Tropical Animal Health and Production (2018) 50:1771–1777
https://doi.org/10.1007/s11250-018-1617-4

REGULAR ARTICLES

Estimation of daily milk yield of Nellore cows grazing tropical pastures

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Received: 28 January 2018 / Accepted: 8 May 2018 / Published online: 28 May 2018

Abstract
Beef cows' milk yield is typically determined by measuring milk yield once daily and then doubling this value to estimate daily production. However, it is not known whether this is accurate. Thus, we aimed to determine the association between morning and afternoon milk yield in grazing Nellore cows. Eighty Nellore cows were used, with initial weight of 516.0 ± 1.0 kg. The experiment was a completely randomized factorial scheme, with 20 replications and four treatments (i.e., + or − pre-partum supplementation in combination with + or − post-partum supplementation): PRMM—1 kg of supplement/cow/day for 90 days pre-partum; MMPS—1 kg of supplement/cow/day for 90 days post-partum; PRPS—1 kg of supplement/cow/day for 90 days pre-partum and 90 days post-partum; and MM—only mineral mix ad libitum during pre- and post-partum. Milk was sampled on days 45, 135, and 225 post-partum (early, middle, and late lactation, respectively). No effects were observed of pre- and post-partum supplementation on milk yield ($P > 0.05$). The afternoon/morning proportion of 0.45 in the early third of lactation was higher than other stages, which had a proportion of 0.41 ($P < 0.05$). Post-partum supplementation increased milk protein in the morning and afternoon milking ($P < 0.05$). There was also no effect of pre- and post-partum supplementation on afternoon-morning proportion other milk components ($P > 0.05$). We conclude that estimating daily milk production of grazing beef cattle by multiplying a once daily milking amount times two is not accurate. Under the conditions of this study, proportion of total daily production represented by the ratio of afternoon/morning milking was 0.45 in early lactation (first third) and 0.41 in mid- and late lactation.

Keywords Animal production · Beef cattle · Milk production · Ruminant nutrition · Supplementation

Introduction

There are several widely used methods to estimate milk yield of beef cows; however, they consider milk yield observed in the afternoon milking is similar to that obtained in the morning. Overestimation of beef cow milk yield affects nutrient requirement determination of their offspring, generating systematic errors in the elaboration of the calf requirements by various committees. Besides that, measuring milk yield can be carried out twice daily when cows are in confinement systems but may not be feasible in a pasture-based system.

Although the methods that measuring milk yield once daily and then doubling this value to estimate the total daily milk yield are accepted (Clements et al. 2017; Restle et al. 2003; Silva et al. 2016), the data found in the literature for milk yield in dairy cows indicate that they do not produce the same amount of milk in the afternoon as in the morning (Rémond et al. 2009).

Thus, we hypothesize that in beef cows, the daily distribution of milk yield follows a similar pattern observed for dairy cows, and milk yield in the morning is different from that in the afternoon. Therefore, as no data were found in the literature on the distribution of beef cow's 24-h milk yield, the objective was to determine the afternoon/morning proportion of milk yield for use in research with lactating Nellore cows in grazing system.

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Material and methods

The experiment was conducted at the Federal University of Viçosa, located in the municipality of Viçosa-MG (20° 45′ S and 42° 52′ W), between July 2013 and June 2014. The seasons were categorized as dry season, dry-rainy season, rainy, and rainy-dry season. The experiment lasted 360 days, starting at 90 days before calving (pre-partum) and 270 days after calving (post-partum). Post-partum data was sub-divided in early (1 to 90 days), middle (91 to 180 days), and late lactation (181 to 270 days).

Eighty Nellore cows (6 months of gestation) with mean initial weight of 516 ± 1.0 kg and initial body condition score of 4.68 ± 0.15 were used. Animals were assigned to an experimental area of 70 ha, consisting of four 17.5-ha paddocks uniformly covered with *Urochloa decumbens* grass. Paddocks were equipped with drinking fountains and troughs, which were covered and accessible from both sides. Animals were continuously stocked such that all four paddocks were stocked with cattle throughout the entire experiment. Specifically, all animals from a given supplement treatment were assigned to one of the 17.5-ha paddocks at all times. Each treatment group of animals was moved sequentially from one paddock to the next every 14 days in an attempt to minimize any effects of different paddock conditions on the response to supplement treatments.

