Revista Brasileira de Zootecnia

ISSN 1806-9290
www.sbz.org.br

R. Bras. Zootec., v.41, n.4, p.1051-1059, 2012

Carcass characteristics and meat quality of Aberdeen Angus steers finished on different pastures

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ABSTRACT - The present study was conducted to assess carcass features, physicochemical and sensory parameters of meat from steers finished on three types of pastures: natural pasture; natural pasture improved, fertilized and oversown with winter species; and annual summer grassland. The experiment was conducted from December 14, 2009 to November 30, 2010, with treatments distributed in a completely randomized design with a different number of replicates. Animals were used as experimental units. Experimental animals were Aberdeen Angus steers with twenty months of initial age and 354±27.4 kg of live weight, on average. The highest average daily gains were obtained for the annual summer grassland. There was no effect of treatments on carcass conformation. The highest carcass yield was obtained on the improved natural pasture. Forequarter yield, side cut yield and *longissimus* muscle area were similar between the pastures. Moisture and total lipids were not affected by the pasture. Thawing and cooking losses were higher in improved natural pasture and lower in sorghum pasture. Regardless of the treatment, the meat had luminosity ranging from intermediate to dark, high in red, high in yellow, and considered within the normal range for beef. Meat of higher shear force was found in natural pasture, and lower shear force was observed in meat from annual summer grassland. Average live weight daily gain explained 18% of the shear force. Sensory evaluation by duo-trio test showed differences between samples from distinct pastures in flavor. All the studied systems allow for desirable characteristics in carcass and meat.

Key Words: average daily gain, fertilized natural pasture, sensory panel, sorghum pasture, tenderness

Introduction

In Southern Brazil, the main nutritional base of the livestock production is still the rangelands of Bioma Pampa. (Sebrae/Senar/Farsul, 2005). The herbage vegetation with a huge floristic biodiversity (Boldrini, 2002) provides conditions to sustainable production of meat products, which can be one of the ways to supply the current demand of the market and provide financial advantages to farmers (Nabinger & Sant'Anna, 2007). Besides that, rangelands play an important ecological role, which makes their conservation indispensable (Bencke, 2009). Nowadays, consumers have been demanding information about the method of production, food insurance warranties and also, the appeal for products engaged in environmental conservancy has been observed the (Prache & Thériez, 1999). Producing beef on natural grasslands concomitantly with nature conservation may present a method to provide with a huge part of these demands. However, beef produced in this environment should not only show ecological value, but also have the basic quality attributes desired by consumers: shiny red color, little fat covering, tenderness, juiciness and an pleasant taste (Felício, 1998).

The correct managing of the rangeland allows slaughtering steers with up to four definitive teeth exclusively based on this resource (Castilhos et al., 2007; Ferreira, 2009). Besides that, this production system offers lots of advantages, increasing the outcome rate, farm productivity, a higher rate of return and better business economic efficiency (Gottschall, 2005).

On the other hand, annual pasturelands such as *Sorghum sp*. are an alternative which would allow minimizing the steers finishing period due to high individual weight gains (Restle et al., 1996; Muehlmann et al., 1997), even thought that would represent higher costs than the natural grasslands.

In light of this, it is necessary to develop studies about meat quality produced on the different alternatives of grasslands in Southern Brazil. Therefore, the objective of this study was to evaluate the carcass characteristics and physicochemical and sensorial aspects of Aberdeen Angus beef cattle finished on natural grassland, improved natural

Received May 24, 2011 and accepted October 24, 2011.
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grassland oversown with winter species and fertilization and annual summer-grassland.

Material and Methods

The experiment was carried out on a private farm located in Dom Pedrito rural area (31°21'39.26"S 54°34'56.20" W) between 12/14/2009, and 11/29/2010. The climate, according to the Köppen classification system, was a Cfa 2 (sub-tropical climate) and the soil was a Mollisol with vertisol properties (Chernossolo Háplico Órtico Vértico) (Streck et al., 2002). The experimental area was composed of five paddocks with approximately 15 ha each. The treatments were three systems of cattle finishing based on pastures: natural grassland; semi-natural grassland; natural grassland oversown with cultivated winter species + fertilization; and annual summer-grassland (Sorghum). Mechanical-mowing in the natural grassland system was done in May and September, 2010, aiming at the weed control and the sward maintenance.

