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Effects of pregnancy and feeding level on carcass and meat quality traits of Nellore cows

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ABSTRACT

Carcass and meat quality traits of 16 pregnant and 5 non-pregnant cows fed at 1.2 times maintenance and 16 pregnant and 6 non-pregnant fed ad libitum were evaluated. Pregnancy did not affect final body weight (FBW; $P=0.0923$), cold carcass yield (CCY; $P=0.0513$), longissimus muscle area (LMA; $P=0.8260$), rib fat thickness (RFT; $P=0.1873$) and shear force (WBSF; $P=0.9707$). A lower FBW ($P=0.0028$), LMA ($P=0.0048$) and RFT ($P=0.0001$) were observed in feed restricted cows. However, no differences were found for CCY ($P=0.7243$) and WBSF ($P=0.0759$) among feeding level groups. These data suggests that carcass and meat quality traits are not affected by pregnancy status in Nellore cows. Moreover, although cows experiencing feed restriction did have reduced deposition of subcutaneous fat and lean tissue, there were no major impacts on meat quality traits.

1. Introduction

Fluctuation of beef prices is commonly seen in the beef industry and rapid price declines can lead beef producers to harvest dams to reduce feeding costs. Harvest of cull female cattle has a substantial contribution to total beef production world-wide (Graham & Price, 1982; Wooten, Roubicek, Marchello, Dryden, & Swingle, 1979; Wythes, Shorthose, Fordyce, & Underwood, 1990) and in many cases cows are pregnant at slaughter (Macedo et al., 2007; Wythes et al., 1990). As pregnancy is marked by substantial homeorhetic controls necessary to support the physiological state such as rates of lipogenesis and lipolysis, carcass and meat quality traits are potentially altered due to pregnancy (Bauman & Bruce Currie, 1980). Even though pregnant cows are often used in beef production, little information is known about the quality of meat from pregnant cows (Wythes et al., 1990).

In tropical regions such as Brazil, beef cattle production is based on pastures, which represent the lowest cost feed source for ruminant animals. Consequently, the distribution and seasonal variation in quantity and quality of forage is one of the main problems faced by beef producers in these areas (Sampaio et al., 2010). Considering that the breeding season in most grazing production systems in Brazil occurs between November and January, pregnant cows usually experience feed restriction at some point during gestation, which overlaps with the dry season in most of the production areas.

Both pregnancy and feed restriction cause physiological challenges in the live animal that potentially affect carcass and meat quality traits. A study evaluating effects of feed restriction on calpain and calpastatin activity in skeletal muscle of pregnant cows has shown that calpastatin activity was down-regulated while no differences in calpain activity were observed in muscle of feed-restricted cows (Du, Zhu, Means, Hess, & Ford, 2004). Consequently, meat quality traits such as tenderness and water holding capacity might change since the calpain system plays an important role in proteolysis postmortem. Therefore, this study was developed to evaluate effects of pregnancy and feeding on carcass and meat quality traits of Nellore cows.

2. Material and methods

2.1. Animals and management

All animal care and handling procedures were approved by the Animal Care and Use Committee of the Department of Animal Science of the Universidade Federal de Viçosa, Brazil (protocol 047/2012). Forty-three multiparous Nellore cows with average initial body weight of 451 ± 67 kg, aged 5.6 ± 1.9 years and body condition score of 4.6 ±

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1.1 (1 to 9 scale) were used. Pregnancy of the cows was detected by ultrasound 25 days after mating and the day of mating was considered as day 0 of pregnancy. Thus, on day 27 of gestation cattle were confined in collective pens (48 m^2, 6 cows per pen) with individual electronic head gate system (Kloppen Soluções Tecnológicas, Pirassununga, SP, Brazil) for adaptation to individual feeders. At day 47 after conception, cows were randomly assigned to two groups with different feeding levels where 16 pregnant and 5 non-pregnant cows were fed at 1.2 times maintenance (NRC, 2000) and 16 pregnant and 6 non-pregnant were fed ad libitum. Cows were fed the same diet with differences only in the feeding level. The experimental diet composition is presented in Table 1. The restricted feeding level used was estimated to be enough to maintain the pregnancy of the dam through the experimental period avoiding abortion at any period of gestation and the ad libitum level allowed tissue deposition by the dams.

