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Feed Restriction and Compensatory Growth in Guzerá Females

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ABSTRACT : This study examined the effect of restricting feed intake and the subsequent compensatory growth in Guzerá females. Eighteen animals with an initial age of 21 months and a mean weight of 268.17 kg were placed in three groups according to the alimentary regime: feed *ad libitum*; feed restricted to 20% dry matter; and feed restricted to 40% dry matter. In the restricted feed phase, the dry mater intake decreased as the restriction levels increased, influencing the reduction in intake of other nutrients. In the realimentation phase, the 40% restricted feed group ingested more dry matter (% BW) and crude protein (weight$^{0.75}$) than the group fed *ad libitum* ($p<0.001$). The serum nutrient concentrations were inversely proportional ($p<0.001$) to the restriction level, and there was no difference ($p>0.001$) in the realimentation phase. In the restricted feed phase, the final live weight decreased ($p<0.05$) as the restriction level increased. For the daily mean weight gain in the control group, there was no difference ($p>0.05$) compared to the animals with 20% feed restriction, but this was higher than in the group with 40% feed restriction. In the re-alimentation phase, the group with 40% feed restriction achieved higher weight gain rates, which was different from the control and 20% restriction groups. In both phases, the animals in the group with 40% feed restriction presented better feed conversion which was different ($p<0.05$) from the control group. In the feed restriction phase, it was observed that the intake of N, nitrogen excreted in feces and urine, nitrogen balance and nitrogen retention decreased ($p<0.05$) with the restriction level. None of the variables were influenced in the re-alimentation phase. These results show that feed restriction by 40% can be adopted as a nutritional management practice. (**Key Words :** Compensatory Growth, Metabolites, Nitrogen, Nutrition, Zebu)

INTRODUCTION

The use of tropical dual purpose (beef and dairy) breeds has contributed to livestock rearing sustainability in semi-arid regions, because these animals are more resistant to common problems in the livestock productive chain. Although the focus on beef production was the incentive in the early days of Zebu raising, there have been reports from Brazil since the middle of 20th century regarding animals of the Guzerá breed, in particular, with high milk production that makes them an attractive option in the region (Lôbo et al., 2000).

Raising cattle in the Brazilian northeast normally subjects animals to alternate periods of food abundance and scarcity, often as a consequence of the quantity and quality of the food available. Along with this, the efficiency of food use is one of the main nutritional factors that affect the profitability of the cattle farms.

Several experiments have shown that animals subjected to feed restriction, when feed is made available again, have high growth rates and exceed those of animals that were well fed throughout the same period, because of a physiological impulse called compensatory gain (Hoch et al., 2003). However, when this happens in females it is desirable that it does not occur during puberty so that there is no reproductive damage, but rather reduces feeding costs. It is important to monitor the metabolism of these animals to reduce these problems by following serum nutrient concentrations and ruminal metabolism because the blood accurately reflects the nutritional state of the animals. The objective of this study was to determine the effects of different feed restriction levels and later realimentation in pre-puberty Guzerá females.

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MATERIALS AND METHODS

Experimental materials and procedures

The experiment was carried out from June to October 2008 in the Alagoinha-PB Experimental Station (Paraíba, Brazil). Eighteen Guzerá females were used with an average age of 21 months at the start of feed restriction and an average body weight of 268.17 kg. After restriction, the realimentation phase was started, with the animals presenting 316.0 kg initial average weight. They were placed in three groups of six animals, so that two restriction levels were generated in the feed restriction phase compared to the group that fed *ad libitum*, as follows: group 1 (control), in which the heifers were fed on a quantity of dry matter that met 100% of the nutritional requirements for a 700 g/d gain, according to the NRC (1996), group 2, in which the heifers were fed with a quantity of dry matter to meet 80% of the nutritional requirements of the control group; and group 3, in which the heifers were fed a quantity of dry matter to meet 60% of the nutritional requirements of the control group. All the animals received the same diet in the realimentation phase.

The ingredients used in the diets (elephant grass, cassava roots, corn meal, soybean meal, urea and a mineral mixture) were processed and supplied in the form of complete feed. Samples were collected every 15 days representative of the components of the diet supplied, orts and feces, and compound samples were made of the diet and orts, per animal and per period, that were frozen for later analysis. The dry matter (DM), mineral matter (MM), total nitrogen (TN), ether extract (EE), neutral detergent fiber (NDF) and in acid detergent fiber (ADF) were determined according to Silva and Queiroz (2002). The crude protein (CP) was obtained from the product between the total nitrogen content and a factor of 6.25. The non-fibrous carbohydrates (NFC) were calculated according to Weiss (1999) as NFC (%) = 100-(% NDFcp+% CP+% EE +% ash).

The chemical composition of the ingredients is shown in Table 1. Table 2 shows the proportion of the ingredients and the chemical composition of the experimental diet of each period based on the dry matter.