On the semi-natural grassland, the soil acidity was corrected with three tons of lime per hectare in November 2009. In March 2010, fertilization using 200 kg/ha of diammonium phosphate (DAP: 18-45-00) was done. In May 2010, mechanical mowing and urea application (100 kg/ha) were conducted. At that time, 36 kg of *Lolium multiflorum* Lam. pure live seed/ha, 5.4 kg of *Lotus corniculatus* cv. São Gabriel pure live seed/ha), both spread, were oversown.

At the end of the fattening cycle, which is the period of highest body fat deposition on the animals, the floristic evaluation in the natural grasslands-based finishing systems was proceeded using Botanal method (Tothill, 1978). In natural grassland system, the species which had most contribution in the forage mass (FM) were *Coelorachis selloana* (20.2%), *Paspalum notatum* (14.1%), *Paspalum dilatatum* (9.05%), *Piptochaetium stipoides* (8.6%), *Botriochloa laguroides* (7.1%) and *Saccharum angustifolium* (6.4%). In semi-natural grassland system the species which had most contribution in FM were *Lolium multiflorum* (25.6%), *Paspalum notatum* (22.4%), *Piptochaetium stipoides* (13.9%), *Axonopus affinis* (5.2%) and *Paspalum ditatatum* (4.2%).

A hybrid forage sorghum (*Sorghum bicolor* × *Sorghum sudanense)* cv AGR 2501 was sown in 01/01/2010 in the annual-summer grassland system. The sowing density was 22 seeds/m with 0.45 m distance between rows in a no-tillage system. Soil acidity correction and fertilization were performed according to a prescription based on soil analysis. Animals started grazing on 02/03/2010, when the sward height was about 90 cm. Before getting in to the sorghum pasture, the animals were in a natural grassland area which was similar to the Natural grassland system.

Experimental animals (test animals) were 43 Aberdeen Angus steers with about 20 months of age, distributed as follows: natural grasslands (n = 16), semi-natural grasslands (n = 18) and annual summer grassland (n = 9). The treatments natural grassland and semi-natural grassland were composed of two paddocks each, in which the animals from those treatments were distributed equally and kept until the end of the experimental period. An explanation for keeping two paddocks in natural grasslands and improved-natural grasslands is because of the higher heterogeneity of those treatments when they are compared with mono-specific pastures (e.g. sorghum pasture), therefore, monitoring their productive conditions (herbage mass, sward height, floristic composition) would be important for their characterization.

The animal average live weight in the beginning of grazing on natural grassland and improved-natural grassland (December, 2010) was 353±20.8 kg. Animal live weight was 354±27.4 kg in annual-summer grassland at the beginning of grazing. Their weight was not different from the other treatments at the same period (P>0.05).

Natural grassland and improved-natural grasslands animals were kept in continuous grazing with variable stocking rate aiming at a forage allowance of 13 kg of dry matter for 100 kg of live weight. Besides the test animals, a variable number of regulators (Mott & Lucas, 1952) were used. Stocking adjustment was done monthly, except for July and October, concomitantly with evaluation of forage mass and accumulation. In natural grassland and improved-natural systems, the average forage mass and height were respectively 1802 kg DM/ha and 8.9 cm (Table 1).

Values of forage mass and sward height were close to the range of 1,476 - 1,765 kg DM/ha recommended by Moojen & Maraschin (2002) and between 10-12 cm of height indicated by Gonçalves et al. (2009). For these last authors, managing natural grasslands at this height corresponded to the best estimation of animal production potential. In the annual summer-grassland treatment, animals were kept in a strip stocking. The animals started grazing when the sward reached 90 cm height on average and the stocking rate was adjusted to demote the height until 30 cm in a one-week period.