2.2. Harvest, carcass traits and sample processing

For evaluation of effects of gestational period on carcass and beef quality traits, pregnant cows were slaughtered at four different stages of gestation. Each feeding level group (maintenance and ad libitum) was randomly divided into four groups with four cows in each group to be slaughtered at 136, 189, 239, and 269 days of gestation. Non-pregnant cows were slaughtered at the end of the experimental period. Pre-harvest handling was in accordance with good animal welfare practices, and slaughtering procedures followed the Sanitary and Industrial Inspection Regulation for Animal Origin Products (Brasil, 1997).

After slaughter, all carcasses were refrigerated at 4 °C for approximately 24 h. Carcass temperature chilling rate was monitored by measuring the carcass temperature at 2, 4, 6, 8, 10, 12, 16, 20 and 24 h post-mortem. After the postmortem chill period the cold carcass weight (CCW), 12th rib fat thickness (RFT) and 12th rib longissimus muscle area (LMA) were measured on the left side of each carcass. Longissimus muscle areas were traced on transparencies and measured later with a planimeter and RFT measurements were taken 3/4 the length ventrally over the longissimus muscle (Greiner, Rouse, Wilson, Cundiff, & Wheeler, 2003).

The difference between the chilled and hot carcass weights was used to calculate 24 h shrink loss. Carcass yield percent was calculated using cold carcass weight (CCW) divided by final shrunk body weight (SBW) and then multiplying the result by 100.

A boneless longissimus section 10 cm thick was removed from the 11th to 13th ribs. Longissimus muscle samples were individually vacuum-packaged and held at −20 °C for 2 days. After that, each frozen longissimus muscle sample was standardized from the posterior end into one 2.54 cm thick steak sample (AMSA, 1995) for Warner–Bratzler shear force measurement and one 1 cm thick steak for determination of myofibrillar fragmentation index (MFI). All steaks were vacuum-packed and held at −20 °C for 10 days until the analyses were performed. Another 1 cm thick steak was sampled from the longissimus muscle for water holding capacity analysis at 24 h post-mortem.

Table 1
Composition of experimental diet.

Item	% Dry matter basis
Ingredients	
Corn silage	84.3
Soybean meal	5.1
Corn meal	8.5
Urea/ammonium sulfate[a]	1.4
Mineral mixture[b]	0.7
Nutritional composition	
Total digestible nutrients	64.8
Crude protein	13.5

[a] Urea/ammonium sulfate proportion = 9:1.
[b] Composed of 15% calcium; 9% phosphorus; 0.13% manganese; 0.2% cooper; and 100 mg/kg cobalt.

2.3. Estimation of postmortem muscular ATP depletion

Muscular ATP depletion was estimated by determination of the R-value throughout the post-mortem period. The determination of the R-value is a fast spectrophotometric method for the estimation of the inosine/adenosine ratio in muscle. In the case of postmortem changes in muscle it represents the degree of transformation of ATP to IMP (Honikel, Fischer, Hamid, & Hamm, 1981). For determination of the R-value, 5 g samples of longissimus muscle were collected between the 9th–11th ribs from the same half of the carcass from which boneless longissimus steak samples were collected. Muscle samples were manually collected using a metal core at 2, 4, 6, 8, 10, 12, 16, 20 and 24 h post-mortem in order to determine the time rigor mortis was established. After collection, samples were immediately frozen, powdered in liquid nitrogen and kept in liquid nitrogen (−196 °C) until the analysis was performed. The determination of the R-value was as described by Honikel et al. (1981).

2.4. Water holding capacity

Water-holding capacity was assessed using a centrifugation method (Honikel & Hamm, 1994) on samples collected at 24 h post-mortem. Each 1 cm steak was trimmed of external fat and minced. Duplicate 10-g minced samples were placed into centrifuge tubes and centrifuged for 10 min at 40,000 ×*g* at 4 °C using a JA-17 (Beckman Coulter, Fullerton, CA) rotor in an Avanti J-25 centrifuge (Beckman Coulter, Fullerton, CA). After centrifugation, the liquid was removed and the sample meat reweighed. Water lost was also recorded as a percentage of the original weight of the steak.

