DOI: 10.5433/1679-0359.2016v37n2p1007

Carcass physical composition and physic-chemical characteristics of meat from Nellore cattle

Composição física da carcaça e características físico-químicas da carne de bovinos da raça Nelore

Aline Kellermann de Freitas[1]; João Restle[2*]; Regis Luis Missio[3]; Paulo Santana Pacheco[4]; João Teodoro Padua[5]; Fabrícia Rocha Chaves Miotto[6]; Leandro Ferreira Greco[7]; Moacir Evandro Lage[5]; José Neuman Miranda Neiva[6]

Abstract

Assessment of carcass physical composition and physicochemical characteristics of meat from Nellore males distributed randomly into three treatments: males castrated at 13 months of age at puberty (n=26); castrated at 18 months of age, 15 days before confinement (n=26); and young bulls (n=25). For the evaluation of meat chemical characteristics, we used samples of 12 animals taken at random from each treatment. The experimental design was completely randomized. Animals were slaughtered at 22 months of age after 100 days of confinement. The carcasses of young bulls showed higher contents of muscle (66.46 %) and bone (16.03 %), and lower fat content (17.66 %), in relation to that of steers castrated at 13 (62.83,15.28, and 22.11 %, respectively) or 18 months (63.99, 15.29, and 21.53%, respectively), which did not differ amongst themselves. The meat of young bulls was darker (3.07 points) than the meat from those castrated at 13 months of age (3.43 points), while the meat from those castrated at 18 months displayed an intermediate color (3.29 points), not differing from the others. Young bulls yielded meat with lower content of intramuscular fat (3.18 points) and lipids (3.81%) in relation to those castrated at 13 (4.58 points and 6.77%, respectively) or 18 months (4.52 points and 5.66%, respectively). Protein content was higher ($P<.05$) in meat from steers castrated at 13 months in relation to young bulls. The shear strength of the muscle fibers was not altered ($P> 0.05$) by the age of castration, with young bulls having lower values in relation to the castrated males. Castration of Nellore young bulls in early puberty increases the edible portion of the carcass due to the higher body fat deposit.

Key words: Cattle. Sexual condition. Age at castration. Lipids.

[1] Discente do Curso de Mestrando do Programa de Pós-Graduação em Ciência Animal, Universidade Federal de Goiás, UFG, Goiânia, GO, Brasil. E-mail: akfreitas@hotmail.com

[2] Bolsista PVNS CAPES, Escola de Medicina Veterinária e Zootecnia, Universidade Federal do Tocantins, UFT, Araguaína, TO, Brasil. E-mail: jorestle@terra.com.br

[3] Prof., Deptº de Agronomia, Universidade Tecnológica Federal do Paraná, UTFPR, Pato Branco, PR, Brasil. E-mail: regisluismissio@gmail.com

[4] Prof., Deptº de Zootecnia, Universidade Federal de Santa Maria, UFSM, Santa Maria, RS, Brasil. E-mail: pacheco.dz.ufsm@hotmail.com

[5] Profs., Deptº de Zootecnia, UFG, Goiânia, Brasil. E-mail: teodoro@ufg.br; moacir@ufg.br

[6] Profs., Escola de Medicina Veterinária e Zootecnia, UFT, Araguaína, TO, Brasil. E-mail: fabriciarchaves@hotmail.com; araguaia2007@gmail.com

[7] Discente do Curso de Medicina Veterinária, Universidade Federal de Goiás, UFG, Goiânia, GO, Brasil. E-mail: leandrogreco@hotmail.com

* Author for correspondence

Recebido para publicação 09/04/15 Aprovado em 09/09/15

Resumo

Avaliação da composição física da carcaça e das características físico-químicas da carne de tourinhos e novilhos Nelore distribuidos aleatoriamente em três tratamentos: machos castrados aos 13 meses de idade, no início da puberdade (n=26); castrados aos 18 meses, 15 dias antes do início do confinamento (n=26); e não castrados (n=25). O delineamento experimental utilizado foi o inteiramente casualizado com 12 repetições. Os animais foram abatidos com 22 meses de idade após 100 dias de confinamento. Os tourinhos apresentaram maior conteúdo de músculo (66,46%) e osso (16,03%), e menor conteúdo de gordura (17,66%) na carcaça em relação aos castrados com 13 (62,83; 15,28 e 22,11%, respectivamente) ou 18 meses (63,99; 15,30 e 20,96%, respectivamente), que não diferiram entre si. A carne de tourinhos foi mais escura (3,07 pontos) em relação aos castrados aos 13 meses de idade (3,43 pontos), enquanto a carne dos castrados aos 18 meses apresentou coloração intermediária (3,29 pontos), não diferindo dos demais. Tourinhos produziram carne com menor conteúdo de gordura intramuscular (3,18 pontos) e de lipídios (3,81%) em relação aos castrados com 13 meses (4,58 pontos e 6,77%, respectivamente) ou 18 meses de idade (4,52 pontos e 5,66%, respectivamente). O teor de proteína foi maior ($P<0,05$) na carne dos novilhos castrados aos 13 meses em relação aos tourinhos. A força de cisalhamento das fibras musculares foi maior nos animais castrados aos 13 meses em relação aos não castrados. A castração de tourinhos Nelore no início da puberdade aumenta a porção comestível da carcaça em razão do depósito de gordura corporal.