Animals were monthly weighed with a 12-hour period of solid and liquid fasting. At weighing procedures, to accompany the growth and fat deposition, ultrasonic measurements of the rib eye area and fat thickness were taken between the 12^{th} and 13^{th} ribs and fat thickness on *Biceps femoris* on the P8 site. Production and acquisition of ultrasonic images were obtained by a main unit – eco

Table 1 - Height, forage mass and stocking rate in different periods in natural grassland (NG) and improved grasslands (ING) (2009/2010)

	Dec	Jan	Feb	Mar	Apr	May	Jun	Aug	Sep	Nov
					Sward height (cm)					
NG	12.7	7.9	10.4	11.2	9.8	6.7	8.3	7.3	7.2	12.2
ING	9.1	9.4	9.9	11.0	9.4	6.0	8.2	6.5	6.5	
					Forage mass (kg DM/ha)					
NG	1,755	1,441	2,186	2,464	2,514	1,801	1,513	1,397	1,280	1,966
ING	1,608	1,147	1,875	2,392	2,423	1,661	1,508	1,305	1,101	
					Stocking rate (kg LW/ha)					
NG	650	417	507	578	488	222	212	215	242	278
ING	749	822	736	740	505	267	236	449	332	

DM - dry matter; LW - live weight.

camera Aloka SSD 500 V (Eletro Medicina Berger, Ltda) – equipped with a linear transducer UST 5049 with 3.5 MHz frequency and 17.2 cm length.

Average daily gain (ADG, kg/day of LW) was obtained by the difference between initial and final average live weight of test animals. To allow comparisons between treatments, animals were slaughtered in the same degree of physiological maturity. Three millimeters of fat thickness was adopted as slaughter criterion.

Slaughtering procedures were carried out at Marfrig slaughterhouse, in the city of Bagé, Rio Grande do Sul state (SIF 232) on the days 06/10/2010 for animals from Annual-summer grassland treatment, 10/22/2010 for animals from the improved grassland treatment, and 11/30/2010 for animals from the natural grassland treatment. Slaughter followed the slaughterhouse routine and carcasses were evaluated according to the Brazilian carcasses grading system - Ordinance 612/1989 (Brasil, 1989). Half-carcasses were stored in a cold room for 24 hours, and after this period pH 24 h *post-mortem* was measured. The right half of the carcass was weighed and cut into three primary cuts: forequarter, hindquarter and side cut. Those cuts were weighed to calculate their relationship to the entire carcass.

Carcass yield (CY kg/100 kg of live weight) was obtained using the equation CY= (HCW/SW) × 100, where HCW = hot carcass weight (kg) and SW = slaughter weight measured on the farm (kg).

A portion of the *longissimus* muscle between the 12^{th} and 13^{th} rib with bones was taken off from each right half carcass. Those portions were packed in permeable plastic, then in paper, indentified and then frozen in a domestic freezer at -18 ºC for 20, 45, 164 days for natural Grassland, improved grassland and annual-summer grassland, respectively. The different freezing times were because of the distinct slaughter dates in the treatments. Measurements and analysis were carried out at Laboratório de Carnes of Embrapa CPPSUL in the city of Bagé/RS. Two 2.5-cm-thick samples (sample A and B) and a 1-cm-thick sample (sample C) were taken off from the frozen portion. Frozen samples “A” were weighed and then arranged on a tray covered with permeable plastic to be thawed in a refrigerator at 1.5-5 ºC for about 20 hours. Thawing losses were calculated by the difference between frozen and thawed weight. On thawed “A” samples, after 30 minutes of oxygen exposure, color measurements of L* (lightness) a* (redness) and b* (yellowness) were taken according to CIE system, using a portable colorimeter Chroma Meter Cr-400 (Minolta Camera Co., Ltda., Osaka, Japan), iluminante D65, 10º for standard observation, and calibrated for a white pattern. After removal of the remaining pieces of bones and fat from the sample, they were cooked in an oven at 180 ºC until the steak temperature reached 70 ºC in their geometric center. The temperature measurement was done using thermocouples in each beef. After cooking, steaks were chilled at room temperature and then weighed to calculate cooking losses.

Seven cores (1.27 cm diameter) were cut from the cooked and chilled “A” steaks parallel to the direction of the muscle fibers. Meat tenderness was evaluated by the maximum shear force in kgf/cm^2 in a Warner-Bratzler cell with a 1.016-mm blade coupled in Texture Analyzer TA-500 (Lloyd Instruments) using NEXYGEN software. Maximum shear force was logged for each sub-sample in NEXYGEN software curve. The average of seven sub-samples was used for each steak in the statistics analysis.