2.5. Cooking loss

Steak cooking loss was evaluated on the steaks that were also used for WBSF measurement. Cooking loss of each steak was recorded after steaks were oven-broiled. Total cooking loss was calculated as the difference between the weight of the steaks before and after oven-broiling.

2.6. Warner–Bratzler shear force measurement

Warner–Bratzler shear force (WBSF) steaks were thawed at 4 °C for 24 h and oven-broiled in an electric oven (Layr, Luxo Inox) preheated to 150 °C. Internal steak temperatures were monitored by 20-gauge copper–constantan thermocouples (Omega Engineering, Stamford, CT) placed in the approximate geometric center of each steak and attached to a digital monitor. When the internal steak temperature reached 35 °C, the steak was turned over and allowed to reach an internal temperature of 70 °C before removal from the oven. Cooked WBSF steaks were cooled for 24 h at 4 °C (AMSA, 1995). Eight round cores (1.27 cm diameter) were removed from each steak parallel to the long axis of the muscle fibers (AMSA, 1995). Each core was sheared once through the center, perpendicular to the fiber direction by a Warner–Bratzler shear machine (G-R Manufacturing Company, Manhattan, KS, USA).

2.7. Myofibrillar fragmentation index

Myofibrillar fragmentation indices (MFI) were determined on fresh muscle according to Olson, Parrish, and Stromer (1976) and modified by Culler, Parrish, Smith, and Cross (1978). The protein concentration of the myofibril suspension was determined by the Biuret method (Gornall, Bardawill, & David, 1949). Aliquots of the myofibril suspension were diluted with an isolating medium to reach a protein concentration of 0.5 ± 0.05 mg/ml. The diluted myofibril suspension was stirred and poured into a cuvette and the absorbance of this suspension was measured immediately at 540 nm. Absorbance was multiplied by 200 to give a MFI for each sample.

2.8. Sarcomere length

Longissimus muscle samples were collected at 24 h post-mortem and small cubes (3.0 × 3.0 × 2.0 cm) were excised in triplicate from each sample. Cubes were then fixed as described by Koolmees, Koreknie, and Smulders (1986). Sarcomere length was measured by laser diffraction using a 05-LHR-021 laser, Melles Griot, (Carlsbad, CA) and calculated as described by Cross, West, and Dutson (1981). From each cube, sarcomere length of six fiber samples was determined and used for sarcomere length average calculation.

3. Statistical analysis

The response variables were analyzed using PROC MIXED in SAS 9.2. With the exceptions of the R-value and carcass temperature, all variables were analyzed as the following model:

$$Y_{ijkl} = \mu + D_i + G_j + (D^*G)_{ij} + T_{(j)k} + (D^*T)_{i(j)k} + e_{i(j)kl}$$

where:

D_i ith level of the fixed effect of Diet
G_j jth level of the fixed effect of Gestation
$T_{(j)k}$ kth level of the fixed effect of Time within Gestation
$e_{i(j)kl}$ random error associated with Y_{ijkl}.

The repeated measurements in time (R-value and carcass temperature) were analyzed as the following model:

$$Y_{ijklmn} = \mu + D_i + G_j + (D^*G)_{ij} + T_{(j)k} + (D^*T)_{i(j)k} + e_{i(j)kl} + M_m + (D^*M)_{im} + (G^*M)_{jm} + (D^*G^*M)_{ijm} + (T^*M)_{(j)km} + (D^*T^*M)_{i(j)km} + e_{i(j)klm}$$

where:

D_i ith level of the fixed effect of Diet
G_j jth level of the fixed effect of Gestation
$T_{(j)k}$ kth level of the fixed effect of Time within Gestation
$e_{i(j)kl}$ random error associated with the lth replicate of the kth level of T within the jth level of G and ith level of D
M_m mth level of the fixed effect of Time of Measurement
$e_{i(j)klm}$ random error associated with Y_{ijklm}.

