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Performance of crossbred Holstein x Gyr dairy cows, with and without energy supplementation, in BRS Kurumi elephant grass pastures

Desempenho de vacas Holandês x Gir, com e sem suplementação energética, em pastagem de capim-elefante BRS Kurumi

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Highlights

A daily supply of 3 kg of ground corn per cow reduced the pasture DM intake by 23.4%.
Energy supplementation increased the milk yield by 11.8%.
Energy supplementation increased the efficiency in the use of dietary nitrogen.

Abstract

This study evaluated the effect of energy supplementation with ground corn on the performance of crossbred dairy cows in BRS Kurumi elephant grass pastures managed under rotational stocking during the rainy season. Six Holstein × Gyr cows were used, with average milk production, body weight, body condition score, and days in milk of 18.0±2.89 kg day^{-1}, 560±66 kg, 2.50±0.21, and 99±12, respectively. The experimental design used was the complete reversion (switchback), and the evaluations were conducted over three grazing cycles, with adaptation periods of 14 days and six days of sample collection. The concentrate supplement (ground corn) was supplied twice a day, at a rate of 2 kg cow^{-1} day^{-1} in the morning and 1 kg cow^{-1} day^{-1} in the afternoon (as-fed basis). A reduction of 23.4% was observed in the pasture dry matter (DM) intake (PDMI) in cows that received energy supplementation, which corresponds to 2.96 kg day^{-1} less of PDMI when compared to the group without supplementation. This corresponds to a substitution rate of 1.1 kg of pasture per kg of concentrate consumed (DM basis), which reduced the intake (kg cow^{-1} day^{-1}) of neutral detergent fiber and crude protein by 18.9% and 13.9% in the cows that received ground corn. There were increases of 11.8%, 9.0%, and 10.1%, respectively, in the milk yield, the

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3.5% fat-corrected milk yield, and the energy-corrected milk yield of the cows that received ground corn. The response to supplementation in kg of milk per kg of DM of concentrate consumed was 0.57, and the milk contents of fat, protein, and lactose did not differ between treatments. The energy supplementation with 3 kg cow^{-1} day^{-1} of ground corn resulted in an increase of 11.8% in the milk yield of Holstein × Gyr dairy cows grazed on BRS Kurumi elephant grass, as well as promoted increases in the daily protein, lactose, and total solids yields. In addition, the provision of 3 kg day^{-1} of ground corn for lactating cows grazing on BRS Kurumi increased the efficiency in the use of dietary nitrogen.
Key words: Crude protein. Dry matter intake. Milk production. *Pennisetum purpureum.* Rotational stocking. Tropical forage.

Resumo

O objetivo do estudo foi avaliar o efeito da suplementação energética com milho moído sobre o desempenho de vacas em pastagem de capim-elefante BRS Kurumi manejado sob lotação rotacionada durante o período chuvoso. Foram utilizadas seis vacas Holandês x Gir, com produção média de leite, peso corporal, escore de condição corporal e dias em lactação de 18,0±2,89 kg dia^{-1}, 560±66 kg, 2,50±0,21 e 99±12, respectivamente. O delineamento experimental utilizado foi o de reversão completa (switchback) e as avaliações foram realizadas durante três ciclos de pastejo, com períodos de adaptação de 14 dias, e seis dias de coletas de amostras. O suplemento concentrado (milho moído) foi fornecido duas vezes ao dia, à razão de 2 kg vaca^{-1} dia^{-1} pela manhã e 1 kg vaca^{-1} dia^{-1} à tarde (base da matéria natural). Observou-se redução de 23,4% no consumo de matéria seca (MS) de pasto nas vacas que receberam a suplementação energética, o que corresponde a menos 2,96 kg de MS de forragem dia^{-1}, quando comparado ao grupo sem suplementação. Isto corresponde a uma taxa de substituição de 1,1 kg de pasto por kg de concentrado consumido (base da MS), o que reduziu o consumo (kg vaca^{-1} dia^{-1}) de fibra em detergente neutro e proteína bruta em 18,9% e 13,9%, respectivamente, nas vacas que receberam milho moído. Foram observados aumentos de 11,8%, 9,0% e 10,1%, respectivamente, na produção de leite (PL), PL corrigida para 3,5% de gordura e PL corrigida para energia das vacas que receberam milho moído. A resposta à suplementação em kg de leite por kg de MS de concentrado consumido foi de 0,57, e os teores de gordura, proteína e lactose não diferiram entre tratamentos. A suplementação energética com 3 kg dia^{-1} de milho moído promoveu incremento de 11,8% na produção de leite de vacas Holandês x Gir em pastejo de capim-elefante BRS Kurumi, bem como aumento nas produções diárias de proteína, lactose e sólidos totais. Além disso, o fornecimento de 3 kg dia^{-1} de milho moído para vacas em lactação em pastejo de BRS Kurumi aumentou a eficiência na utilização do nitrogênio da dieta.
Palavras-chave: Consumo de matéria seca. Forrageira tropical. Lotação rotacionada. *Pennisetum purpureum.* Produção de leite. Proteína bruta.