Analysis

The quantities of the food supplied and the orts of the food were recorded daily, to estimate intake of the nutrients. In the restriction phase, the animals were weighed individually at 15-day intervals after a 14h fasting period from solids. In the realimentation phase, the animals were weighed every 10 days to assess the compensation index, following methodology by Wilson and Osbourn (1960) to quantify the intensity of the weight compensation of the animals during realimentation, according the Equation Index = (A-B)/A, where A corresponds to the weight of the animals that did not suffer feed restriction during the first part of the experiment and B represents the groups that suffered restriction (20% and 40% in the case of the present experiment) in one period and were refed shortly afterwards.

Table 1. Chemical composition of the ingredients in the experimental diets in the feed restriction and re-alimentation periods

	Elephant grass	Cassava roots	Corn meal	Soybean meal
Feed restriction				
Dry matter[1] (DM)	26.00	38.30	88.90	85.55
Ash[1]	11.06	3.20	2.36	6.91
Crude protein[1] (CP) (N×6.25)	6.15	3.83	12.19	45.23
Ether extract[1] (EE)	2.17	1.27	5.47	1.19
Neutral detergent fiber[1] (NDF)	71.23	17.98	16.36	14.84
Neutral detergent fiber ap[1,2] (NDFap)	67.39	11.72	12.98	8.13
Acid detergent fiber[1] (ADF)	42.55	9.74	8.07	8.29
Nonfiber carbohydrates[1] (NFC)	13.23	79.98	67.00	38.54
	Elephant grass	Sugar cane	Corn meal	Soybean meal
Re-alimentation periods				
Dry matter[1](DM)	26.89	24.49	86.26	86.45
Ash[1]	10.98	4.56	1.45	6.84
Crude protein[1] (CP) (N×6.25)	4.11	3.93	10.13	44.41
Ether extract[1] (EE)	1.78	1.14	5.37	1.71
Neutral detergent fiber[1] (NDF)	78.65	58.06	13.55	14.82
Neutral detergent fiber ap[1,2] (NDFap)	71.74	49.20	9.87	10.73
Acid detergent fiber[1] (ADF)	49.26	37.33	4.54	9.99
Nonfiber carbohydrates[1] (NFC)	11.39	41.17	73.18	36.31

[1] Percentage of dry matter. [2] NDF corrected for ash and protein (NDFap).

Table 2. Participation of the ingredients and chemical composition of the animals' experimental diet based on dry matter, in the feed restriction and realimentation periods

Ingredient	Feed restriction	Re-alimentation periods
	---------- % ----------	
Elephant grass	28.00	17.70
Cassava roots	35.31	-
Sugar cane	-	41.29
Corn meal	24.70	30.00
Soybean meal	9.10	7.52
Urea	1.28	1.49
Mineral mixture [3]	1.61	2.00
Chemical composition	---------- % ----------	
Dry matter	51.64	50.70
Ash[1]	5.43	4.77
Crude protein[1] (N×6.25)	13.82	12.93
Ether extract[1]	2.51	2.52
Neutral detergent fiber[1]	31.69	43.07
Neutral detergent fiber ap[1,2]	26.95	36.78
Acid detergent fiber[1]	18.10	26.24
Nonfiber carbohydrates[1]	52.00	43.00

[1] Dry matter percentage.
[2] NDF corrected for ash and protein (NDFap).
[3] Percent composition: NaCl (64.57%); KCl (23.07%); NH_3SO_4 (7.69%); $ZnSO_4$ (3.85%); $CuSO_4$ (0.77%); $CoSO_4$ (0.015%).

Blood samples were collected by puncturing external jugular vein without a tourniquet excessive vessel, using vacutainer system, in siliconized glass tubes, and the samples kept at room temperature to facilitate clot retraction. The samples were kept at room temperature and approximately three hours later were centrifuged at 2,200× g for 20 minutes to obtain serum. This was aliquoted and stored at -20°C in plastic microtubes until the biochemical analyses were carried out (Bezerra, 2006).

The blood biochemistry was analyzed using LABTEST® biochemical kits and biochemical determinations were made using an AMS® light spectrometer and the following colorimetric methods: total protein (biuret), albumin (bromocresol green), urea (Urease-Labtest), glucose (GOD-Trinder), cholesterol (Trinder enzymatic), calcium (methylthymol blue) and phosphorus (methylthymol blue) (Alves et al., 2004).

Spot urine samples were taken by spontaneous miction on the 60th day (feed restriction) and on the 115th day of the experiment (realimentation) approximately four hours after supplying feed in the morning. 10 L aliquots were diluted with 40 ml H_2SO_4 at 0.036 N. The pH of these samples was adjusted to values below 3.0 to prevent bacterial destruction of the urine purine bases and uric acid precipitation. The samples were then stored at -20°C until submitted to analyses for creatinine, urea, alantoin and uric acid.

The urea and creatinine in the urine were analyzed following the diacetyl methods modified with the use of picrate and acidifier (Kit LABTEST®), respectively, and a light absorption spectrophotometer was used. The alantoin and uric acid were analyzed by the colorimetric method according to the technique by Fujihara et al. (1987).