Palavras-chave: Bovinos. Condição sexual. Idade de castração. Lipídios.

Introduction

The carcass and meat quality reflects the productive environment, in which sanity and nutrition are the major obstacles for the national beef cattle chain. The Brazilian production system has the notable characteristic of performing slaughter at an advanced age, and animals finished with an inappropriate carcass fat cover, which influence the quality of carcass and meat (PACHECO et al., 2005; WEBB; O'NEILL, 2008). These productive characteristics are determined mainly by the inadequate nutritional management and the practice of finishing animals intact. Coupled with this, the zebu cattle have a high participation in the Brazilian herd, and this genotype is recognized for producing meat of lower quality compared with specialized European breeds. This lower quality is a consequence of the lower marbling, high content of insoluble collagen and muscle calpastatin, and the temperament of these animals being more prone to stress, which can culminate in lower muscle glycogen stores pre-slaughter and the production of darker, less juicy, and less palatable meat (FELÍCIO, 1997; ALVES et al., 2005).

The slaughter of intact animals may be a paradigm. Although the performance of these animals is superior to that of castrated animals (SILVA et al., 2012), the meat from the former presents less desirable characteristics, such as darker color, less marbling, and less tenderness (RESTLE et al., 1996; KUSS et al., 2010). According to Restle et al. (1996), these less desirable characteristics of the carcass and meat of intact cattle result in less carcass fat cover, mainly. The moment of castration, in this scenario, seems to be the way to overcome this situation, as it can modulate the period of action of androgenic hormones, the main responsible for the differentiation of carcass and meat characteristics between intact and castrated animals (GALBRAITH et al., 1978; SEIDEMAN et al., 1982). The castration performed pre-puberty, in this regard, has been studied as an option to benefit the animal performance without impairing the carcass and meat characteristics (MICOL et al., 2009; PRADO et al., 2014). However, few studies have been carried out evaluating castration indices in feedlot-finished Nellore cattle, which would be relevant, since breed and nutrition are important factors to puberty in cattle (SCHILLO et al., 1992;

CASAS et al., 2007). Therefore, the objective of the present study was to evaluate the physical composition of the carcass and the physicochemical composition of the meat from feedlot-finished Nellore young bulls or steers castrated at 13 or 18 months of age.

Material and Methods

Seventy-seven Nellore male cattle with an average initial weight of 222 kg were distributed randomly into three treatments: 26 castrated at 13 months of age (early puberty), 26 castrated at 18 months of age (fifteen days before the beginning of confinement), and 25 intact males. Castration was performed by scrotal incision. The animals spent their post-weaning period (January to July) on a *Brachiaria brizantha* cv. Marandu pasture, receiving mineral supplementation *ad libitum*, with the stocking rate fixed at 2 animals/ha. From August, the animals, having an average body weight of 290±20,5 kg, were confined and fed *ad libitum* three daily meals (08h00, 12h00, and 17h00), for 100 days. Feed intake was controlled daily by weighing the feed supplied and orts. The diet was formulated to provide a gain of 1.2 kg/day, considering an intake of 2.4% of the body weight, according to NRC (1996). The roughage/concentrate ratio of the diet was 60/40 (dry-matter basis). The roughage utilized was corn silage. The diet contained 53.7% dry matter (DM), 12% crude protein/kg DM, 48.8% neutral detergent fiber/kg DM and 2.9 Mcal digestible energy/kg DM.

The animals were slaughtered in a commercial meatpacking plant, after a total feed-deprivation period of 14-16 h, following the normal flow of the slaughter line. After slaughter, the carcasses were identified, sectioned in half, weighed, washed, and chilled for 24 at a temperature between 0 and 2 ºC. The HH section (9th to 11th ribs; HANKINS; HOWE, 1946) was taken from the right half-carcass, and separated into muscle, fat, and bone, whose weights were used to estimate their participation in the carcass. The marbling (1 to 3 = traces; 4 to 6 = slight; 7 to 9 = little; 10 to 12 = medium; 13 to 15 = moderate; 16 to 18 = abundant), color (1 = dark; 2 = dark red; 3 = slightly-dark red; 4 = red; 5 = bright red), and texture (1 = too coarse; 2 = coarse; 3 = slightly ; 4 = fine; 5 = too fine) of the meat were determined on the surface of the *longissimus dorsi* muscle, between the 12th and 13th ribs (MÜLLER, 1987).