To evaluate water-holding capacity, 1 cm-thick samples were submitted to the removal of superficial fat and then, the meat was triturated in a multiprocessor until it hand a homogeneous aspect. An aliquot of 2 g was taken from this paste, which was put between two sheets of filter paper and then submitted to a pressure of 10 kg weight for five minutes. Water-holding capacity values were expressed in g/kg and were obtained by the equation (FW*1000/IW), where FW = sample weight after being submitted to pressure and IW = sample weight before being submitted to pressure (Grau & Hamm, 1953, modified by Sierra, 1973). About 1.5 g of triturated sample was put in filter bags and sent to a dryer at 105 °C for three hours in order to evaluate moisture. After that, aiming to quantify total lipids, fat extraction was carried out using an Ankon XT-20 Fat Analyzer for 60 min at 90 °C in petroleum ether under nitrogen pressure. Total lipids content was expressed in g/kg on the entire matter.

The "B" samples were arranged on a tray, covered with permeable plastic and were thawed in a refrigerator at 1.5-5 ºC for about 20 hours for sensory evaluation. After that, remaining pieces of bones and fat were removed from the samples, which were cooked in an oven at 180 ºC until the steak temperature reached 70 ºC in their geometric center. Steaks were cut in 1.5 × 1.5 cm cubes, which were wrappedd in aluminum paper and kept warm at 60 °C. Sensory panel was composed of trained assessors who were familiarized with the technique and with the attributes that were going to be evaluated by ordination tests and semantic differential scales skills. A duo-trio test with eight assessors and three replicates were performed as discrimination method (ABNT-NBR 13169, 1994). Assessors received three samples, one reference sample and two coded samples, one of them identical to reference samples. Assessors were asked to indicate which one of the two samples was equal to the reference sample, considering flavor and smell aspects. Results were obtained based on correct decisions, according to Roessler Table (Roessler et al., 1978).

The experimental design was completely randomized with a different number of replicates (n = 16, 18, 9 for natural grassland, improved grassland and annual-summer grassland, respectively). Each animal was considered a replicate. Meat and carcass data were submitted to ANOVA and F test. When differences were detected, the Tukey test was done (PROC MIXED). To create a relationship between ultrasonic measurements and live weight, regression analysis was done (PROC REG). Models comparison was done by confidence interval of the biological parameters. Correlation analysis (PROC COR) and "stepwise" multiple regression (PROC STEPWISE) were done. Discrete variables were analyzed by chi-square test (PROC FREQ). Statistic analyses of the data were performed using the statistical software package SAS (Statistical Analysis System, version 9.2) adopting $\alpha = 0.05$.

Results and Discussion

The decrease of the growth pace of the animals (Figure 1) fed in natural grassland in the fall is a classic behavior (Grossmann & Mordieck, 1956). This fact occurs due to the lower forage accumulation and quality of the pasture at this period of the year (Heringer & Jacques, 2002). Similar behavior was obtained by Castilhos et al. (2007) in an improved system in the same physiographic region of the present study. The bodyweight loss observed in June and July on the improved grassland treatment may be due to the highest stocking rate used on the previous months in this treatment aiming to better establish the winter species. This managing must be reflected in lower sward structure, because even though presenting similar forage mass and canopy height, the animal performance was worse than obtained in natural grassland treatment. In July, probably due to a higher contribution of the exotic winter species on improved grassland, recovery of the bodyweight was observed, in a possible compensatory gain. Generally, aiming to provide better conditions to winter species establishment, studies that evaluated fattening cattle on improved-natural grassland had deferment conducted on these areas, with experimental animals removed to other areas during this period (Castilhos et al., 2007; Ferreira, 2009). However, as the present study was conducted to investigate possible relationships between kinds of grasslands and meat characteristics, experimental animals were kept in the same feeding systems during all experimental period.

The average daily gain between February and June (0.824 kg/day) obtained on the annual summer grassland allowed that the animals feeding on this system reached weigh and fat cover adequate to slaughter at ages lower than at other treatments.