Introduction

In Brazil, dairy farming is an activity that supports thousands of families and occurs in almost all the municipalities in the country. Brazilian milk production is based mainly on the use of pastures, which occupy approximately 160 million hectares (Parente & Ferreira, 2018).

Properly managed pastures are the least expensive source of nutrients on a dairy farm, and the aim of the pasture-based milk production system should be to optimize the use of pastures in the diet of lactating cows (Hills, Wales, Dunshea, Garcia, & Roche, 2015). The efficiency of this type of milk production system depends on the genetics of the herd and the nutritional value of the forage, which is higher when genetically improved forage is used. This use is associated with the correct management of the pastures. The main advantage of milk production in intensive pasture-based systems is the low cost of feeding the herd compared to systems based on the use of large amounts of concentrate supplements and roughage preserved in the form of silage and hay. In addition, there is less demand for labor since the forage is harvested by the animal itself (Clark et al., 2016).

Intensive pasture management results in forage with high levels of crude protein (CP), resulting from high doses of nitrogen fertilizers and short pasture defoliation intervals (Pontes et al., 2017). In this scenario, energy becomes the main limiting factor for milk production (Hills et al., 2015). The excess of dietary CP can cause a reduction in the energy available for milk yield due to the energy expenditure to eliminate ammonia N via urea synthesis and represent an increase in financial costs due to concentrate supplementation. When intensively managed tropical grasses have CP contents ranging from 15 to 21% dry matter (DM), it is only necessary to use energy supplements in order to meet the nutritional requirements of cows producing 20 kg day^{-1} of milk (Danes, Chagas, Pedroso, & Santos, 2013). Therefore, energy supplementation in intensive pasture-based milk production systems becomes an important strategy to both mitigate the protein–energy imbalance in the rumen and meet the nutritional requirements of the cows.

The elephant grass [*Cenchrus purpureus* (Schumach.) Morrone (syn. *Pennisetum purpureum* Schumach.)] cultivar BRS Kurumi was launched by Embrapa Dairy Cattle (Juiz de Fora, MG, Brazil) in 2012 as an alternative to improve pasture-based milk production systems. The resulting improvement is mainly due to the excellent structure of this grass, which has a high proportion of leaves and small elongation of the stems (Pereira, Lédo, & Machado, 2017). In addition, BRS Kurumi stands out for its high nutritional value, with high levels of CP, total digestible nutrients (TDN), and high digestibility (Gomide et al., 2015). Positive results on the performance of dairy heifers managed in BRS Kurumi have been reported by Paciullo et al. (2015). However, there is no information on the productive performance of lactating cows grazing in BRS Kurumi pastures. In addition, there is a scarcity of studies in the literature regarding the use of energy supplementation in tropical pastures intensively managed during the rainy season of the year.

Therefore, this study aimed to evaluate the effect of energy supplementation on the performance of lactating Holstein × Gyr dairy cows grazing on BRS Kurumi elephant grass, managed under rotational stocking during the rainy season.

Material and Methods

The study was carried out in approximately three hectares at the Campo Experimental José Henrique Bruschi, belonging to Embrapa Dairy Cattle, located in the municipality of Coronel Pacheco, Minas Gerais, Brazil. The climate of the region, according to the Köppen classification, is of the Cwa type (mesothermal), with a well-defined hot/rainy season (spring–summer) from October to March and a cold/dry season (autumn–winter) from April to September. The geographical coordinates are 21° 33′ S and 43° 16′ W, and the average altitude is 435 m.