The *longissimus dorsi* muscle from the HH section was identified and frozen at -18 ºC. Three months later, a 2.5-cm-thick steak was taken from each portion of the muscle, and then identified, conditioned in aluminum trays, and thawed for 12 h at 4 ºC. Afterwards, steaks were roasted in an oven until their internal temperature reached 70 ºC. After, cooked steaks were chilled for 24 h at 4 ºC. Of these, three cylinder-shaped cuts with an area of 1.0 cm^2 were extracted per steak, cut perpendicular to the fiber direction in a Warner-Bratzler Shear machine, and the shear force of the muscle fibers was read.

To evaluate the chemical characteristics of the meat, samples of the *longissimus dorsi* muscle from 12 animals were taken randomly from each treatment. The samples, without the fat layer, were dried in a forced-air oven (100 ºC) and ground in a Wiley mill (1 mm particle). The dry matter, mineral matter, crude protein, and ether extract contents in these samples were determined according to AOAC (1990).

Once satisfied the assumptions of normality and homogeneity of variance, the data were submitted to ANOVA and orthogonal contrasts, and the averages compared by Tukey test at 5% probability, using the PROC GLM of SAS (Statistical Analysis System, version 9.2). The sum of squares of the contrasts analysis of treatments was decomposed in the orthogonal contrast: castrated at different ages vs. intact males. The general mathematical model used was: $\gamma_{ij} = \mu + \tau_i + \varepsilon_{ij}$, where: γ_{ij} = dependent variable; μ= general average; τ_i= effect of the treatment i; ε_{ij} = residual experimental error.

Results and Discussion

Delaying castration age increased (P<0.05) the amount of muscle (kg) in the carcass of the castrated animals, which showed lower values as compared with the intact ones (Table 1). The increased amount of muscle caused by delaying the castration age can be attributed to the period of activity of the androgenic hormones. According to McCarthy et al. (1979), significant increases in the secretion of this hormone occurs from four to six months of age, and it is four times greater in pubertal than pre-pubertal Nellore bulls. Although the absolute amount of muscle in the carcasses increased with the delaying of the castration age, no alterations in the percentage of muscle of the carcasses were observed with the of castration age from 13 to 18 months, demonstrating that the increase in the absolute amount of muscle in the carcass was not sufficient to change its proportion in relation to the cold carcass weight. However, the percentage of muscle was higher (P<0.05) in the carcass of the intact compared with the castrated cattle, which may be attributed to the activity of the androgenic hormones (MCCARTHY et al., 1979). The amount of fat in the carcass, on the other hand, was not changed (P>0.05) by delaying the age at castration, with higher values observed in the castrated compared with the intact animals. According to Galbraith et al. (1978) and Seideman et al. (1982), the action of androgenic hormones, especially testosterone, reduces the catabolism of amino acids and increases the utilization of urea in the synthesis of amino acids, thereby increasing the muscle synthesis over the fat synthesis.

Table 1. Physical composition of intact males housing (I) or neutered (C) to 13 months (C13) or 18 months (C18) old, feedlot finished.

Items	Treatments			CV	Contrast
	C13	C18	I	(%)	I *vs*. C
Slaughter weight, kg	371,73b	379,81b	395,00a	6,14	<0,001
Cold carcass weight, kg	193,33b	199,53b	212,21a	4,46	0,015
Muscle, kg	121,40c	127,70b	141,11a	8,64	<0,001
Muscle, % cold carcass weight	62,83b	63,99b	66,46a	4,24	<0,001
Fat, kg	42,76a	41,75a	37,44b	14,62	0,001
Fat, % cold carcass weight	22,11a	20,96a	17,66b	12,72	<0,001
Bone, kg	29,56b	30,58b	34,00a	11,20	<0,001
Bone, % cold carcass weight	15,28b	15,30b	16,03a	7,23	0,008
Muscle/bone	4,13	4,20	4,18	9,88	0,872
Muscle/fat	2,87b	3,11b	4,03a	11,83	<0,001
Muscle + fat/bone	5,59a	5,58ab	5,30b	9,31	0,024

Means followed by different letters, in the row, differ (P <0.05) by Tukey's test; CV = coefficient of variation.