The experimental design was completely randomized, with a factorial arrangement of the four treatments. There were 20 replications per treatment, and an individual cow was considered to be the experimental unit. Supplement for a given treatment was fed in a common feeder in each paddock to represent what is done in commercial practice. The strategies evaluated were PRMM—supplemented with 1 kg of concentrate per head daily for 90 days pre-partum; MMPS—supplemented with 1 kg of concentrate per head daily for 90 days post-partum; PRPS—supplemented with 1 kg of concentrate per head daily for 90 days pre-partum and 90 days post-partum; MM—non-supplemented, received only mineral mix ad libitum during the pre (90 days) and post-partum (90 days). After 90 days post-partum, all animals received only mineral mixture ad libitum until the end of the experiment. The mineral mix was composed of 50% dicalcium phosphate, 47.2% sodium chloride, 1.5% zinc sulphate, 0.7% copper sulphate, 0.05% cobalt sulphate, 0.05% potassium iodate, and 0.5% manganese sulphate. A single supplement containing 28% CP was supplied to cows. Supplement composition was ground corn grain (24.65%), ground sorghum grain (24.65%), soybean meal (45.7%), and mineral mixture (5%).

Milk yield was evaluated on three samplings: early third (at day 45 after calving), middle third (day 135 after calving), and late third (day 225 after calving). Cows and calves were separated at 1400 h. The cows returned to paddock while the calves remained in the cattle shed. At 1700 h, calves were fed for 30 min in order to deplete the milk produced by cows. There was a total emptying of the udders by all calves at the same time. Then they were separated again, with cows released to the paddock. Milking was performed at 0530 h (12-h after calving separation) and at 1730 h on the following day (24-h after calving separation). Cows were immobilized in the squeeze chute. Milking was performed mechanically, and they were milked in the same sequence in both periods. Milk secretion was stimulated with 2 mL of oxytocin (10 UI/mL, Ocitovet ®, Brazil) in the mammary artery, initiating milking immediately after oxytocin administration. After each milking, milk was weighed and duly registered. Three milk samples were taken at the beginning of the experiment to adapt cows to the mechanical milking.

Total milk yield was calculated by summing milk yield of morning and afternoon milking times. Individual samples of 50 mL of homogenized milk from each milking were taken for analyses of protein (MP), fat (MF), lactose (ML), and total solids (TS). Samples were stored at 4 °C in a refrigerator using a bronopol tablet per sample as preservative. Milk samples were analyzed using spectroscopy (Foss MilkoScan FT120, Hillerød, Denmark). The produced milk was corrected to 4% fat, calculated using the following equation: Milk 4% (kg) = 0.4 × (milk production) + [15 × (fat production × milk production/100)] (NRC 2001).

The forage samples were collected every 15 days for evaluation of the forage mass per hectare. At each paddock, four forage samples were randomly selected using a metal square (0.5 × 0.5 m) and cut approximately 1 cm above the ground. Subsequently, the forage samples (200 g) were immediately taken to the oven at 60 °C for 72 h and then weighed.

The forage samples for analysis of the chemical composition (forage quality) were collected at intervals of 30 days by the hand-plucking method, then dried in a forced air circulation stove at 60 °C for 72 h and ground in a knife mill with sieves of 1 and 2 mm. Forage nutritive value samples were grouped per lactation stage: pre-partum (90 days before calving), early third (1 to 90 days), middle third (91 to 180 days), and late third lactation (181 to 270 days).

The supplement and forage samples obtained by the hand-plucking method were quantified with regard to DM (INCT-CA G-003/1), crude protein (CP; INCT-CA N-001/1), ether extract (EE; INCT-CA G-004/1), neutral detergent fiber corrected for ash, and protein (apNDF; INCT-CA F-002/1), using thermostable α-amylase, without using sodium sulfite; nitrogen insoluble in neutral detergent (NDIN; INCT-CA N-004/1) according to Detmann et al. (2012); and iNDF, according to Valente et al. (2011), obtained after in situ incubation in (F57 Ankom®) bags for 288 h.