The daily urine volume was estimated from the mean daily creatinine excretion, obtained in the experiment in mg/kg BW/d, and the creatinine concentration (mg/L) in the urine spot sample. This volume was used to calculate the estimated daily urea, alantoin and uric acid excretions of each animal.

The nitrogen compound balance was obtained from the difference between the total ingested nitrogen and the total excreted nitrogen in the feces and urine. The estimated daily excretions of N-urea in the urine were calculated from the product of the urea urinary concentration by the estimated urinary volume, multiplied by 0.466 (corresponding to the N content of urea). Total feces collection was carried out to determine the daily estimated N-urea excretions. The total nitrogen in the feces was determined according the methodology by Silva and Queiroz (2002).

The total purine derivative excretion was the result of the sum of the alantoin and uric acid urinary excretions. From these, the absorbed microbial purines were calculated (X, mmol/d), using the following equation (Verbic et al., 1990): $Y = 0.85X+0.385\ BW^{0.75}$, where 0.85 is the recovery of purines absorbed as purine derivatives in the urine and $0.385\ BW^{0.75}$ represents the endogenous contribution for purine excretion.

The intestinal flow of microbial nitrogen (N) compounds (Y, g N/d) was calculated as the function of the absorbed purines (X, mmol/d), using the equation $Y = (70X)/(0.83\times0.134\times1,000)$, where 70 represents the N content of purines (mg N/mmol); 0.83 represents the digestibility of the microbial purines and 0.134 represents the N-purine:total N ratio in bacteria (Valadares et al., 1999).

Statistical analysis

A complete randomized design was used with three treatments and six replicates per treatment, in a total of 18 plots. The metabolites were analyzed using the analysis plan of plots split in time, with the restriction levels in the main plot and the collection time in the secondary plots. Thus, the variables for performance and microbial protein production were submitted to analysis of variance and the means test using the GLM procedure, while the variables of the nutrient serum metabolic concentrations were analyzed by the MIXED procedure, both from the SAS program (SAS, 2000). The statistical models can be presented as follows: $Y_{ij} = \mu+r_i+e_{ij}$, where: Y_{ij} = the observed value j of the restriction level i; μ = general mean; r_i = the effect of the restriction level i; e_{ij} = the random error association to

each observation. For the metabolites, where time was considered in the subplot, the model can be described as: $Y_{ijk} = \mu+r_i+\alpha_{ij}+t_k+(rt)_{ik}+e_{ijk}$, where: Y_{ijk} = the observed value j of the restriction level i in time k; μ = general mean; r_i = the effect of the restriction level i; α_{ij} = the residual effect of the plots, characterized as error (a); t_k = the effect of k time level; $(rt)_{ik}$ = the effect of the interaction of the restriction level i with time level k; e_{ijk} = the residual effect of the subplots, characterized as error (b). In the presence of a treatment effect, the means of the treatments were compared by the Tukey test at 5% significance for all the tests carried out.

RESULTS AND DISCUSSION

In the feed restriction period, the intake of dry matter (DM) and crude protein (CP) in (kg/d, % BW and $BW^{0.75}$), neutral detergent fiber (NDF), ether extract (EE), non-fibrous carbohydrates (NFC) and mineral matter (MM) in (kg/d) were influenced ($p<0.05$) by the applied restriction levels (Table 3).

The intake of these nutrients decreased as the restriction level increased. The smaller DM intake of the groups submitted to restriction resulted from the small quantity of feed offered and its intake was regulated as a function of the dry matter ingested by the control group (20% and 40%, respectively) that also influenced the reduction in the intake of the other nutrients. Costa et al. (2007) submitted heifers to the compensatory growth system and also observed smaller DM and NDF intake (kg/d, % BW) during the restriction period.

It was observed that DM intake was 27% less in the group restricted by 20% and 45% less in the group restricted by 40%. Clark et al. (2007) reported that when cattle were submitted to a 20% reduction in dry matter ingestion, they reduced the normal sustainable ruminal fermentation and altered nutrient losses through the feces.

The acid detergent fiber (ADF) (kg/d) and NDF

Table 3. Means, coefficients of variation (CV) and probability (P) in the mean daily intakes of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), ether extract (EE), non-fibrous carbohydrates (NFC) and ash in Guzera females as a function of the feed restriction levels and realimentation growth periods