Least square means were estimated for all effects and compared using Tukey's method at $\alpha = 0.05$.

4. Results

There was no interaction ($P < 0.05$) among treatments. Thus, effects of pregnancy and feeding level are discussed independently.

No effects of pregnancy status were detected on final body weight (FBW; $P = 0.0923$), cold carcass weight (CCW; $P = 0.3125$), cold carcass yield (CCY, $P = 0.0513$), carcass shrink loss (CSL; $P = 0.7875$), longissimus muscle area (LMA; $P = 0.8260$), rib fat thickness (RFT; $P = 0.1873$) and carcass final pH (pHu; $P = 0.0898$). Additionally, no differences were observed for FBW ($P = 0.1274$), CCW ($P = 0.3699$), CCY ($P = 0.4637$), CSL ($P = 0.6208$), LMA ($P = 0.4529$), RFT ($P = 0.2888$), and pHu ($P = 0.1156$) among cows at different days of gestation (Table 2).

Pregnancy status did not affect Warner–Bratzler shear force (WBSF; $P = 0.9707$), myofibrillar fragmentation index (MFI; $P = 0.0917$), cooking loss (CL; $P = 0.5502$), water holding capacity (WHC; $P = 0.3291$), and sarcomere length (SL; $P = 0.2242$). No effects of days of gestation were observed for WBSF ($P = 0.7581$); MFI ($P = 0.4759$), CL ($P = 0.6921$), WHC ($P = 0.5641$), and SL ($P = 0.2195$) (Table 3).

A lower FBW was observed ($P = 0.0028$) in cows fed at maintenance compared to those fed ad libitum which shows the effectiveness of the feed restriction level used in this study. The CCW was also lower ($P = 0.0105$) in cows fed at maintenance compared to those fed ad libitum. No differences were found for CCY ($P = 0.7243$) and CLS ($P = 0.4704$) among the feeding level groups. Cows fed ad libitum had greater LMA ($P = 0.0048$) and RFT ($P = 0.0001$) compared to those fed at maintenance. No differences were observed among feeding level groups ($P = 0.5758$) for pHu (Table 4).

Cows fed ad libitum had similar WBSF values ($P = 0.0759$) to those fed at maintenance. No differences were found among feeding level groups for MFI ($P = 0.5759$), CL ($P = 0.7554$), WHC ($P = 0.5902$), and SL ($P = 0.9628$) (Table 5).

Similar R-values were observed throughout the post-mortem period among cows fed at maintenance and ad libitum ($P = 0.4260$; Fig. 1). However, pregnancy status affected the R-value throughout the post-mortem period and rigor onset occurred earlier in non-pregnant cows ($P = 0.0008$; Fig. 2). There was no effect of days of gestation on R-value during the post-mortem period ($P = 0.3551$).

Carcass temperature during the post mortem period was affected by feeding level ($P < .0001$) and significant differences were observed after 6 h post mortem where lower temperatures were observed in carcasses from cows fed at maintenance (Fig. 2). No effect of pregnancy status was observed ($P = 0.4476$) for carcass temperature during the postmortem period.

Table 2
Carcass quality traits of non-pregnant and pregnant Nellore cows at different stages of gestation.

Item[a]	Pregnancy status		Days of gestation				*P*-value	
	Non-pregnant	Pregnant	136 days	189 days	239 days	269 days	Pregnancy	Days of gestation
	n = 11	n = 32	n = 4	n = 4	n = 4	n = 4		
FBW, kg	487.38 ± 21.99	531.53 ± 12.84	508.75 ± 25.68	492.56 ± 25.68	555.62 ± 25.68	569.19 ± 25.68	0.0923	0.1274
CCW, kg	287.55 ± 14.32	304.56 ± 8.36	294.94 ± 16.72	284.98 ± 16.72	317.40 ± 16.72	320.93 ± 16.72	0.3125	0.3699
CCY, %	58.94 ± 0.71	57.26 ± 0.42	57.95 ± 0.83	57.83 ± 0.83	57.00 ± 0.83	56.27 ± 0.83	0.0513	0.4637
CSL, %	1.90 ± 0.09	1.87 ± 0.06	1.92 ± 0.11	1.96 ± 0.11	1.76 ± 0.11	1.84 ± 0.11	0.7875	0.6208
LMA, cm^2	64.31 ± 2.38	64.92 ± 1.42	64.38 ± 2.78	64.09 ± 2.78	68.75 ± 2.78	64.45 ± 2.78	0.8268	0.4529
RFT, mm	6.75 ± 0.89	8.14 ± 0.52	7.24 ± 1.04	8.10 ± 1.04	7.39 ± 1.04	9.83 ± 1.04	0.1873	0.2888
pHu	5.61 ± 0.05	5.50 ± 0.03	5.54 ± 0.06	5.61 ± 0.07	5.43 ± 0.06	5.41 ± 0.06	0.0898	0.1156

