beef cattle. Journal of Animal Science. 2015: 93; 1581–1591.

Marti S, Devant M, Amatayakul-Chantler S, Jackson JA, Janzen ED, Schwartzkopf-Genswein KS. Effects of anti-gonadotropin-releasing factor (GnRF) vaccine and band castration on carcass quality in beef cattle under North American management practices. ADSA - Asas Joınt Annual Meeting, 8-12 July 2013, Indianapolis, Indiana.

Marti S, Jackson JA, Slootmans N, Lopez E, Hodge A, Pérez-Juan M, Devant M, Amatayakul-Chantler S. Effects on performance and meat quality of Holstein bulls fed high concentrate diets without implants following immunological castration. Meat science. 2017: 126; 36-42.

Meloen RH, Turkstra JA, Lankhof H, Puijk WC, Schaaper WM, Dijkstra G, Wensing CJ, Oonk RB. Efficient immunocastration of male piglets by immunoneutralization of GnRH using a new GnRH-like peptide. Vaccine. 1994: 12;741–746.

Miesner MD, Anderson DE. Surgical management of common disorders of feedlot calves. The Veterinary Clinics of North America: Food Animal Practice. 2015: 31; 407–424. vi–vii.

Molenaar GJ, Lugard-Kok C, Meloen RH, Oonk RB, de Koning J, Wensing CJ. Lesions in the hypothalamus after active immunisation against GnRH in the pig. J. Neuroimmunol. 1993: 48; 1–11.

Moreira AD, Siqueira GR, Lage JF, Benatti JMB, Moretti MH, Miguel GZ, Oliveira IM, Resende FD. Castration methods in crossbred cattle raised on tropical pasture. Animal Production Science. 2017: 58, 1307-1315.

Pazdiora RD, Resende FD, Faria MH, Siqueira GR, Almeida GBS, Sampaio RL, Pacheco PS, Prietto MSR. Animal performance and carcass characteristics of Nellore young bulls fed coated or uncoated urea slaughtered at different weights. Brazilian Journal of Animal Science. 2013: 42; 273–283.

Pérez-Linares C, Bolado-Sarabia L, Figueroa-Saavedra F, Barreras-Serrano A, Sánchez-López E, Tamayo-Sosa AR, Godina AA, Ríos-Rincón F, García LA, Gallegos E. Effect of immunocastration with Bopriva on carcass characteristics and meat quality of feedlot Holstein bulls. Meat science, 2017: 123; 45-49.

Price E, Adams T, Huxsoll C, Borgwardt R. Aggressive behavior is reduced in bulls actively immunized against gonadotropin-releasing hormone. Journal of animal science. 2003: 81(2); 411-415.

Prior RL, Smith SB, Schanbacher BD, Mersmann HJ. Lipid metabolism in finishing bulls and steers implanted with oestradiol-17 β-dipropionate. Animal Production. 1983: 37(1); 81–88.

Ribeiro ELA, Hernandez JA, Zanella EL, Shimokomaki M, Prudêncio-Ferreira SH, Youssef E, Ribeiro HJSS, Bogden R, Reeves JJ. Growth and carcass characteristics of pasture fed LHRH immunocastrated, castrated and intact Bos indicus bulls. Meat Science. 2004: 68(2); 285–290.

Robertson IS, Wilson JC, Fraser HM. Immunological castration in male cattle. Vet. Rec. 1979: 105; 556-557.

Rodriguez RE, Wise ME. Ontogeny of pulsatile secretion of gonadotropin-releasing hormone in the bull calf during infantile and pubertal development. Endocrinology. 1989: 124; 248– 256.

Rodriguez RE, Wise ME. Advancement of postnatal pulsatile luteinizing hormone secretion in the bull calf by pulsa tile administration of gonadotropin-releasing hormone during infantile development. Biol. Reprod. 1991: 44(3); 432-9.

Sherwood NM, Lovejoy DA, Coe IR. Origin of mammalian gonadotropin-releasing hormones. Endocrine Reviews. 1993: 14; 241–254.

Thompson DL. Immunization against GnRH in male species (comparative aspects). Animal Reproduction Science. 2000: 60; 459-469.

Wierbicki E, Cahill VR, Kunkle LE, Klosterman EW, Deatherage FE. Meat quality, effect of castration on biochemistry and quality of beef. Journal of Agricultural and Food Chemistry. 1955: 3; 244–249.