Intake of nutrients	Levels of feed restriction			CV %	p
	0%	20%	40%		
Feed restriction					
Dry matter (kg/d)	9.66^{a}	7.13^{b}	5.35^{c}	8.65	>0.0001
Dry matter (% BW)	3.17^{a}	2.48^{b}	1.96^{c}	5.94	>0.0001
Dry matter (g/$BW^{0.75}$)	132.57^{a}	102.10^{b}	79.87^{c}	6.32	>0.0001
Crude protein (kg/d)	1.34^{a}	1.15^{b}	0.86^{c}	8.64	>0.0001
Crude protein (% BW)	0.63^{a}	0.47^{b}	0.37^{c}	4.75	>0.0001
Crude protein (g/$BW^{0.75}$)	26.65^{a}	19.33^{b}	15.11^{c}	5.57	>0.0001
Neutral detergent fiber (kg/d)	3.36^{a}	2.75^{b}	2.06^{c}	10.05	>0.0001
Neutral detergent fiber (% BW)	1.10^{a}	0.95^{a}	0.76^{b}	8.67	>0.0001
Acid detergent fiber (kg/d)	1.28^{a}	1.22^{ab}	0.92^{b}	15.18	>0.0001
Ether extract (kg/d)	0.12^{a}	0.09^{b}	0.07^{c}	7.39	>0.0001
Nonfiber carbohydrates (kg/d)	3.91^{a}	2.72^{b}	2.04^{c}	9.03	>0.0001
Ash (kg/d)	0.57^{a}	0.44^{b}	0.33^{c}	8.76	>0.0001
Re-alimentation periods					
Dry matter (kg/d)	8.33	8.05	8.01	3.59	0.5712
Dry matter (% BW)	2.84^{b}	2.95^{b}	3.08^{a}	5.16	0.0480
Dry matter (g/$BW^{0.75}$)	117.53	119.85	123.61	4.17	0.0639
Crude protein (kg/d)	1.18	1.17	1.14	3.51	0.3016
Crude protein (% BW)	0.39^{b}	0.43^{ab}	0.45^{a}	6.44	0.0249
Crude protein (g/$BW^{0.75}$)	16.16^{b}	17.60^{ab}	18.16^{a}	5.42	0.0298
Neutral detergent fiber (kg/d)	3.86	3.71	3.76	5.07	0.6033
Neutral detergent fiber (% BW)	1.32^{b}	1.35^{ab}	1.44^{a}	4.39	0.0166
Acid detergent fiber (kg/d)	2.56	2.78	2.92	9.83	0.3367
Ether extract (kg/d)	0.18	0.19	0.19	4.64	0.6703
Nonfiber carbohydrates (kg/d)	3.48	3.42	3.31	3.26	0.1601
Ash (kg/d)	0.58	0.56	0.56	3.78	0.5595

Means followed by the same letter in the same row do not differ statistically by the Tukey test at 5% probability ($p>0.05$).

(% BW) intake differed ($p<0.05$) only between the control and 40% restriction groups and both were similar ($p<0.05$) to the 20% restriction group. The reduction in the effective fiber level in the diet may result in a series of events in a cascade as: less chewing by the animal, less buffering saliva secretion, a change in the microbial population and a reduced acetate:propionate (A:P) ratio as observed by Mertens (2001).

No difference was observed in the realimentation periods among the groups for nutrient intake in kg/d. However, when analyzed as a function of BW the intake of DM, CP and NDF was greater ($p<0.05$) in the 40% restriction group than in the group without feed restriction, but neither group differed ($p<0.05$) from the group submitted to 20% intake restriction. The increase in ingestion compared to the live weight meant that a significantly greater proportion of the food was used for gain. In this case, depending on the synergism of hormone signals (Hoch et al., 2003) the digestive tract of the animal recovered its full potential so that ingestion increased compared to the animals without restriction, Ryan et al. (1993) reported that the increase in intake in the realimentation period is related to the severity of feed restriction. This statement corroborates the results of the present experiment, because there was no difference ($p<0.05$) between the control group and the group where the feed restriction was most severe (40%).

When the restriction severity increased, it was observed that the serum concentrations of total proteins, globulin, urea, glucose, calcium and phosphorus decreased ($p<0.05$) In the realimentation phase, no difference was observed among the groups for the serum concentration of the nutrients analyzed and no difference was observed ($p<0.05$) among the groups for serum concentrations of the nutrients analyzed (Table 4).

In ruminants, reducing food ingestion for a period can result in alterations in ruminal fermentation (Chelikani et al., 2004), electrolyte balance and nutrient serum concentrations (Cole, 2000). Animals invoke adaptation processes to maintain homeostasis and as a consequence do not present metabolic disturbances. These interactions include those related to nutrient entry, because if the quantity of nutrients ingested by the animal is restricted there is ruminal imbalance and an imbalance in protein use and in the protein:energy ratio. This situation is more evident when the compensatory growth effect is observed on metabolism (Ford and Park, 2001). The smaller intake generates an energy deficiency and nutrient mobilization in an attempt to maintain energetic homeostasis resulting in reduced serum levels of nutrients, especially in glucose content. Amstalden et al. (2002) also detected a reduction in glucose plasma concentrations when they submitted beef cattle to prolonged fasting. During feed restriction, a change in the energy balance has been observed due to reduced glucose levels in the blood and the use of fatty acids as the main source of energy (Chelikani et al., 2004). Glucose serum concentrations recovered after realimentation as a result of a higher ruminal production of propionic acid, associated with a greater concentration of carbohydrates.