[a] FBW = final body weight; CCW = cold carcass weight; CCY = cold carcass yield; CSL = carcass shrink loss; LMA = longissimus muscle area; RFT = rib fat thickness; and pHu = carcass final pH.

Table 3
Beef quality traits of non-pregnant and pregnant Nellore cows at different stages of gestation.

Item[a]	Pregnancy		Days of gestation				*P*-value	
	Non-pregnant	Pregnant	136 days	189 days	239 days	269 days	Pregnancy	Days of gestation
	n = 11	n = 32	n = 4	n = 4	n = 4	n = 4		
WBSF, kg	4.48 ± 0.22	4.49 ± 0.13	4.69 ± 0.26	4.54 ± 0.28	4.29 ± 0.28	4.44 ± 0.26	0.9707	0.7581
MFI, %	52.35 ± 2.86	50.33 ± 1.67	47.67 ± 3.34	47.94 ± 3.34	51.62 ± 3.34	54.08 ± 3.34	0.0917	0.4759
CL, %	19.91 ± 1.10	20.68 ± 0.64	19.82 ± 1.29	21.67 ± 1.29	21.22 ± 1.29	20.03 ± 1.29	0.5502	0.6921
WHC, %	1.76 ± 0.21	1.53 ± 0.13	1.77 ± 0.26	1.46 ± 0.24	1.58 ± 0.24	1.34 ± 0.26	0.3291	0.5641
SL, μm	2.20 ± 0.08	2.08 ± 0.05	2.01 ± 0.09	2.18 ± 0.09	2.19 ± 0.09	1.96 ± 0.09	0.2242	0.2195

[a] WBSF = Warner–Bratzler shear force; MFI = myofibrillar fragmentation index; TL = thawing loss; CL = cooking loss; WHC = water holding capacity; and SL = sarcomere length.

5. Discussion

In a study evaluating the effects of pregnancy status on beef quality of non-pregnant cows, cows at early to mid gestation (1 to 5 months) and cows at late gestation (more than 6 months) Wythes et al. (1990) reported that females may increase in live and carcass weight during pregnancy but they still have lighter carcasses than their non-pregnant contemporaries. However, in the present study although a greater BW in cows due to pregnancy was expected, differences in BW and CW were not observed among pregnant and non-pregnant cows (Table 2). This might be explained by the mobilization of energy stores in pregnant animals to meet the requirements of the growing fetus. An increase in catabolism in pregnant animals has been demonstrated by Naismith and Morgan (1976) who observed a net protein loss due to pregnancy. Thus, the lack of effect of pregnancy on final BW and CW observed in this trial demonstrates the magnitude of the demands of pregnancy on cow's body tissue.

Although there was no difference on CCW and BW throughout the gestational period, both characteristics increased simultaneously as gestation advanced leading to a similar CCY from cows at different days of gestation. These results are supported by the amount of lean and subcutaneous adipose tissues, which are the main tissues responsible for variations on carcass weight and yield. As presented in Table 2, no differences were observed on LMA and RFT due to pregnancy status and days of gestation, which might explain the lack of differences in CCY.