Average daily gain values (Table 2) obtained with sorghum forage were lower than that reported by Restle et al. (2002), which was 1.121 kg LW/day, but higher than those 0.631 kg LW/day found by Neumann et al. (2005). Slaughter

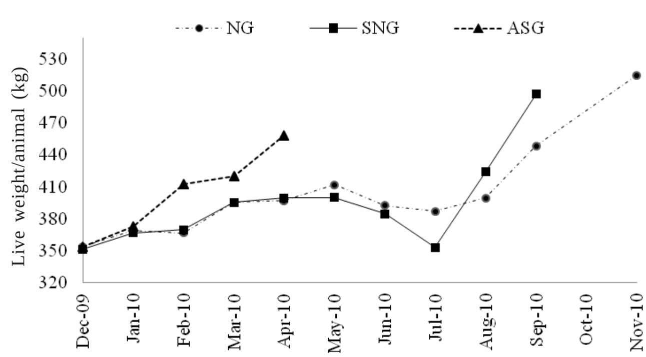

Figure 1 - Development of Aberdeen Angus steers (kg of live weight/animal) finished on natural grassland (NG), improved-natural grassland (ING) and annual summer grassland – sorghum (ASG).

weight was also lower in this treatment, which can be explained by the lower age. Cattle performances in natural grassland and improved-natural grassland were similar to those obtained by Castilhos et al. (2007) and Ferreira et al. (2011), who studied similar finishing systems.

Ultrasound analysis reflected the growth pace obtained with the treatments. Rib eye area development related to live weight (Figure 2) showed a linear behavior and non-dependent on the treatment, which was different than the behavior described by Hamlin et al. (1995). However, in those studies, animals are conducted from 135 kg until 720 kg, and the quadratic regressions obtained by them reflect the normal growth curve.

Fat deposition on *biceps femoris* at the P8 site (Figure 3) adjusted to a linear regression model for animals finished on the annual summer grassland and to a quadratic model for animals which were fed on natural grassland and improved natural grassland, following the animal weight gain curve. For relationships between fat thickness between the 12th and 13th ribs and live weight (Figure 4), the behavior was quadratic on the natural pasture and linear for improved-natural pasture and annual summer grassland. The linear behavior for animals that were fed the improved-natural pasture and annual summer pasture could be due to the higher forage mass and also forage quality at the most critical moment to finishing. In this case, animals which were fed with natural pasture, even having reached maturity and also having fat deposition on *biceps femoris* at the P8 site did not have enough quality in their diet to begin depositing fat between the 12th and 13th ribs, which is the least anatomic site for fat deposition (Di Marco, 1994). At slaughter, fat thickness between the 12th and 13th ribs and

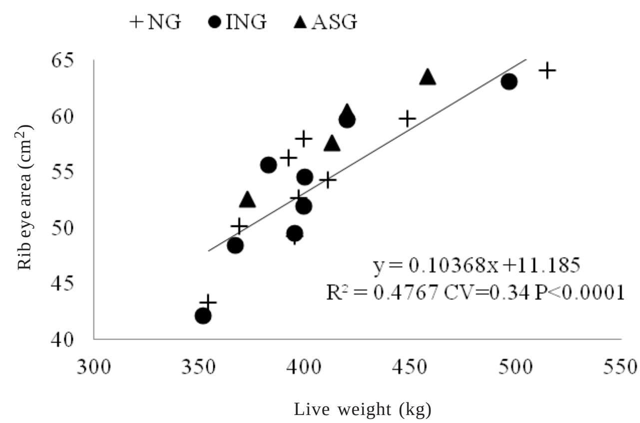

Figure 2 - Evolution of rib eye area between 12th and 13th rib as a function of live weight in Aberdeen Angus steers finished on natural grassland (NG), improved-natural grassland (ING) and annual summer grassland – sorghum (ASG), measured by ultrasound.

Table 2 - Age at slaughter, weight at slaughter, average daily gain, carcass characteristics and meat physicochemical characteristics of Aberdeen Angus steers finished on natural grassland (NG), improved-natural grassland (ING) and annual-summer grassland (ASG)