The reduction in calcium and phosphorus serum

Table 4. Means, coefficients of variation (CV) and probability (P) in the serum concentrations for total protein (g/dl), albumin (g/dl), globulin (g/dl), urea (mg/dl), glucose (mg/dl), calcium (mg/dl) and phosphorus (mg/dl) in the Guzera females submitted to feed restriction and realimentation periods

Metabolites	Levels of feed restriction			CV%	p
	0%	20%	40%		
Feed restriction					
Serum total protein (g/dl)	7.07[a]	5.88[b]	4.78[c]	7.72	<0.0001
Serum albumin (g/dl)	3.39[a]	2.90[b]	2.19[c]	12.48	<0.0001
Serum globulin (g/dl)	3.68[a]	2.98[b]	2.59[c]	15.83	<0.0001
Serum urea (mg/dl)	54.98[a]	49.95[b]	44.16[c]	10.55	<0.0001
Serum glucose (mg/dl)	63.64[a]	56.51[b]	50.37[c]	14.51	<0.0001
Serum calcium (mg/dl)	10.87[a]	9.36[b]	8.85[c]	15.99	<0.0001
Serum phosphorus (mg/dl)	5.53[a]	4.76[b]	4.32[c]	10.64	<0.0001
Re-alimentation periods					
Serum total protein (g/dl)	7.08	6.76	6.92	3.85	0.1850
Serum albumin (g/dl)	3.35	3.52	3.31	6.19	0.1390
Serum globulin (g/dl)	3.73	3.24	3.61	9.58	0.0564
Serum urea (mg/dl)	52.91	58.82	54.91	10.48	0.2364
Serum glucose (mg/dl)	65.55	66.78	63.11	10.86	0.6664
Serum calcium (mg/dl)	10.36	10.78	10.61	7.05	0.7213
Serum phosphorus (mg/dl)	5.15	5.11	5.30	7.25	0.6745

Means followed by the same letter in the same row do not differ statistically by the Tukey test at 5% probability ($p>0.05$).

concentration ($p<0.05$) was due to the low ingestion of the two minerals. If this decrease is very severe and prolonged, it can be reflected in reduced bone tissue development and reproductive problems, because young animals are more efficient at absorbing these minerals due to their high bone development rate (McDowell, 1999). It has been pointed out that phosphorous metabolism control is associated with that of calcium and that a high ratio should be maintained to control the homeostasis of these two elements. According to the values detected in this experiment, the calcium:phosphorous ratio obtained for the groups was between 1.9:1 and 2.2:1, respectively, and showed the correct proportion of these minerals for the age of the animals (Taylor et al., 2008).

Significant ratios were observed between dietary nutrient entry and the concentrations of some metabolites in the blood. Generally, the serum concentrations of glucose, total protein, albumin and urea nitrogen are related to the dietary entry of energy and crude protein. These ratios are the base for the practical use of metabolic profile tests and allow the occurrence of metabolic events to be followed.

In the feed restriction phase, as the restriction levels increased, the final weight decreased and there was a difference ($p<0.05$) among the experimental groups (Table 5). The animals in the control group presented final weight values 8% greater than the group restricted by 20% and 15% greater compared to the group restricted by 40%. According to Wilson and Osbourn (1960), the growth of an animal can be delayed if any nutrient in the diet is missing, especially if energy and protein availability limit weight gain. As the animal has small protein reserves, protein restriction usually causes greater damage than energetic restriction. This fact can be proved by observing the intake and analysis of the protein and energy serum concentrations.

In the feed restriction phase, the mean daily weight gain of the animals in the control group did not differ ($p>0.05$) from those animals that received feed restricted by 20% and was greater ($p<0.05$) than the group with 40% restriction. This was a reflection of higher intake than necessary for maintenance that made more nutrients available for tissue deposition (Hoch et al., 2003). There was no difference ($p>0.05$) in the weight gain of the animals in the restriction groups.

In the realimentation phase, the animals in the 40% feed restriction group presented the lowest mean daily weight gain in the experiment (0.918 kg/d) differing ($p<0.05$) from the animals in the control and 20% restriction groups. Hoch et al. (2003) reported that during the compensatory growth phase, the animal's metabolism continues to adjust to low food ingestion while the animals are not restricted. The base energetic metabolism of the animal remains low and increases slowly, adjusting to the new regimen. Thus, energy and protein use become more efficacious while the energetic needs for growth remain low, which could explain the greater weight gain in these animals.

The restricted energy in the restriction phase resulted in a smaller weight gain in the females, so that they gained less weight compared to the animals which were fed normally. Realimentation permitted a return to normal weight gain. Greater energy intake than necessary for maintenance caused a greater proportion of ingested energy to be available for growth and resulted in compensatory growth.