The bone tissue was not changed (P>0.05) by delaying the castration age from 13 to 18 months, with lower values found in the castrated compared with the intact animals (Table 1). Evaluating two castration ages (2 or 7 months), Micol et al. (2009) did not find alterations in the carcass tissues of Charolais steers, which was explained by the fact that the castration was performed before the establishment of the androgen receptors. Likewise, Climaco et al. (2006) did not observe alterations in the amount of bone in the carcass between intact or castrated steers, which was attributed to the similar body development of these animals. However, the obtained results agreed with those presented by

Restle et al. (1996), Kuss et al. (2010), and Moletta et al. (2014), who found a larger quantity of bone in the carcasses of young bulls, as a consequence of the greater body development of this category. This hypothesis can also explain the obtained results, since the intact animals had a heavier body weight as compared with the castrated, which did not differ amongst themselves. These results demonstrate that the intact animals had greater body development and were thus physiologically older at slaughter, which possibly anticipated their bone growth in relation to the castrated animals. The bone tissue has its greatest growth impulse occurring in the younger life stage of the animal, whereas the muscle tissue growth is boosted in the intermediate life stage, and the fat tissue in a more advanced stage (OWENS et al., 1995). It should be noted that physiological maturity corresponds to the current weight in relation to the maximum body weight, whereas the maturity rate and the fat-cover rates are related to the body-weight-increase rates and to the earliness of deposition of body fat, respectively (DI MARCO et al., 1994). Thus, intact cattle can be characterized as having rapid maturation and late finishing, whereas castrated cattle can be characterized as having early finishing, but not faster maturation. This occurs because the intact cattle usually have higher body weight gain rates than the castrated, but body fat starts to be deposited later in relation to the castrated (BERG; BUTTERFIELD, 1976).

The muscle/bone ratio did not change ($P>0.05$) with the castration age, in castrated or intact animals (Table 1). These results demonstrate that the variation in muscle tissue as a function of castration age or category (castrated or intact) was not sufficient to change the muscle/bone ratio. This ratio has a great importance because, of the tissues that compose the carcass, the muscle is the most desired by the consumer (DI MARCO et al., 1994). The muscle/fat ratio, on the other hand, was higher ($P<0.05$) in the intact compared with the castrated animals, not differing between the animals castrated at 13 and 18 months of age. These results show that finishing animals intact can be an alternative to meet the demand for leaner meats. The presented results were similar to those obtained by Vaz et al. (2014), who found a higher muscle/bone ratio in young bulls of a dairy breed compared with castrated animals. These authors reported, however, that the castrated animals had the lower muscle/bone ratio compensated when the total carcass edible tissues (muscle + fat) were evaluated, because of the greater fat content.

The edible portion (Table 1), represented by the muscle + fat/bone ratio, was larger in the animals castrated at 13 months as compared with the intact males, which showed carcasses with similar edible portion to that of those castrated at 18 months, which in turn did not differ from those castrated at 13 months. These results show that delaying the castration aiming at obtaining benefits with the action of androgenic hormones was not viable, because keeping the animals intact for a longer period reduced the deposition of body fat, and consequently the carcass edible portion was reduced. Similarly, Lazzaroni and Biagini (2008) evaluated the characteristics of the carcass of Piedmontese young bulls or steers castrated at five months of age (pre-puberty) or at 13 months of age (post-puberty), slaughtered at 18 months of age, and concluded that there are no advantages, from the meat-yield perspective, in delaying the castration age compared with performing the castration before puberty. The most evident differences found by these researchers occurred between intact and castrated animals, with the edible portion being, differently from the present study, greater in the intact animals. The difference between the results obtained in the present study and by the abovementioned researchers can be somehow attributed to the genotype of the animals, since, unlike the genotype utilized in this study (Nellore), the Piedmontese breed is characterized as having “double muscling”, with little deposition of body fat. Restle et al. (1996), however, also found a greater yield for the edible portion in steers castrated by different methods (Burdizzo or knife) at eight months of age in relation to the intact; both categories originating from the cross between the Charolais and Nellore breeds and raised on pasture, slaughtered at 25 months of age. Knight et al. (2010) evaluated the carcass traits of young bulls or steers castrated at 7 or 17 months of age and concluded that the weight loss from castration post-puberty is greater than the change in the carcass attributes, with little opportunity of exploiting this type of castration to obtain economic advantages.

The intact young bulls produced meat with a darker color (P<0.05) compared with those slaughtered at 13 months of age (Table 2); those castrated at 18 months of age displayed intermediate values for this attribute. Overall, the meat was classified as "slightly dark red", in which the meat from the young bulls displayed (P=0.059) a darker color which may be explained by the more reactive behavior of this animal category. The increased pre-slaughter stress can result in a reduction of the stores of muscle glycogen, limiting the post-slaughter pH decline (SEGATO et al., 2005; KUSS et al., 2010; CAFE et al., 2011). The maintenance of a higher pH is followed by a low redox potential and formation of oxymyoglobin, responsible for the meat bright red color (ABRIL et al., 2001; MUCHENJE et al., 2009).

Table 2. Meat characteristics of intact males (I) or castrated (C) to 13 (C13) or 18 (18) months old, feedlot finished.