Pregnancy is characterized by a series of metabolic changes that promote adipose tissue accretion in early gestation, followed by insulin resistance and facilitated lipolysis in late pregnancy. In early pregnancy, insulin secretion increases, while insulin sensitivity is unchanged, decreased, or may even increase (Barbour et al., 2007). However, in late gestation, maternal adipose tissue depots decline, as the ability of insulin to suppress whole-body lipolysis is reduced during late pregnancy (Valsamakis, Kumar, Creatsas, & Mastorakos, 2010). Therefore, increase in lipolysis in pregnant cows slaughtered at late gestation might explain the lack of differences for RFT of cows harvested at different days of gestation (Table 2).

Similarly, the lack of effects of days of gestation on LMA may be due to the increase of insulin resistance by skeletal muscle. It has been demonstrated directly in skeletal muscle fibers that pregnancy alone was associated with a marked reduction in insulin-stimulated glucose transport as gestation advances (Friedman et al., 1999). As the role of insulin is to increase glucose uptake controlled initially by the transport of glucose across the cell membrane, which takes place by facilitated diffusion through glucose transporters, insulin resistance in skeletal muscle reduces the energy availability for muscle hypertrophy. As a consequence, increase in muscularity may be impaired in pregnant animals leading to similar values of LMA among cows slaughtered at different days of gestation (Table 2).

As expected, cows fed ad libitum had greater FBW and CCW than cows fed at maintenance which shows the effectiveness of the feed restriction level used (Table 4). However, there was a lack of differences in CCY among feeding level groups which is possibly due to greater gastrointestinal contents of cows fed ad libitum (data not shown). Additionally, differences in viscera and internal fat weights have been reported in heifers under different feeding levels (Ferreira, Valadares Filho, & Barbosa, 1998; Lage et al., 2012). This possibly occurred in this study where cows fed ad libitum likely had greater viscera and internal fat weights than those fed at maintenance, contributing to differences in FBW, and concomitantly, similarity of CCY among feeding level groups (Table 4).

Nutrition management is one of the main factors that affect animal growth. When cattle are fed at maintenance there is a priority for energy utilization to maintain vital functions, as some internal organs of the body such as liver, kidney, heart and gastrointestinal tract are responsible for up to 40% of the energy requirement for maintenance of fasting cattle (Oliveira et al., 2011). These tissues have relatively higher protein turnover than muscle tissue resulting in high cost of energy for a basal metabolism leading to impaired muscle growth, as observed in this study where cows fed at maintenance had lower values of LMA than those fed ad libitum (Table 4).

It has been reported that transcription factors responsible for adipose tissue deposition reduce their expression in feed restriction

Table 4
Carcass quality traits of Nellore cows fed at two feeding levels.

Item[a]	Feeding level		*P*-value[b]		
	Ad libitum	Maintenance	FL	FL × PR	FL × DG
	n = 21	n = 22			
FBW, kg	545.0 ± 18.61	473.91 ± 17.39	0.0028	0.5382	0.7179
CCW, kg	315.92 ± 12.12	276.20 ± 11.32	0.0105	0.7544	0.6833
CCY, %	58.03 ± 0.60	58.17 ± 0.56	0.7243	0.4903	0.8064
CSL, %	1.84 ± 0.08	1.93 ± 0.07	0.4704	0.5343	0.4370
LMA, cm^2	67.94 ± 2.01	61.28 ± 1.90	0.0048	0.1269	0.3291
RFT, mm	9.43 ± 0.75	5.46 ± 0.70	0.0001	0.4992	0.3924
pHu	5.53 ± 0.04	5.57 ± 0.04	0.5748	0.5607	0.0702

[a] FBW = final body weight; CCW = cold carcass weight; CCY = cold carcass yield; CSL = carcass shrink loss; LMA = longissimus muscle area; RFT = rib fat thickness; and pHu = carcass final pH.
[b] FL = effects of feeding level; FL × PR = effects of interaction of feeding level and pregnancy status; FL × DG = effects of interaction of feeding level and days of gestation.

Table 5
Beef quality traits of Nellore cows fed at two feeding levels.