In both phases, the animals submitted to 40% feed restriction presented better food conversion ($p<0.05$) compared to the group without restriction and there was no difference ($p>0.05$) between these groups and the 20% group in any of the phases, indicating greater efficiency in

Table 5. Means and coefficients of variation in the initial weight (kg/d), final weight (kg/d), mean daily weight gain (kg/d), food efficiency, food conversion and compensation index (%) as a function of live weight and metabolic weight of pre-puberty Guzerá females submitted to periods of feed restriction and realimentation

Variable	Levels of feed restriction			CV%	p
	0%	20%	40%		
Feed restriction					
Initial live (kg)	270.83	270.33	263.33	6.73	0.0820
Final live (kg)	333.37[a]	308.43[b]	284.00[c]	8.78	0.0325
Average daily gain (kg/dia)	0.776[a]	0.664[ab]	0.607[b]	15.67	0.0435
Feed conversion[1]	12.44[b]	10.73[ab]	8.81[a]	32.96	0.01
Re-alimentation periods					
Final live (kg)	365.43[a]	343.80[a]	329.93[b]	6.24	0.0233
Average daily gain (kg/dia)	0.641[b]	0.707[b]	0.918[a]	17.89	0.0367
Feed conversion[1]	12.99[b]	11.38[ab]	8.72[a]	27.54	0.2318
Compensation em body weight (%)	-	95	94	8.34	0.4098
Compensation em weight $^{0.75}$ (%)	-	96	93	8.13	0.5621

Means followed by the same letter in the same row do not differ statistically by the Tukey test at 5% probability ($p>0.05$).
[1] FC in kg DM/kg ADG.

the more restricted group when in compensatory gain. Food conversion was much better during the realimentation of the animals submitted to restriction, indicating the possibility of manipulating intake for a period to reduce the ratio between weight gain and DM intake in the following period, resulting in a more economic intake without affecting body weight.

Analysis of the compensation index (live weight and weight$^{0.75}$) showed that all the experimental groups presented compensation close to 100% and there was no difference ($p>0.05$) among the restriction levels. Although there was no total compensation, both the feed restriction groups (20 and 40%) presented high compensation rates. According to Ryan (1990), compensation is complete when the gain rate is higher than the compensatory growth and fully compensates for the poorer performance in the restriction period, or partial compensation, where the higher gain rates of the compensation period are not sufficient to recover all that could not be gained in the restriction period.

There was partial compensation in the present experiment for both restrictions (20 and 40%), but only the 40% restriction group presented greater weight gain compared the unrestricted group in the realimentation period, suggesting that these animals had a rapid increase in energy storage or a lower rate of decrease in lost energy after realimentation.

The compensatory growth effect on nitrogen metabolism has been observed in several studies (Ford and Park 2001; Ruiz et al., 2002; Valkeners et al., 2004; Yan et al., 2007). In the present study, it was observed that the intake, urinary and fecal excretion, nitrogen balance and microbial nitrogen decreased ($p<0.05$) with the restriction levels applied in the feed restriction period (Table 6).

N intake (g/d) decreased ($p<0.05$) with the restriction levels because the restriction was as a function of dry matter intake. The decrease in dry matter and nitrogen intake may negatively influence the flows of dietary and microbial N (Yan et al., 2007).

Nitrogen excretion in the urine and feces was greater ($p<0.05$) in the animals fed freely and decreased with restriction intensity, a fact related to the magnitude of nitrogen intake. According to Yan et al. (2007) nitrogen excretion in the feces and urine is directly related to the crude protein concentration in the diet and to nitrogen ingestion by the animal and one of the most effective strategies to reduce nitrogen excretion is to manipulate its dietary concentration. Therefore, feed restriction may be an efficient tool to reduce N elimination in the feces and urine that does not harm the animal's performance.

Mean N urinary excretion compared to the respective mean intake was similar among the groups and totaled 10.05%, 10.00% and 9.7% in the control, 20% and 40% feed restriction groups, respectively. The values were also similar in the feces and ranged from 49.91 in the groups where the restriction was most severe (40%) and 51.05% in the 20% restriction group.

The nitrogen balance decreased ($p<0.05$) with the restriction levels applied, where the animals with feed restricted by 40% presented the smallest values. A positive nitrogen balance was an indication that protein was retained in the animal, resulting conditions in which there was no weight loss in the experimental animals. (Zanton and

Table 6. Means, coefficients of variation (CV) and probability (P) of ingested nitrogen compounds, fecal and urinary excretion, N balance and microbial nitrogen compounds (Nmic) in Guzerá females as a function of the restriction levels and realimentation growth periods

Parameters	Levels of feed restriction			CV%	p
	0%	20%	40%		
Feed restriction					
Ingested nitrogen (g/d)	837.50[a]	718.75[b]	537.50[c]	29.25	<0.0001
Urinary nitrogen (g/d)	84.16[a]	71.87[b]	52.46[c]	19.67	0.0005
Fecal nitrogen (g/d)	419.25[a]	366.92[b]	268.26[c]	21.33	0.0056
Nitrogen balance (g/d)	344.09[a]	279.96[b]	216.78[c]	20.06	0.0047
Retained nitrogen (g/d)[1]	41.08	38.91	40.33	17.55	0.0837
Microbial nitrogen (g/d)	285.99[a]	243.20[b]	169.43[c]	2.54	<0.0001
Re-alimentation periods					
Ingested nitrogen (g/d)	737.50	731.25	712.50	3.79	0.3182
Urinary nitrogen (g/d)	100.3	87.01	104.73	23.12	0.2352
Fecal nitrogen (g/d)	328.92	334.91	321.33	18.29	0.7530
Nitrogen balance (g/d)	308.28	309.33	286.44	17.33	0.5263
Retained nitrogen (g/d)[1]	41.80	42.30	40.19	15.32	0.5691
Microbial nitrogen (g/d)	286.13	293.32	285.27	4.01	0.4133

Means followed by the same letter in the same row do not differ statistically by the Tukey test at 5% probability ($p>0.05$).
[1] Nitrogen balance/Ingested nitrogen.