Items	Treatments			CV	Contrast
	C13	C18	I	(%)	I *vs*. C
Color, points	3,43a	3,29ab	3,07b	19,29	0,059
Texture, points	3,66a	3,61ab	3,29b	18,95	0,036
Marbling, points	4,58a	4,52a	3,18b	23,78	0,003
Shear force, kgf/cm³	10,96a	11,11a	9,12b	25,95	0,005
Dry matter, % natural matter	24,95a	24,62ab	23,97b	3,45	0,010
Mineral matter, % dry matter	4,25b	4,34ab	4,50a	3,53	0,074
Crude protein, % dry matter	22,41a	21,99ab	21,59b	3,56	0,034
Ether extract, % dry matter	6,77a	5,66a	3,81b	18,55	0,001

Means followed by different letters, in the row, differ (P <0.05) by Tukey's test; CV = coefficient of variation.

The meat from the intact young bulls had a coarser texture (P<0.05) in relation to that of the animals castrated at 13 months of age (Table 2), and intermediate values were found for those castrated at 18 months of age. The meat texture was classified, in general, as "slightly coarse", with the young bulls having coarser meat (P<0.05) than the steers, which agrees with the results obtained by Restle et al. (1996). Micol et al. (2009) evaluated two ages at castration (2 or 10 months) and found an increase in the area of the muscle fibers by delaying castration, which was attributed to the action of androgen hormones. Another aspect that might have contributed to these results is the lower fat-cover degree of intact cattle (RESTLE et al., 2000), which can result in a larger loss of liquids during the chilling period (WEBB; O'NEILL, 2008). The increase in the loss of liquids may lead to greater dehydration of the muscle fibers and consequent reduction of their area, since the texture was evaluated subjectively, according to the methodology of Müller (1987), based on the granulation that the muscle surface showed after the cut.

Marbling did not change (P>0.05) with the castration age, but it was higher in the castrated compared with the intact males (Table 2). Micol et al. (2009) did not find marbling alterations by advancing the castration age from 2 to 10 months of age, which is associated with the fact that castration occurred before puberty. Segato et al. (2005), on the other hand, found increased marbling by anticipating the castration age from 12 to 10 months of age. In the present study, the similar intramuscular fat contents between the castration ages were possibly associated with the similar body development of the animals. The results observed in presented study were similar to those reported by Restle et al. (1996) and Kuss et al. (2010), who observed greater meat marbling in castrated animals compared with the intact ones. The present results indicate, in this context, that intact cattle need to be fed up to more advanced ages and/or body weights so that they can achieve similar meat marbling to that of castrated cattle.

The shear force of the muscle fibers was not altered ($P>0.05$) by the castration age, and was lower in the intact animals as compared with the castrated (Table 2). The presented results were consistent with those found in the literature, in which castrations performed between 15 days and 5 months of age (PRADO et al., 2014), 5 and 13 months of age (DESTEFANIS et al., 2003), or 7 and 16 months of age (PARRASSIN et al., 1999) did not result in changes in meat tenderness. However, Field (1971), in a review about castrated and intact cattle, stated that studies reporting intact cattle providing more-tender meat in relation to the castrated are not common. In general, it is expected to shear force majeure in intact males due to intact animals have greater excitability pre-slaughter, and by the maintenance of higher meat pH at the post-slaughter (VAZ; RESTLE, 2000; KUSS et al., 2010), lower fat-cover content and marbling (KOOHMARAIE et al., 1996; RODRIGUES; ANDRADE, 2004), greater insoluble collagen content (GERRARD et al., 1987; DESTEFANIS et al., 2003), and higher level of muscle calpastatin (MORGAN et al., 1993; MICOL et al., 2009). Even so when differences in favor of the bulls for shear force are found, refer to animals slaughtered aged up to 14 months (VAZ; RESTLE, 2000).

The dry matter was higher ($P<0.05$) in the meet of the animals castrated at 13 months of age in relation to the intact cattle (Table 2). Intermediate values were found in those castrated at 18 months, which did not differ from the others. These results were attributed to the marbling of the meat, given that the fat tissue has lower water content than the muscle tissue (OWENS et al., 1995). Similar results were obtained by Destefanis et al. (2003), who, evaluating meat from young bulls or steers castrated at 5 or 13 months of age, detected higher moisture contents in the young bulls compared with the castrated animals, which did not differ amongst themselves. Likewise, Climaco et al. (2006) found that young bulls yielded meat with a greater moisture content in relation to the steers, which is also attributed to the greater water-holding capacity, which kept pH values high in the meat from the intact compared with steers.