The soil in the experimental area had the following chemical characteristics in the layer from 0 to 20 cm depth: pH in water = 5.7; organic matter = 1.8%; phosphorus = 10.45 mg dm^{-3}; potassium = 171 mg dm^{-3}; calcium = 2.7 cmolc dm^{-3}; magnesium = 1.4 cmolc dm^{-3}; hydrogen + aluminum = 0.2 cmolc dm^{-3}; and base saturation = 52%.

BRS Kurumi seedlings were planted in March 2018 in 70-cm spaced furrows. Liming was performed to increase the base saturation of the soil to 60%. Phosphate fertilization was carried out at the bottom of the planting furrow, with a dose of 100 kg ha^{-1} of P_2O_5. Forty days after planting the seedlings, fertilization was carried out with 40 kg ha^{-1} of N and K_2O. The pasture maintenance fertilization was carried out after the cows had left the grazed paddock, with the application of 220 kg ha^{-1} of NPK 20-05-20 in each grazing cycle.

The Ethics Commission on Animal Use of Embrapa Dairy Cattle approved the experimental procedures used (CEUA Protocol n. 2636081118). A switchback design with two treatments (with and without energy supplementation) and six 1/2 to 7/8 Holstein × Gyr dairy cows after the peak of lactation were used. At the beginning of the study, the average milk yield, body weight (BW), body condition score (BCS), and days in milk of the cows were 18.0±2.89 kg day^{-1}, 560±66 kg, 2.50±0.21, and 99±12, respectively. The evaluations were carried out during three grazing cycles, with adaptation periods of 14 days and six days of sample collections.

The energy concentrate (ground corn) contained levels of DM, CP, ether extract (EE), and TDN of 87.5%, 7.3%, 5.1%, and 85%, respectively. The supplement was provided twice a day (during milking), with 2 kg cow^{-1} day^{-1} in the morning and 1 kg cow^{-1} day^{-1} in the afternoon (as-fed basis), in order to reduce the dietary energy–protein imbalance and also to meet the energy requirements of the cows (National Research Council [NRC], 2001). The cows had access to a drinking fountain with water and a trough with a mineral mixture.

Performance assessments were carried out based on the variables: nutrient intake, milk yield (kg cow^{-1} day^{-1}), and its composition in fat, protein, lactose, total solids, and urea nitrogen. The fat-corrected (3.5%) milk (FCM) yield was calculated according to the equation: (0.432 + 0.1625 × % milk fat) × kilograms of milk (Sklan, Ashkenazi, Braun, Devorin, & Tabori, 1992), and the energy-corrected milk (ECM) yield was calculated by the formula: [(0.327 × milk yield, kg) + (12.95 × fat yield, kg) + (7.20 × protein yield, kg)] (Li, Chang, Liu, Shan, & Li, 2014).

Twenty-nine paddocks of approximately 900 m² were used, with ten paddocks for each treatment, in addition to nine reserve paddocks. The grazing method used was rotational stocking, with two days of paddock occupation and a variable grazing rest period, based on assessments previously carried out on BRS Kurumi pastures (Chaves et al., 2013). The resting period of the pasture corresponded to the time necessary for the canopy to reach 80 cm in height (pre-grazing), which was 18 days, and the height of the residue corresponded to 50% of the entrance height, therefore, 40 cm. According to the management targets (residue height), the stocking adjustment was done using the put-and-take stocking technique (Allen et al., 2011), with extra animals with BW and genetic composition similar to the animal testers.

The cows were mechanically milked twice a day (07h00 and 14h00). In each phase of the switchback, records of milk yield were made during the six days of feces collection and used to estimate the pasture DM intake (PDMI). In the first three days of this period, individual milk samples (30 mL) from the morning and afternoon milking (2/3 at morning milking + 1/3 at afternoon milking) were collected in bottles containing the preservative bronopol and sent to the Milk Quality Laboratory of Embrapa Dairy Cattle (Juiz de Fora, MG), for the determination of the protein, fat, lactose, total solids, and urea nitrogen contents.

The canopy height was determined using a ruler graduated in centimeters, with 30 random points per paddock, under pre- and post-grazing conditions. The height of each point corresponded to the average height of the canopy around the ruler.