The pdDM was estimated according to the following equation (Paulino et al. 2008):

$$pdDM = 0.98 \times (100{-}NDF) + (NDF{-}iNDF)$$

Table 1 Chemical composition of the supplement and forage

Item	Supplement	Forage[d]			
		Pre-partum	Early third	Middle third	Late third
Dry matter[a]	887	504	294	297	299
Organic matter[b]	919	920	920	915	912
Crude protein[b]	286	71	98	85	74
NDIN[c]	372	311	257	242	223
Ether extract[b]	25	09	12	18	16
apNDF[b]	156	634	606	664	647
NFC[b]	452	206	204	148	175
iNDF[b]	28	355	217	221	222

NDIN, neutral detergent insoluble nitrogen; *apNDF*, neutral detergent fiber corrected for residual ash and protein; *NFC*, non-fibrous carbohydrates; *iNDF*, indigestible neutral detergent fiber

[a] /In g/kg of natural matter

[b] /In g/kg of dry matter

[c] /In g/kg of total nitrogen

[d] /Mean values of samples obtained by hand-plucking method (every 30 days) within each stage

where NDF = neutral detergent fiber (%); iNDF = indigestible neutral detergent fiber (%); pdDM = potentially digestible dry matter (%); and 0.98 = true digestibility of the cell contents.

Statistical analyses

Data were submitted to analyses of variance, using a completely randomized design, in a 2 × 2 factorial scheme. The factors were supplemented or non-supplemented in the pre-partum (factor 1) and supplemented or non-supplemented in the post-partum (factor 2). In addition, the third of lactation was included in the model as a time-repeated measure. The PROC MIXED procedure of the SAS software (Statistical Analysis System, SAS University Edition) was applied for all statistical analyses. When the effect of lactation thirds was significant, lsmeans were compared using the student's *t* test, using $\alpha = 0.05$ as the critical level of type 1 error probability. The denominator degrees of freedom were calculated using the approximation Kenward-Roger.

Results

The mean availability of total dry matter (TDM) of the *Urochloa decumbens* forage was 4930 and 3980 kg/ha before and after calving (average of early, middle, and late lactation samples), respectively, and the forage pdDM was 3150 and 3090 kg/ha before and after calving, respectively. The *Urochloa decumbens* forage, obtained by hand-plucking, had a mean concentration of 71.0 and 85.7 g of CP/kg dry matter (DM) before and after calving (Table 1), respectively.

There was no effect of pre- and post-partum supplementation, or interaction on milk yield, morning milk yield, afternoon milk yield, afternoon/morning proportion, afternoon/total proportion, and milk yield corrected for 4% fat (MY4F; $P < 0.05$; Table 2). The MY was higher in the early third of lactation (7.2 l/day), followed by the middle third of lactation (5.0 l/day) and, the late third of lactation (4.1 l/day) ($P < 0.05$; Table 2; Fig. 1).

The afternoon/morning proportion observed during the early third of lactation was 0.45, and it was higher ($P < 0.05$; Fig. 2a) than the other thirds (middle and late). While in the other thirds, the proportion was 0.41 and did not differ ($P > 0.05$; Fig. 2a). Thus, the afternoon/total proportion observed

Table 2 Effects of supplementation on pre-partum, post-partum, or interaction on MY, MY morning, MY afternoon, MY afternoon/morning, MY afternoon/total, and MY4F

Item	*P* value[a]						
	Pre	Pos	Pre × Pos	Third	Pre × Third	Pos × Third	Pre × Pos × Third
MY	0.561	0.185	0.970	0.001	0.269	0.903	0.468
MYm	0.900	0.088	0.772	0.001	0.353	0.427	0.467
MYa	0.181	0.934	0.626	0.001	0.275	0.414	0.631
MY a/m	0.310	0.083	0.370	0.012	0.848	0.121	0.812
MY a/t	0.252	0.074	0.355	0.009	0.888	0.117	0.770
MY4F	0.956	0.096	0.733	0.001	0.663	0.999	0.546