Heinrichs, 2008). Taylor-Edwards et al. (2009), Pereira et al. (2007) and Valkeners et al. (2004) reported that greater nitrogen compound ingestion resulted in greater N retention in the animal. However, no difference ($p>0.05$) was observed in the N retention of the experimental groups throughout the experiment. Protein retention allows the animals to gain weight when energy requirements are met.

A decrease was observed in microbial N production as a function of the restriction levels ($p<0.05$), where in the highest restriction level (40%) the smallest means ($p<0.05$) were observed. This result may be related to the fact that the animals performed similarly for DM intake (in kg/d). Thus, the animals that ingested more nutrients presented better ruminal organism synthesis. Furthermore, the feed restriction to which the animals were submitted may have resulted in peptide deficiencies and/or amino acid deficiencies for microbial growth. Microbial N production presented maximum values in the control group and minimum values in the group submitted to 40% feed restriction.

The greater nutrient availability resulting from greater ingestion also caused a greater efficiency in microbial protein synthesis, which improved animal performance, because the availability of energy and N in the rumen seems to interact positively with the ingestion level, determining above all greater efficiency in microbial protein synthesis (Firkins et al., 2007).

In the realimentation phase, no effect was observed ($p<0.05$) in relation to the feed restriction levels on the variables which analyzed nitrogen balance. This was expected because the animals ingested the same diet in this phase.

The application of feed restriction decreased food ingestion and consequently the serum levels of nutrients and ammonia N available, but did not damage the microbial microflora, although it resulted in reduced animal performance. However, after starting normal realimentation, the animals subjected to feed restriction presented a more intense growth rhythm than would have occurred if they had had continuous growth. With this, part of the growth that did not take place at the time of restriction was compensated for during the compensatory growth period.

Restricting feed by 40% can be adopted as a nutritional management practice for young Guzerá females in periods of food scarcity, followed by compensatory gain. Animals subjected to 40% restriction had better food conversion and greater weight gain in the compensation period, with 96% and 93% weight compensation for the groups with 20% and 40% restriction, respectively.

REFERENCES

Alves, M., F. González, N. Carvalho, P. Mühlbach, V. Lima, T. R. Conceição and V. Wald. 2004. Feeding dairy cows with soybean by-products: effects on metabolic profile. Ciência Rural, 34(1):239-243.

Amstalden, M., M. R. Garcia, R. L. Stanko, S. E. Nizielski, C. D. Morrison, D. H. Keisler and G. L. Williams. 2002. Central infusion of recombinant ovine leptin normalizes plasma insulin and stimulates a novel hypersecretion of luteinizing hormone after short-term fasting in mature beef cows. Biological Reproduction 66:1555-1561.

Bezerra, L. R. 2006. Performance and metabolic behavior of Santa Inês lambs fed with different concentrations of Spirulina platensis in diluted cow's milk. 173f. Dissertation (Master in Zootechny) - University of Campina Grande, Paraíba.

Chelikani, P. K., J. D. Ambrose, D. H. Keisler and J. J. Kennelly. 2004. Effect of short-term fasting on plasma concentrations of leptin and other hormones and metabolites in dairy cattle. Domest. Anim. Endocrinol. 26:33-48.

Clark, J. H., K. C. Olson, T. B. Schmidt, M. L. Linville, D. O. Alkire, D. L. Meyer, G. K. Rentfrow, C. C. Carr and E. P. Berg. 2007. Effects of dry matter intake restriction on diet digestion, energy partitioning, phosphorus retention, and ruminal fermentation by beef steers. J. Anim. Sci. 85:3383-3390.

Cole, N. A. 2000. Changes in postprandial plasma and extracellular and ruminal fluid volumes in wethers fed or unfed for 72 h. J. Anim. Sci. 78:216-223.

Costa, P. B., A. C. Queiroz, M. T. Rodrigues, A. L. R. Magalhães, M. G. Costa, F. L. B. Toral, T. A. Carvalho, L. Monteiro, K. Zorzi and M. S. Duarte. 2007. Performance of dairy heifers under management compensatory growth supplementation with ionophore. Rev. Bras. Zootec. 36(2): 461-470.

Ford, J. A. Jr. and C. S. Park. 2001. Nutritionally directed compensatory growth enhances heifer development and lactation potential. J. Dairy Sci. 84:1669-1678.

Firkins, J. L., Z. Yu and M. Morrison. 2007. Ruminal nitrogen metabolism: perspectives for integration of microbiology and nutrition for dairy. J. Dairy Sci. 90 (Suppl. 1):E1-16.

Fujihara, T., E. R. Orskov and P. J. Reeds. 1987. The effect of protein infusion on urinary excretion of purine derivatives in ruminants nourished by intragastric nutrition. J. Agric. Sci. 109:7-12.