The total forage mass in the pre- and post-grazing conditions was estimated using the direct (destructive) method. For this, a 1 m × 1 m square metal frame was used, randomly placed in three points per paddock, which were taken as representative of the average height of the canopy. The forage contained in each square was cut close to the ground and taken to the laboratory. For the evaluation of the morphological components of the forage, a sub-sample (~1 kg) representative of the samples collected was used to determine the total forage mass in the pre- and post-grazing. This subsample was separated into fractions containing leaf blades, stems (stem + sheath), and dead material, which were weighed and pre-dried in a forced air circulation oven, regulated at 55 °C until a constant weight was reached. The forage mass values were converted to kg ha^{-1} of DM. Based on the information regarding the forage biomass, the BW of the cows, and the PDMI, the stocking rate of the pasture was determined based on the number of tester animals grazing in each cycle, plus the extra cows, which eventually were used. The data obtained from these evaluations are compiled in Table 1. From the forage samples collected in each grazing cycle, the removal of forage by the animals was calculated. The difference between the pre-grazing forage mass and the post-grazing forage mass was considered to be removal.

Table 1
Stocking rate and morphological composition of pasture samples from BRS Kurumi, obtained in paddocks with cows receiving 0 or 3 kg day^{-1} of ground corn

Item	Ground corn (kg cow^{-1} day^{-1})		Standard error of the mean
	0	3	
Dry matter (DM) in pre-grazing, kg ha^{-1}	4,709	4,717	182.71
DM in post-grazing, kg ha^{-1}	2,115	1,934	75.58
Removal of pasture DM, kg ha^{-1}	2,593	2,783	128.45
Leaf DM, kg ha^{-1}	2,771	2,810	113.14
Stem DM, kg ha^{-1}	1,658	1,481	123.53
Dead material DM, kg ha^{-1}	296	292	78.2780
Leaf: stem ratio	1.7	1.9	0.0916
Forage height (pre-grazing), cm	81.5	81.6	0.8502
Forage height (post-grazing), cm	42.9	42.2	0.7185
Stocking rate, AU ha^{-1}	9.0	9.0	-

To determine the chemical composition of the pasture, sampling was performed using the simulated grazing technique for obtaining a representative sample of the fraction potentially ingested by the cow, collected above the residue height (50% of the pre-grazing height). Samples of the energy supplement (ground corn) were collected weekly. After collection, the forage and ground corn samples were pre-dried in a forced ventilation oven (55 °C) until a constant weight was reached, milled (to 1 mm), stored in properly identified bottles, and analyzed for DM at 105 °C, EE, and mineral matter according to Detmann et al. (2012). The contents of neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin were determined according to the INCT-CA F-001/1, INCT-CA F-003/1, and INCT-CA F-005/1 methods, respectively (Detmann et al., 2012). TDN was estimated according to the NRC (2001), where $TDN = NFC_d + CP_d + (FA_d \times 2.25) + NDF_{dn} - 7$, with the value of 7 corresponding to the metabolic fecal TDN; NFCd = digestible non-fibrous carbohydrates; CP_d = digestible CP; FA_d = digestible fatty acids; and NDF_{dn} = NDF corrected for digestible nitrogen. The *in vitro* DM digestibility (IVDMD) was also determined (Tilley & Terry, 1963). The chemical composition of the forage is shown in Table 2.

For the determination of the nitrogen fractions, analyses were performed according to Sniffen, O'Connor, Van Soest, Fox and Russell (1992). The N analyses were performed using the INCT-CA N-001/1 method (Detmann et al., 2012), and a correction factor of 6.25 was used for the conversion to CP.

The PDMI was estimated for the three grazing cycles using the external marker titanium dioxide (TiO_2) associated with the pasture and ground corn IVDMD. TiO_2 was administered orally to the cows immediately before milking, for 12 consecutive days, in two daily doses of 5 g each. The first 6 days served to establish a constant level of TiO_2 in the feces, while the remainder were used for the collection of feces. The samples of feces were pre-dried in a forced ventilation oven (55 °C, until a constant weight was reached), milled (1 mm), and subjected to acid digestion with 15 mL of sulfuric acid, followed by the addition of 10 mL of hydrogen peroxide (H_2O_2) 30% v/v and subsequent quantification of the TiO_2 content by spectrophotometry, according to the INCT-CA M-007/1 method (Detmann et al., 2012).