Variable	NG	ING	ASG	P-Value	SE
Age at slaughter (days)	1012a	955a	860b	0.0009	17.32
Weight at slaughter (kg LW)	514.8a	496.9a	458.1b	0.0023	6.15
Average daily gain (kg LW/day)	0.466b	0.491b	0.833a	<0.0001	0.02
Carcass characteristics					
Hot carcass weight (kg)	251.4a	258.0a	225.6b	0.0008	3.30
Cold carcass weight (kg)	246.6a	249.4a	218.7b	0.0026	3.18
Carcass yield (kg/100 kg LW)	48.9b	51.9a	49.2b	<0.0001	0.30
Hindquarter yield (kg/100 kg cold carcass)	46.4b	47.4a	46.2b	0.0012	0.15
Forequarter yield (kg/100 kg cold carcass)	37.8	37.1	38.0	0.1437	0.20
Sidecut yield (kg/100 kg cold carcass)	15.8	15.5	15.8	0.5309	0.13
Fat thickness - 12th and 13th ribs (mm)	1.9	2.6	2.1	0.4014	0.22
Fat thickness - *biceps femoris* (mm)	4.0	5.1	3.2	0.1158	0.34
Rib eye area (cm^2)	63.0	63.1	63.6	0.9600	0.75
Ultimate pH	5.67b	5.61b	5.85a	<0.0001	0.02
Physicochemical characteristics of the meat					
Thawing losses (g/kg)	27.6b	36.0a	23.9b	0.0016	1.52
Cooking losses (g/kg)	340.0ab	351.9a	326.4b	0.0091	3.41
L*	35.3ab	36.6a	34.6b	0.0117	0.27
a*	23.3a	23.7a	21.2b	0.0075	0.31
b*	8.9a	9.3a	7.3b	0.0011	0.20
Water-holding capacity (g/kg)	633.7b	672.5a	681.8a	<0.0004	5.32
Moisture (g/kg)	744.5	750.2	736.6	0.1054	2.81
Total lipids (g/kg)	19.6	18.2	24.8	0.0640	1.11
Shear force (kgf/cm^2)	7.1a	6.3ab	5.5b	0.0563	0.25

Means followed by distinct letters, in the same rows, are significantly different (P<0.05) by Tukey test.
SE - standard error; LW - live weight; L* - lightness, a* - redness e b* - yellowness.

at the P8 site was similar (P>0.05) for animals in all treatments. This demonstrates that animals were slaughtered at similar physiological maturity (Table 2).

No effect of finishing systems was found on carcass conformation (P>0.05). Sub-rectilinear carcasses were most frequent (86%), followed by rectilinear carcasses (14%). Carcass conformation is a muscular expression evaluation that considers mainly the muscular covering of the hindquarter where the most valued cuts are located. However, this characteristic is more related with animal genetics than with feeding characteristics (Faturi et al., 2002; Vaz et al., 2005; Igarasi et al., 2008).

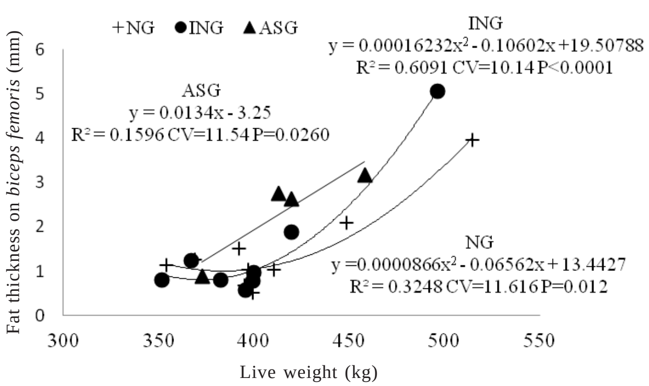

Figure 3 - Evolution of fat thickness on *biceps femoris* at the P8 site as a function of live weight in Aberdeen Angus steers finished on natural grassland (NG), improved-natural grassland (ING) and annual summer grassland – sorghum (ASG), measured by ultrasound.

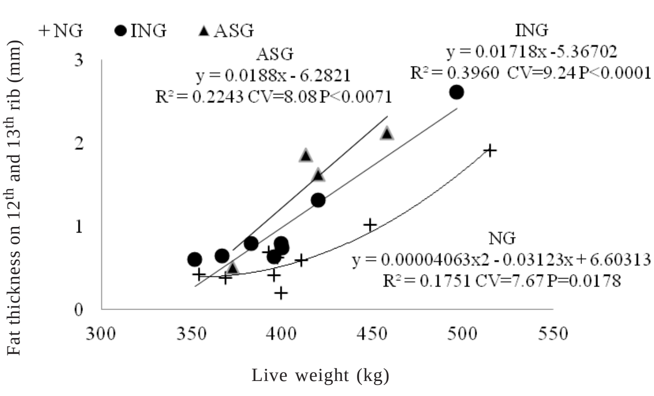

Figure 4 - Evolution of fat thickness on the 12th and 13th ribs as a function of live weight in Aberdeen Angus steers finished on natural grassland (NG), improved-natural grassland (ING) and annual summer grassland – sorghum (ASG), measured by ultrasound.