The ash content was higher ($P<0.05$) in the meat from the castrated at 13 months of age compared with the intact cattle, and intermediate values were present in the meat from the castrated at 18 months of age (Table 2). These results were consistent with those presented by Prado et al. (2014) and Segato et al. (2005), who did not find alterations in the ash content of meat from steers castrated at different ages. In this study, the ash content was lower ($P=0.074$) in the meat from the castrated compared with the intact animals. Rodrigues and Andrade (2004) observed a lower ash content in the meat from castrated cattle. According to these researchers, the greater fat content in the meat from castrated cattle provides a reduction in the other meat components as compared with the intact cattle. Nevertheless, most of the studies demonstrate similar ash contents in the meat from intact and castrated cattle (FERNANDES et al., 2009; ZHANG et al., 2010). It is noteworthy that the values observed for the ash content in the meat were higher than those presented in the literature (FERNANDES et al., 2009; ZHANG et al., 2010; PRADO et al., 2014), in which the ash content from the meat of male cattle varied between 1% and 1.86%. The cause-and-effect factors that determined the higher values for the ash content in the meat from the animals of this study in relation to the consulted literature were not elucidated.

The meat from the steers castrated at 13 months of age had a higher ($P<0.05$) protein content as compared with that from the intact steers (Table 2), and those castrated at 18 months displayed with intermediate values, not differing from the others. These results were somewhat similar to those obtained by Prado et al. (2014), who found that the crude protein of the meat tended to be higher in animals castrated at 15 days of age as compared with those castrated at 5 months of age. However, Segato et al. (2005) found a trend of castrated animals at younger ages to have meat with a lower crude protein content as compared with those castrated at later ages. Destefanis et al. (2003), in the same way, found variable results for the meat crude protein content, in which the animals castrated at 5 months had higher values than the intact males, and intermediate values were found in those castrated at 13 months age. Like in the present study, Climaco et al. (2006) also obtained a higher crude protein content in the meat from castrated animals, but the elucidation of the cause-and-effect factors determining these results was not established. Yet, in general, a greater proportion of muscle in the carcass of intact animals is expected to be translated into a higher percentage of crude protein in the meat (SEGATO et al., 2005).

The ether extract content of the meat did not change ($P>0.05$) with the castration age (Table 2); however, it was higher in the castrated compared with intact cattle, which may be attributed to the greater meat intramuscular fat content. Destefanis et al. (2003) mentions that castration leads to a decrease in moisture and an increase in the fat content of muscles, with a more pronounced effect in animals castrated younger, affecting the meat ether-extract content. In general, the obtained results were similar to those presented in the literature (CLIMACO et al., 2006; ZHANG et al., 2010), in which greater ether extract contents have been found in meat from castrated compared with intact animals.

Conclusions

The castration of young Nellore bulls in early puberty increases the edible portion of the carcass compared with intact animals slaughtered at a similar age, as a result of the greater deposition of body fat.

When intact and castrated cattle are slaughtered at similar ages, castration provides a higher percentage of fat in the carcasses and meat physicochemical properties of better acceptability by consumers.

References

ABRIL, M.; CAMPO, M. M.; ÖNENÇ, A. Beef color evolution as a function of ultimate Ph. *Meat Science*, New York, v. 58, n. 1, p. 69-78, 2001.

ALVES, D. D.; TONISSI, R. H. de; GOES, B.; MANCIO, A. B. Maciez da carne bovina. *Ciência Animal Brasília*, Goiânia, v. 6, n. 3, p. 135-149, 2005.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS - AOAC. Official methods of analysis. 15th ed. Washington D. C.: 1990. 1141 p.

BERG, R. T.; BUTTERFIELD, R. M. *New concepts of cattle growth*. Sydney: Sydney University Press, 1976. 240 p.

CAFE, L. M.; ROBINSON, D. L.; FERGUSON, D. M.; GEESINK, G. H.; GREENWOOD, P. L. Temperament and hypothalamic-pituitary-adrenal axis function are related and combine to affect growth, efficiency, carcass, and meat quality traits in Brahman steers. *Domestic Animal Endocrinology*, New York, v. 40, n. 4, p. 230-240, 2011.

CASAS, E.; LUNSTRA, D. D.; CUNDIFF, L. V.; FORD, J. J. Growth and pubertal development of F1 bulls from Hereford, Angus, Norwegian Red, Swedish Red and White, Friesian, and Wagyu sires. *Journal of Animal Science*, Champaign, v. 85, n. 11, p. 2904-2909, 2007.

CLIMACO, S. M.; RIBEIRO, E. L. A.; MIZUBUTI, I. Y.; ROCHA, M. A.; FERREIRA DA SILVA, L. D.; PEREIRA, E. S. Desempenho e características de carcaça de bovinos de corte inteiros ou castrados e suplementados ou não durante o inverno. *Acta Science. Animal. Science*, Maringá, v. 28, n. 2, p. 209-214, 2006.

DESTEFANIS, G.; BRUGIAPAGLIA, M. T.; BARGE, C.; LAZZARONI, C. Effect of castration on meat quality in Piemontese cattle. *Meat Sience*, New York, v. 64, n. 2, p. 215-218, 2003.