Table 2
Chemical composition of BRS Kurumi pasture samples, obtained in paddocks with cows receiving 0 or 3 kg day^{-1} of ground corn

Item	Ground corn (kg cow^{-1} day^{-1})		Standard error of the mean
	0	3	
Dry matter (DM), %	12.3	12.4	0.2463
In vitro DM digestibility, %	83.2	81.6	0.6583
Mineral matter, % DM	15.1	14.8	0.3079
Neutral detergent fiber, % DM	58.3	58.8	0.4266
Acid detergent fiber, % DM	31.3	31.6	0.3464
Lignin, % DM	2.56	2.47	0.0595
Crude protein, % DM	19.09	18.97	0.4216
Fraction B1 + A, % DM	5.25	5.21	0.1583
Fraction B2, % DM	7.85	7.59	0.2058
Fraction B3, % DM	5.34	5.40	0.2467
Fraction C, % DM	0.91	0.85	0.0438
Total carbohydrates, % DM	62.19	62.58	0.5864
Non-fibrous carbohydrates, % DM	10.16	10.05	0.2941
Total digestible nutrients, %	64.70	65.02	0.5044

Fecal DM production (FP, kg cow^{-1} day^{-1}) was calculated using the formula: FP = marker administered (g day^{-1})/marker in the fecal DM (g kg^{-1}). The PDMI was estimated using the formula: PDMI (kg cow^{-1} day^{-1}) = $((FP - FP_{concentrate})/(1{,}000 - IVDMD_{pasture}))/1{,}000$; where: $FP_{concentrate}$ (fecal production regarding the consumption of the ground corn, kg cow^{-1} day^{-1}) = concentrate DM intake*$(1{,}000 - IVDMD_{concentrate})/1{,}000$; where $IVDMD_{pasture}$ and $IVDMD_{concentrate}$ = IVDMD (g kg^{-1}) of the pasture and the ground corn, respectively.

The data were submitted to analysis to verify the distribution of the normality of the residues (Shapiro–Wilk, P<0.10). Subsequently, the original or transformed data (when necessary) were analyzed by mixed models using the MIXED procedure of SAS version 9.0. The supplementation level (0 and 3 kg cow day^{-1} of corn ground), period and sequence were considered as fixed effects, while the repetition (cow) nested to sequence, and the experimental error were considered random effects. The results are reported as least squares means. Significant differences were declared at P≤0.05, and P-values from 0.05<P≤0.10 were considered a tendency.

Results and Discussion

The PDMI, expressed in kg cow^{-1} day^{-1} or as a percentage of body weight (g 100 g^{-1} BW), did not differ (P>0.05) between treatments (Table 3), indicating a possible physiological response of cows to regulated DM intake (DMI), considering that the NDF content in the pasture (Table 2) would not limit the forage intake through ruminal repletion in theory. However, there was a significant difference (P=0.0005) for PDMI, which was 23.4% lower in cows that received energy supplementation, which corresponds to 2.96 kg day^{-1} less PDMI when compared to the group without supplementation (Table 3). This corresponds to a substitution rate of 1.1 kg of pasture per kg of concentrate consumed (DM basis). According to Hills et al. (2015), the higher the PDMI, the higher the substitution rate in cows receiving concentrate supplementation, the lower the increase in total DMI, and in the marginal response of milk yield to the concentrate supplement. Due to this substitutive effect, the intake of the ground corn reduced the intake of NDF (Table 3), expressed in kg cow^{-1} day^{-1} and g 100 g^{-1} BW by 18.9% (P=0.0016) and 19.5% (P=0.0060). Cows that received ground corn also ingested 13.9% less CP (Table 3) than those grazing exclusively (P=0.0275). Due to the substitution rate, the intake of these nutrients was reduced without changing the total DMI. However, there was no difference (P>0.05) in the TDN intake (Table 3) due to the low level of supplementation, which offset the differences in TDN levels between the BRS Kurumi pasture (Table 2) and the supplement.

Table 3
Nutrient intake, body weight change, and body condition score (BCS) of Holstein × Gyr cows under grazing in BRS Kurumi elephant grass, receiving 0 or 3 kg day^{-1} of ground corn

Item	Ground corn (kg cow^{-1} day^{-1})		Standard error of the mean	P-value
	0	3		
Nutrient intake from pasture + concentrate supplement (kg cow^{-1} day^{-1})				
Dry matter (DM)	12.63	12.37	0.6366	0.6924
Neutral detergent fiber (NDF)	7.35	5.96	0.3494	0.0016
Crude protein	2.38	2.05	0.1319	0.0275
Ether extract	0.50	0.47	0.0255	0.3140
Total digestible nutrients	8.18	8.84	0.5837	0.2850
DM intake from pasture	12.63	9.67	0.6366	0.0005
Nutrient intake from pasture + concentrate supplement (g 100 g^{-1} of body weight)				
DM	2.28	2.23	0.1328	0.7063
NDF	1.33	1.07	0.0713	0.0060
Body condition				
Body weight change, kg	-7.65	2.1	4.6197	0.0640
BCS change	-0.13	0.02	0.0807	0.0939