Hot and cold carcass weight was lower in animals feeding on annual summer grassland (P<0.05) and similar between animals finished on natural grassland and improved-natural grassland (P>0.05). These differences can be explained by the different ages at slaughter that occurred in the treatments. Carcass yield was higher (P<0.05) in improved-natural grassland. The higher contribution of *Lolium multiflorum* Lam. in this treatment could explain this result, since diets which have higher digestibility provide higher rate of passage, and then, lower ruminal fill, related with higher carcasses yields (Prado et al., 2000). However, this conclusion is not categoric; therefore, for the same animal type, other factors can influence this parameter, such as hours of fasting, and more or less rigidity at thecarcass toilet process.

Differences were not detected for forequarter yield or side-cut yield, and nor for rib eye area between finishing systems (P>0.05) (Table 2). According to Di Marco (1994), variations in the proportions of primary cuts in animals of same age and race are not frequent. These variations only take place when there are marked differences in the animal fat covering, which was not observed on the present study. Costa et al. (2002), working with Red Angus steers, verified that the slaughter weight evolution described linear decreasing behavior in the percentage of hindquarter and increasing behavior in forequarter percentage, with the side cut proportion remaining unaffected. In the present study, this behavior was not observed, since the hindquarter proportion was higher in animals finished in natural grassland; these animals presented the highest slaughter weights. In economic terms, it is desirable to obtain higher yields on hindquarter in relation to the other cuts, once is there that are situated the most valued cuts. These results are consistent with those obtained by Vaz et al. (2008) who found hindquarter yields of 47.7/100 kg in carcasses of 24-year-old Aberdeen Angus, fed rye-grass pasture.

Ultimate pH on meat corresponds to buildup of lactic acid coming from ATP resynsthesis from glycogen stores in muscle. Lower glycogen stores will cause higher ultimate pH, which will compromise meat quality in many aspects (color, water-holding capacity, shelf-life, and others) (Lawrie, 2005). Acute stress before slaughtering is one of the causes of burning of glycogen. Higher (P<0.05) ultimate pH values were observed on carcasses from animals finished in Annual-summer grassland. Higher *post-mortem* pH values (pH>5.8 and pH<6.2) occur more often in *Bos indicus*, which is probably due to their more reactive temperament, in contrast, Rossato et al. (2010) reported ultimate pH of 5,88 in Angus cattle. According to Neath et al., (2007) the meat from animals finished on grasslands has lower glycogen stores at slaughter, showing, hence higher ultimate pH. In contrast, this statement was not verified in the present study, since the animals finished in natural grasslands and Improved-Natural grasslands showed adequate values (Table 2). Thereby, the higher values obtained in Annual-summer grassland cannot be awarded to the grassland, once these can be related to pre-slaughter management or even to industrial processing.

On meat physicochemical aspects (Table 2) there is no treatment effect for moisture or total lipids on edible portion (P>0.05). Intramuscular fat depends on fat thickness. Schoonmaker et al. (2003) suggest that to obtain meat with desirable sensorial attributes, it would be necessary to have 3.0% of intramuscular fat, which would correspond to 8-10 mm of fat covering.

Water-holding capacity is directly associated to fat content, and mainly to the speed of pH decrease during *post-mortem* glycolysis. In cases where there are no differences in meat lipid content, it is assumed that the variation would be determined by ultimate pH (Lawrie, 2005). This tendency was verified in the present study, since that meat of higher ultimate pH also presented higher water-holding capacity, (r = 0. 3203; P = 0. 0362).

Thawing and cooking losses are water-holding capacity linked. Higher thawing and cooking losses (P<0.05) were measured on meat from Improved-natural grassland and Annual-summer grassland. These variables were negatively correlated to ultimate pH values: r = -0.35 (P = 0.0211) for thawing losses and r = -0.43 (P = 0.0040) for cooking losses. This relation reflects the water attraction by the myofibril proteins that occur in higher pH. In lower pH, these proteins do not suffer any denaturation and so they keep their linkage site with water (Hedrick et al., 1994). Cooking losses were similar to the values reported by French et al. (2000) and Vaz & Restle (2005).