Herdt, H. H. 2000. The veterinary clinics of North America: food animal practice. 16(2):408.

Hoch, T., C. Begon, I. Cassar-malek, B. Picard and I. Savary-auzeloux. 2003. Mécanismes et conséquences de la croissance compensatrice chez lês ruminants. INRA Productions Animales 16(1):49-59.

Lôbo, R. N. B., V. M. Penna and F. E. Madalena. 2000. Breeding program evaluation for dual purpose zebu cattle. Revista Brasileira de Zootecnia, 29(5) :1349-1360.

Mcdowell, L. R. 1999. Minerals for grazing ruminants in tropical regions, with emphasis on Brazil. Flórida: University of Florida, 93 p. (Boletim, 3).

Mertens, D. R. 2001. Physical effective NDF and Its Use in Formulating dairy rations. In: INTERNATIONAL SYMPOSIUM ON DAIRY CATTLE, 2, 2001, Florida Dairy Extension, Florida: University of Florida, p. 25-36.

National Research Council (NRC). 1996. Nutrient requirement of dairy cattle. Washington: National Academy of Science, 242.

Pereira, K. P., A. S. C. V. Véras, M. A. Ferreira, A. M. V. Batista,

K. A. Marques and A. C. A. Fotius. 2007. Nitrogen balance and endogenous losses in cattle and buffaloes fed with increasing levels of concentrate. Acta Scientiarum Animal Science 29(4):433-440.

Ruiz, R., L. O. Tedeschi, J. C. Marini, D. G. Fox, A. N. Pell, G. Jarvis and J. B. Russel. 2002. The effect of a ruminal nitrogen (N) deficiency in dairy cows: evaluation of the cornell net carbohydrate and protein system ruminal n deficiency adjustment. J. Dairy Sci. 85:2986-2999.

Ryan, W. J., I. H. Williams and R. J. Moir. 1993. Compensatory growth in sheep and cattle. Growth pattern and feed intake. Aust. J. Agric. Res. Perth, 44:1609-1621.

Ryan, W. J. 1990. Compensatory growth in cattle and sheep. In: Nutrition abstracts and reviews (Series B), 50:653-664.

Silva, D. J. and A. C. Queiroz. 2002. Food analysis (chemical and biological). 3.ed. Viçosa, MG: Universidade Federal de Viçosa, p. 235.

Statistical Analysis System (SAS). 2000. Version 8.12 SAS, INC. Cany, NC, USA, 2000.

Taylor-edwards, C. C., N. A. Elam, S. E. Kitts, K. R. Mc leod, D. E. Axe, E. S. Vanzant, N. B. Kristensen and D. L. Harmon. 2009. Influence of slow-release urea on nitrogen balance and portal-drained visceral nutrient flux in beef steers. J. Anim. Sci. 7:209-221.

Taylor, M. S., K. T. Knowlton, M. L. Mcgilliard, W. M. Seymour and J. H. Herbein. 2008. Blood mineral, hormone, and osteocalcin responses of multiparous jersey cows to an oral dose of 25-hydroxyvitamin d3 or vitamin d3 before parturition. J. Dairy Sci. 91:2408-2416.

Tolla, N., T. Mirkena and L. A. Yimegnuha. 2003. Effect of feed restriction on compensatory growth of Arsi (*Bos indicus*) bulls. Anim. Feed Sci. Technol. 103:29-39.

Valadares, R. F. D., G. A. Broderick, S. C. Valadares Filho and M. K. Clayton. 1999. Effect of replacing alfafa silage with high moisture corn on ruminal protein synthesis estimated from excretion of total purine derivatives. J. Dairy Sci. 82(12): 2686-2696.

Valkeners, D., A. Théwis, F. Piron and Y. Beckers. 2004. Effect of imbalance between energy and nitrogen supplies on microbial protein synthesis and nitrogen metabolism in growing double-muscled Belgian Blue bulls. J. Anim. Sci. 82:1818-1825.

Verbic, J., X. B. Chen and N. A. Macleod. 1990. Excretion of purine derivatives by ruminants. Effect of microbial nucleic acid infusion on purine derivative excretion by steers. J. Agric. Sci. 114:243-248.

Weiss, W. P. 1999. Energy prediction equations for ruminant feeds. In: CORNELL NUTRITION CONFERENCE FOR FEED MANUFACTURERS, 61, 1999, Ithaca. Proceedings... Ithaca: Cornell University, 1999, p. 176-185.

Wilson, P. N. and D. F. Osbourn. 1960. Compensatory growth after under nutrition in mammals and birds. Biological Reviews 35(3):324-363.

Yan, T., J. P. Frost. and T. W. J. Keady. 2007. Prediction of nitrogen excretion in feces and urine of beef cattle offered diets containing grass silage. J. Anim. Sci. 85:1982-1989.

Zanton, G. I. and A. J. Heinrichs. 2008. Analysis of nitrogen utilization and excretion in growing dairy cattle. J. Dairy Sci. 91(4):p.1519-1533.