DI MARCO, O. N. *Crescimento y respuesta animal*. Buenos Aires: Associaccíon Argentina de Producción Animal, 1994. 129 p.

FELÍCIO, P. E. de. Fatores ante et post mortem que influenciam na qualidade da carne bovina. In: PEIXOTO, A. M.; MOURA, J. C. de; FARIA, V. P. de. (Ed.). *Produção do novilho de corte*. Piracicaba: FEALQ-USP, 1997. p. 79-97.

FERNANDES, A. R. M.; SAMPAIO, A. A. M.; HENRIQUE, W.; TULLIO, R. R.; OLIVEIRA, E. A.; MÁXIMO DA SILVA, T. Composição química e perfil de ácidos graxos da carne de bovinos de diferentes condições sexuais recebendo silagem de milho e concentrado ou cana-de-açúcar e concentrado contendo grãos de girassol. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 38, n. 4, p. 705-712, 2009.

FIELD, R. A. Effect of castration on meat quality and quantity. *Journal of Animal Science*, Champaign, v. 32, n. 5, p. 849-856, 1971.

GALBRAITH, H.; DEMPSTER, D. G.; MILLER, T. B. A note on the effect of castration on the growth performance and concentration of some blood metabolites and hormones in british friesian male cattle. *Animal Production*, Cambridge, v. 26, n. 3, p. 339-342, 1978.

GERRARD, D. E.; JONES, S. J.; ABERLE, E. D. Collagen stability, testosterone secretion and meat tenderness in growing bulls and steers. *Journal of Animal Science*, Champaign, v. 65, n. 5, p. 1236-1242, 1987.

HANKINS, O. G.; HOWE, P. E. *Estimation of the composition of beef carcass and cuts*. Washington: Unite State Department of Agriculture, 1946. n. 926, 19 p. (Technical Bulletin).

KNIGHT, T. W.; COSGROVE, G. P.; DEATH, A. F.; ANDERSON, C. B. Effect of interval from castration of bulls to slaughter on carcass characteristics and meat quality. *New Zealand Journal of Agricultural Research*, Melbourne, v. 42, n. 3, p. 269-277, 2010.

KOOHMARAIE, M.; WHEELER, T. L.; SHOCKELFORD, S. D. Sampling, cooking and coring effects on Warner-Bratzler shear force values in beef. *Journal of Animal Science*, Champaign, v. 74, n. 7, p. 1553-1562, 1996.

KUSS, F.; LÓPEZ, J.; RESTLE, J.; BARCELLOS, J. O.; MOLETTA, J. L.; PAULA LEITE, M. C. Qualidade da carne de novilhos terminados em confinamento e abatidos aos 16 ou 26 meses de idade. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 39, n. 4, p. 924-931, 2010.

LAZZARONI, C.; BIANINI, D. Effect of pre- and post-pubertal castration on Piemontese male cattle. II: Carcass measures and meat yield. *Meat Science*, New York, v. 80, n. 2, p. 442-448, 2008.

MCCARTHY, M. S.; HAFS, H. D.; CONVEY, E. M. Serum hormone patterns associated with growth and sexual development in bulls. *Journal of Animal Science*, Champaign, v. 49, n. 4, p. 1012-1020, 1979.

MICOL, D.; OURY, M. P.; PICARD, B.; HOCQUETTE, J. F.; BRIAND, M.; DUMONT, R.; EGAL, D.; JAILLER, R.; DUBROEUCQ, H.; AGABRIEL, J. Effect of age at castration on animal performance, muscle characteristics and meat quality traits in 26-month-old Charolais steers. *Livestock Science*, New York, v. 120, n. 1-2, p. 116-126, 2009.

MOLETTA, J. L.; PRADO, I. N.; FUGITA, C. A.; EIRAS, C. E.; CARVALHO, C. B.; PEROTTO, D. Carcass and meat characteristics of steers or bulls, finished in feedlot and fed with diets containing three levels of concentrate. *Semina: Ciências Agrárias*, Londrina, v. 35, n. 2, p. 1035-1050, 2014.

MORGAN, J. B.; WHEELER, T. L.; KOOHMARAIE, M.; CROUSE, J. D.; SAVELL, J. W. Effect of castration on myofibrillar protein turnover, endogenous proteinase activities, and muscle growth in bovine skeletal muscle. *Journal of Animal Science*, Champaign, v. 71, n. 2, p. 408-414, 1993.

MUCHENJE, V.; DZANA, K.; CHIMONYO, M.; STRYDOM, P. E.; HUGO, A.; RAATS, J. G. Some biochemical aspects pertaining to beef eating quality and consumer health: A review. *Food Chemistry*, New York, v. 112, n. 2, p. 279-289, 2009.