There was a tendency toward reduced BW (P=0.0640) and BCS (P=0.0939) for cows that did not receive a concentrate supplement, which indicates that there was a greater mobilization of body reserves in these cows to maintain milk production (Table 3). According to Hills et al. (2015), when the energy requirement is greater than the energy supply, the rate of lipolysis exceeds that of lipogenesis, and consequently, the cow loses BW, and their BCS decreases.

The treatments affected milk yield (P=0.0009), with an 11.8% higher production for cows that received concentrate supplementation (Table 4). Concentrate supplementation also affected the 3.5% FCM yield (P=0.0188) and the ECM yield (P=0.0081), with increments of 9.0% and 10.1%, respectively, for cows that received concentrate supplementation. The response to concentrate supplementation in kg of milk produced per kg of concentrate consumed was 0.57. According to Hills et al. (2015), supplying concentrate supplements to grazing dairy cows increases milk production and its constituents, but the magnitude of this response depends on the substitution rate. The higher the substitution rate, the lower the milk production response, mainly due to the reduction in the intake of nutrients from the pasture. This explains, at least in part, the value of 0.57 for the substitution rate observed in the present study. However, this value is similar to that of 0.5 presented by Macedo, Batistel, Souza, Chagas and Santos (2016) in a study with Jersey × Holstein cows grazing on elephant grass cv. Cameroon.

Table 4
Milk yield and composition of Holstein × Gyr cows grazing on BRS Kurumi elephant grass, receiving 0 or 3 kg day^{-1} of ground corn

Item	Ground corn (kg cow^{-1} day^{-1})		Standard error of the mean	P-value
	0	3		
Yield (kg cow^{-1} day^{-1})				
Milk	12.7	14.2	0.3116	0.0009
3.5% fat-corrected milk[a] (FCM)	13.3	14.5	0.4102	0.0188
Energy-corrected milk[b] (ECM)	12.9	14.2	0.3822	0.0081
Fat	0.483	0.514	0.0182	0.1227
Protein	0.369	0.425	0.0100	0.0003
Lactose	0.561	0.639	0.0172	0.0014
Total solids	1.527	1.709	0.0458	0.0016
NE_L[c] (Mcal day^{-1})	8.78	9.69	0.2753	0.0092
Composition				
Fat (%)	3.81	3.63	0.0901	0.0769
Protein (%)	2.93	3.00	0.0385	0.1092
Lactose (%)	4.42	4.48	0.0307	0.0861
Total solids (%)	12.05	12.01	0.1150	0.7308
Milk urea nitrogen (mg dL^{-1})	19.5	13.7	0.8499	<0.0001
NE_L[d] (Mcal kg^{-1} of milk)	0.69	0.68	0.0092	0.2780

[a](0.432 + 0.1625 × % milk fat) × kilograms of milk (Sklan et al., 1992); [b][0.327 × milk yield (kg) + 12.95 × fat yield (kg) + 7.20 × protein yield (kg)] (Li et al., 2014); [c]Net energy for lactation (Mcal kg^{-1} of milk) × milk yield; [d](0.0929 × Fat % + 0.0547 × Crude Protein % + 0.0395 × Lactose%) (NRC, 2001).

The intake of CP and TDN (Table 3) observed for cows that received concentrated supplementation would allow the milk yield of 19.81 kg cow^{-1} day^{-1} and 15.70 kg cow^{-1} day^{-1}, respectively, showing that energy was the main limiting factor in the milk production of cows grazing on elephant grass BRS Kurumi. These results corroborate the statement by Higgs, Sheahan, Mandok, Van Amburgh and Roche (2013), who mentioned that in pasture-based systems with low levels of supplementation, energy is the most limiting factor for milk production. As it reduced the PDMI due to the substitution rate, energy supplementation also reduced the intake of energy from forage, which meant that the milk production of cows that received concentrate supplements did not reach 15 kg cow^{-1} day^{-1}.