Item[a]	Feeding level		*P*-value[b]		
	Ad libitum	Maintenance	FL	FL × PR	FL × DG
	n = 21	n = 22			
WBSF	4.26 ± 0.19	4.71 ± 0.18	0.0759	0.5451	0.7785
MFI	53.22 ± 2.42	54.45 ± 2.26	0.5759	0.5394	0.1756
CL	20.35 ± 0.93	20.25 ± 0.87	0.7554	0.1240	0.4796
WHC	1.74 ± 0.18	1.56 ± 0.17	0.5902	0.2225	0.5403
SL, μm	2.13 ± 0.07	2.16 ± 0.06	0.9628	0.2095	0.9181

[a] WBSF = Warner–Bratzler shear force; MFI = myofibrillar fragmentation index; TL = thawing loss; CL = cooking loss; WHC = water holding capacity; and SL = sarcomere.
[b] FL = effects of feeding level; FL × PR = effects of interaction of feeding level and pregnancy status; FL × DG = effects of interaction of feeding level and days of gestation.

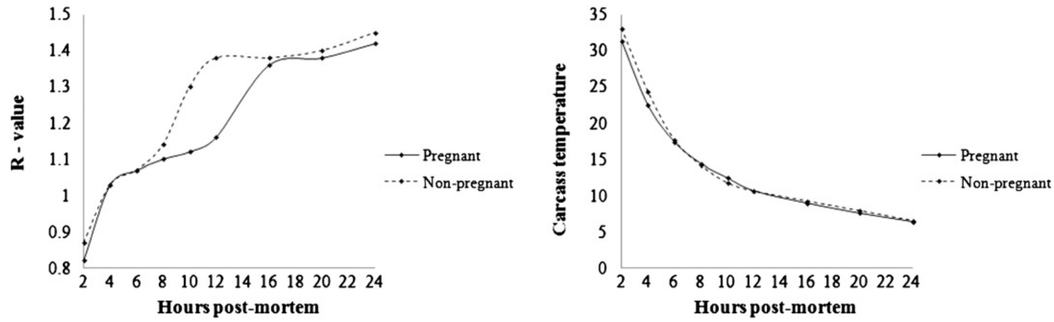

Fig. 1. R-value (250/260 nm absorption ratio) and carcass temperature from pregnant and non-pregnant cows throughout the postmortem period.

situations (Bergen & Burnett, 2012). Moreover, recent studies have shown the ability of the mature adipocyte to dedifferentiate returning into a proliferative state (Dodson, Jiang, Du, & Hausman, 2012; Fernyhough, Hausman, & Dodson, 2008; Kokta, Dodson, Gertler, & Hill, 2004) resulting in different cell lineages such as myogenesis (Dodson et al., 2010; Kazama, Fujie, Endo, & Kano, 2008; Matsumoto et al., 2008; Wei et al., 2012). Therefore, it is possible that in addition to lipolysis that usually occurs in feed restricted animals as a result of energy store mobilization, reduced RFT in feed restricted animals also occurs due to a dedifferentiation of mature adipocytes for formation of tissues having a higher priority than adipose tissue.

Carcass shrink loss is influenced by carcass fat thickness (Lage et al., 2012; Savell, Mueller, & Baird, 2005). Increased fatness may decrease shrinkage by serving as a barrier against moisture loss (preventing evaporation from the lean), or it may act to minimize the total moisture content in the carcass (Savell et al., 2005). Since there are variations in the distribution of back fat on the carcass, a minimum depth of 3 mm of RFT has been recommended to prevent carcass shrinkage and cold shortening during postmortem chill (Lage et al., 2012; Luchiari Filho, 2000). In this study, regardless of pregnancy status, days of gestation and feeding level, all carcasses had RFT greater than 3 mm. Thus, the absence of differences for CSL among the treatments evaluated can be attributed to adequate RFT depth (Tables 2 and 4).

During the postmortem period hydrolysis of intermediate filaments, titin and nebulin occurs mainly by the activity of calpains (Du et al., 2004; Koohmaraie, Kent, Shackelford, Veiseth, & Wheeler, 2002) and it can be predicted by measuring the myofibrillar fragmentation index (MFI) which indicates the extent of proteolysis postmortem and has been used as a predictor for postmortem tenderization. Therefore, the lack of effects of pregnancy status and days of pregnancy on WBSF may be partially explained by the lack of differences on MFI among these treatments (Table 3).