In the present study, the age at slaughter did not affect meat color, once dark meats were found in both natural grasslands (oldest animals) and Annual-summer pastures (youngest animals). Multiple regression considering thawing losses, fat thickness, moisture, total lipids, pH 24 hours *post mortem*, age at slaughter and freezing time as variables showed that thawing losses explained 28.43% of the L* value. This statement is consistent, once the lightness is influenced by the amount of water that is present in sample surface (Purchas, 1990). Thereby, darker meats could be verified in treatments where thawing losses were higher, which could be related to higher ultimate pH values. Redness (a*) is related to the amounts of red pigment in myoglobin and in cytochrome C (Hedrick et al 1983), which can be associated to physical activity and animal age. Lower a* values were found in meats from Annual-summer pasture, which could be explained by lower slaughter ages, but this correlation was not significant (r =0.1095; P=0.4842). On the other hand, the freezing time to which samples from these treatment were submitted (164 days) seems to be more related to a* than the slaughter age (r =-0.4465; P =0.0027), in addition, the same could be set regarding b* values (r = -0.5015; P=0.0006). According the classification proposed by Abularach et al. (1998), the meats of the present study, regardless of treatment, all showed lightness from intermediate to dark, high red values and high yellow values; all of them are considered within the normal range for beef.

Higher shear force (P<0.05) was found in meats from natural grassland, whereas in Annual-summer grassland, lower shear forces were found. Shear force in meats from animals fed in Improved-natural pasture did not differ significantly from the other treatments. Some authors report that differences in grow rates could have impacts on particular kind of muscular fiber (Baillie & Garlick, 1991), and consequently, on meat quality (Maltin et al., 2001). Reduced levels of food, and so, lower animal growth, can lead to a higher frequency of oxidative fibers and lower frequency of glycolitic fibers (Johnston et al., 1981, Seideman & Crouse, 1986), which could be related to tougher meat (Zamora et al., 1996). Another approach to the effect of the grow rate is related to connective tissue composition. Gerrard et al. (1987) and Allingham et al. (1997) demonstrated that, in animal with high grow rates, the soluble collagen synthesis is higher. Compensatory gain also seems to influence the tenderness in beef (Andersen et al., 2005; Perry & Thompson, 2005). According to the authors, the new collagen molecules which are synthesized during this period dilute the older molecules, which are insoluble, resulting in more tender meats. Thereby, it should be noted that besides the 24 hours in cold room, which is under the health laws, the analyzed samples did not take any ageing process.

Multiple regression considering thawing losses, fat thickness, moisture, total lipids, average daily gain, pH 24 hours *post mortem*, age at slaughter and freezing time as variables showed that the average daily gain explained 18% of the shear force in meat (P=0.0092). Thereby, the intermediate values for shear force in meat from Improved-natural pasture suggests that the higher liveweight gains rate in the end of the fattening period in this system seems to have reflected in the tenderness improvement by collagen turnover as reviewed by Purslow (2005). Average values of shear force for animals finished in natural grassland were similar to those 7.86 kgf/cm^2 reported by Rossato et al.

(2010) in 36 months of age Angus cattle which were finished in pastures of Braquiária (*Urochloa brizantha* cv Marandu, *Urochloa decumbens*, *Urochloa humidicula* and *Panicum maximum*) and smaller than the 9. 23 kgf/cm^2 obtained by Vaz et al. (2007) in 24-month-old Angus cattle finished in a *Lolium multiflorum* grassland.

On the sensory evaluation by duo-trio test considering flavor and odor features, the assessors considered that beef samples from the evaluated feeding systems were different, obtaining 31correct judgments in 48 trials (P<0.05).

Conclusions

The finishing systems in natural grassland, Improved-natural grassland, and Annual Summer pasture enables desirable characteristics in the carcass and the meat of Aberdeen Angus cattle, until 34 months of age. The average daily gains defined by the feeding systems explained the differences in meat tenderness obtained in the different treatments. The evaluated finishing systems based on different pastures allowed the perception of distintic flavors and odors on meat of each treatment when analyzed by discrimination test in a trained sensory panel.

Acknowledgements

The authors thank CNPq, Estância do Silêncio de São José, Universidade Federal do Rio Grande do Sul, MARFRIG Group and EMBRAPA Pecuária Sul.

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