The increase in milk production in cows that received concentrate supplement (Table 4) compared to those that did not receive it may be related to the better energy: protein ratio in the rumen established by energy supplementation. Although cows from treatment with concentrate supplementation consumed the same amount of energy (TDN) in relation to those that did not receive supplementation, there was less intake of

CP (Table 3) and, consequently, less nitrogen intake. Therefore, these cows probably expended less energy on converting ammonia N to urea in the liver, which allowed a greater supply of energy for milk production (Danes et al., 2013). According to these authors, high dietary CP contents reduce the metabolizable energy available for milk production, mainly due to the higher energy cost for urea synthesis and excretion. The higher intake of CP in cows that did not receive concentrate supplementation, associated with low energy intake (Table 3), a common characteristic in cows grazing in tropical pastures, may be related to the lower efficiency of N use by these cows (Danes et al., 2013), as well as the lower availability of energy for milk production. The lower intake of CP (Table 3) associated with the higher production of protein in the milk of cows that received ground corn (Table 4) indicates that there may have been a reduction in the excretion of N and, consequently, better efficiency in the use of this nutrient. This is supported by lower concentrations of urea nitrogen in the milk (P<0.0001; Table 4) and in the plasma (P=0.0501; Table 5).

Table 5
Glucose and urea nitrogen concentrations in the plasma of Holstein × Gyr lactating cows grazing on BRS Kurumi elephant grass, receiving 0 or 3 kg day^{-1} of ground corn

Item	Ground corn (kg cow^{-1} day^{-1})		Standard error of the mean	P-value
	0	3		
Glucose, mg dL^{-1}	61.0	58.9	1.3649	0.1536
Urea nitrogen, mg dL^{-1}	42.0	36.6	2.4113	0.0501

The estimated CP content for the diet of cows that did not receive concentrated supplementation was approximately 19% DM. According to Danes et al. (2013), dietary CP levels above 18% in the pasture exceed the levels of requirement for metabolizable protein in the rumen. The high CP content associated with the low NFC content in well-managed tropical pastures causes an imbalance between the availability of energy and protein in the rumen, emphasizing the importance of supplementation with energy concentrates in these milk production systems (Danes et al., 2013). There was no treatment effect (P=0.1092) on the milk protein content. The cows that received ground corn showed a tendency (P=0.0769) for lower milk fat content, with a reduction of 4.7% relative to that of cows that did not receive concentrate supplementation. Further, there was a tendency (P=0.0861) for higher lactose content in the milk of the cows that consumed ground corn (Table 4).

The treatments did not affect milk fat yield (P>0.05). This can be partially explained by the trend (P=0.0769) toward lower fat content in the milk of cows that received concentrate supplementation, making the greater volume of milk produced by these cows compensation for the reduction in milk fat content.

In contrast, the cows treated with concentrate supplementation showed increases of 13.9% and 15.2% in the milk yield of lactose and protein, respectively. This can be partially explained by the higher (P=0.0009) milk yield of the cows that received concentrate supplementation (Table 4). Lactose synthesis is dependent on glycogenic substrates, such as propionate (Hills et al., 2015). Therefore, changes in glucose metabolism are reflected in the milk lactose yield (Bryant, Dalley, Gibbs, & Edwards, 2014). In the present study, concentrate supplementation did not affect (P>0.05) the plasmatic concentrations of glucose (Table 5). This partially explains the absence of an effect (P=0.0861) due to the concentrate supplementation on milk lactose content (Table 4).

There was no effect on the milk total solids content (P>0.05), but there was a difference in the milk total solids yield, which was 11.9% higher (P=0.0016) for the cows that received concentrate supplementation (Table 4).

The net energy for lactation (NEL) content in milk (Mcal kg^{-1} of milk) did not differ (P>0.05) between treatments, while the milk NEL yield (Mcal day^{-1}) was 10.4% higher (P=0.0092) in the milk of cows that received concentrated supplementation.

Conclusions

The energy supplementation with 3 kg cow^{-1} day^{-1} of ground corn resulted in an increase of 11.8% in the milk yield of Holstein × Gyr dairy cows grazed on BRS Kurumi elephant grass, as well as promoted increases in the daily protein, lactose, and total solids yields. In addition, the provision of 3 kg day^{-1} of ground corn for lactating cows grazing on BRS Kurumi increased the efficiency in the use of dietary nitrogen.

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