According to Whiting (1980), if the ATP level falls below about 1 μMol/g as a result of the postmortem breakdown of ATP, not enough ATP might be available for the operation of the ion pump in the sarcoplasmic reticulum leading to a scenario of Ca^{+2} accumulation in the sarcoplasm and consequently to a shortening of the sarcomere. In bovine longissimus muscle the R-value of 0.967 was reported to be equivalent to 1 μMol/g of ATP (Koh, Bidner, McMillin, & Kim, 1993). In the present study significant interaction between pregnancy status and time of measurement throughout the postmortem period was observed ($P = 0.0074$) for R-values measured on the longissimus muscle. Differences in R-value among pregnant and non-pregnant cows were observed ($P = 0.0008$) only after 10 h postmortem (Fig. 1). On the other hand, there was no difference ($P = 0.4476$) in carcass temperature during the postmortem period due to pregnancy status (Fig. 1). It should be noted that in both pregnant and non-pregnant cows the onset of rigor (R-value = 0.967) (Koh et al., 1993) occurred before the carcass temperature reached the critical range that leads to cold shortening, which explains the similarity in sarcomere length of the longissimus muscle from pregnant and non-pregnant cows (Table 3). Together, results of MFI and sarcomere length observed in this study are consistent with the lack of differences in WBSF observed in beef from pregnant and non-pregnant cows.

Carcass temperature was affected by feeding level groups throughout the postmortem period (Fig. 2), which is due to the difference in RFT in carcasses of animals fed at maintenance and ad libitum. The subcutaneous fat acts as a thermal insulator of the carcass during chilling, thus reducing the chilling rate of the carcass. As presented in Table 4, cows fed ad libitum had greater values of RFT than those fed at maintenance which explains the higher temperatures of carcasses from cows fed ad libitum throughout the postmortem period. However, although differences in carcass temperature were observed among feeding level groups, sarcomere length did not differ among cows fed ad libitum or at maintenance (Table 5). There was no effect of feeding level on the R-values of the longissimus muscle during postmortem period (Fig. 2). As previously discussed, the carcass chilling rate was not severe enough to reach temperatures that would cause cold shortening of the muscle and thus, no differences were observed for sarcomere length among feeding level groups. Although cows fed at maintenance had

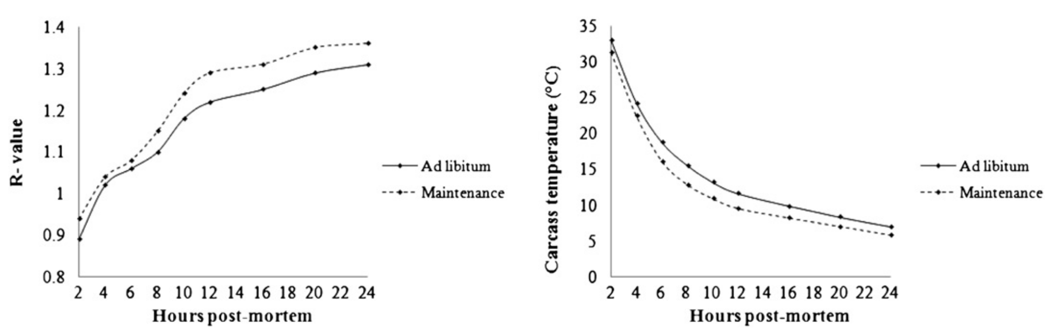

Fig. 2. R-value (250/260 nm absorption ratio) and carcass temperature from cows fed different feeding levels throughout the postmortem period.

lower RFT than cows fed ad libitum, the amount of subcutaneous fat in this study seemed enough to avoid a sudden drop of carcass temperature, preventing toughening by cold shortening.

6. Conclusions

These data suggest that carcass and meat quality traits are not affected by pregnancy status in Nellore cows. Moreover, although cows experiencing feed restriction did have reduced deposition of subcutaneous fat and lean tissue, there were no major impacts on meat quality traits.

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