MÜLLER, L. *Normas para avaliação de carcaças e concurso de carcaças de novilhos*. 2. ed. Santa Maria: UFSM, Imprensa Universitária, 1987. 31 p.

NATIONAL RESEARCH COUNCIL - NRC. Nutrient requirements of domestic animals. 7^{th} ed. Washington: National Academy Press, 1996. 242 p.

OWENS, F. N.; GILL, D. R.; SECRIST, D. S.; COLEMAN, S. W. Review of some aspects of growth and development of feedlot cattle. *Journal of Animal Science*, Champaign, v. 73, n. 10, p. 3152-3172, 1995.

PACHECO, P. S.; RESTLE, J.; SILVA, J. H. S.; BRONDANI, I. L.; PASCOAL, L. L.; ALVES FILHO, D. C.; ARBOITTE, M. Z.; FREITAS, A. K. Composição física da carcaça e qualidade da carne de novilhos jovens e superjovens de diferentes grupos genéticos. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 34, n. 5, p. 1691-1703, 2005.

PARRASSIN, P. R.; THENARD, V.; DUMONT, R.; TROMMENSCHLAGER, J. M. Effet d'une castration tardive sur la production de boeufs Holstein et Montbéliard. *INRA Productions Animales*, Clermont Ferrand, v. 12, n. 3, p. 207-216, 1999.

PRADO, I. N.; CAMPO, M. M.; MUELA, E.; VALERO, M. V.; CATALAN, O.; OLLETA, J. L.; SAÑUDO, C. Effects of castration age, dietary protein level and lysine/methionine ratio on animal performance, carcass and meat quality of Friesian steers intensively reared. *Animal*, Cambridge, v. 8, n. 9, p. 1561-1568, 2014.

RESTLE, J.; GRASSI, C.; FEIJÓ, G. L. D. Características das carcaças e da carne de bovinos inteiros ou submetidos a duas formas de castração, em condições de pastagem. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 25, n. 2, p. 334-344, 1996.

RESTLE, J.; VAZ, F. N.; FEIJÓ, G. L. D. Características de carcaça de bovinos de corte inteiros ou castrados de diferentes composições raciais Charolês x Nelore. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 29, n. 5, p. 1371-1379, 2000.

RODRIGUES, V. C.; ANDRADE, I. F. Características físico-químicas da carne de bubalinos e de bovinos castrados e inteiros. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 33, n. 6, p. 1839-1849, 2004. Suplemento 1.

SCHILLO, K. K.; HALL, J. B.; HILEMAN, S. M. Effects of nutrition and season on the onset of puberty in the beef heifer *Journal of Animal Science*, Champaign, v. 70, n. 12, p. 3994-4005, 1992.

SEGATO, S.; ELIA, C.; MAZZINI, C.; BIANCHI, C.; ANDRIGHETTO, I. Effect of castration age on carcass traits and meat quality of Simmental bulls. *Italian Journal of Animal Science*, Parma, v. 4, p. 263-265, 2005. Supplement 2.

SEIDEMAN, S. C.; CROSS, H. R.; OLTJEN, R. R.; SCHANBACHER, B. D. Utilization of the intact male for red meat production: a review. *Journal of Animal Science*, Champaign, v. 55, n. 4, p. 826-840, 1982.

SILVA, N. R. da.; FERREIRA, A. C. H.; FATURI, C.; SILVA, G. F.; MISSIO, R. L.; NEIVA, J. N. M.; ARAÚJO, V. L.; ALEXANDRINO, E. Desempenho em confinamento de bovinos de corte, castrados ou não, alimentados com teores crescentes de farelo do mesocarpo de babaçu. *Ciência Rural*, Santa Maria, v. 42, n. 10, p. 1882-1887, 2012.

VAZ, F. N.; RESTLE, J. Aspectos qualitativos da carcaça e da carne de machos Hereford, inteiros ou castrados, abatidos aos quatorze meses. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 29, n. 6, p. 1894-1901, 2000.

VAZ, F. N.; RESTLE, J.; PÁDUA, J. T.; MORALES, D. C. S. P.; PACHECO, P. S.; MAYSONNAVES, G. S. Características de carcaça e da carne de bovinos mestiços não castrados ou submetidos a diferentes métodos de castração. *Ciência Animal Brasileira*, Goiânia, v. 15, n. 4, p. 428-436, 2014.

WEBB, H. A.; O'NEILL, H. A. The animal fat paradox and meat quality. *Meat Science*, New York, v. 80, n. 1, p. 28-35, 2008.

ZHANG, Y. Y.; ZAN, L. S.; WANG, H. B.; XIN, Y. P.; ADOLIGBE, C. M.; UJAN, J. A. Effect of sex on meat quality characteristics of Qinchuan cattle. *African Journal of Biotechnology*, Nairobi, v. 9, n. 28, p. 4504-4509, 2010.