MY, daily milk yield; *MYm*, milk yield in the morning; *Mya*, milk yield in the afternoon; *MY a/m*, proportion of milk yield afternoon/morning; *MY a/t*, proportion of milk yield afternoon/total; *MY4F*, milk yield corrected to 4% fat

[a] /Probability values for the effects of pre-partum supplementation (Pre), post-partum supplementation (Pos), interaction between pre-partum supplementation and post-partum supplementation (Pre × Pos), lactation third (Third), interaction between pre-partum supplementation and lactation third (Pre × Third), interaction between post-partum supplementation and lactation third (Pos × Third) and interaction between pre-partum supplementation, post-partum supplementation and lactation third (Pre × Pos × Third)

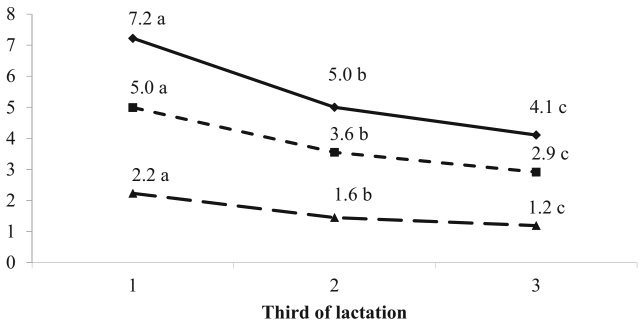

Fig. 1 Morning (▬ ■▬), afternoon (▬▲ ▪) and total milk yield (▬♦▬). a, b, c; means followed by different letters, differed by Student's *t* test ($P < 0.05$)

in the early third was also higher (0.31; $P < 0.05$; Fig. 2b) than in the last two thirds, which did not differ between each other (0.29; $P > 0.05$; Fig. 2b).

There was no effect of pre- and post-partum supplementation or interaction on milk fat (MF) and milk lactose (ML) in the morning and afternoon ($P > 0.05$; Table 3). Pre-partum supplementation or interaction did not affect milk protein (MP) and total milk solids (TS) in the morning and afternoon ($P > 0.05$). Post-partum supplementation increased MP in the morning and afternoon milking by the same magnitude and increased TS values only at the morning milking ($P < 0.05$; Table 3).

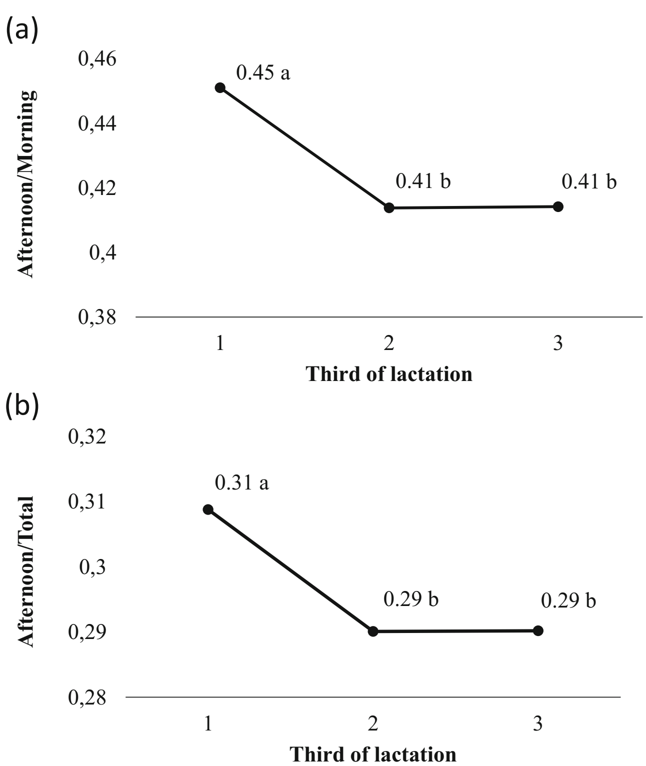

Fig. 2 Afternoon/morning proportion (**a**) and afternoon/total proportion (**b**) of milk yield. a, b; means followed by different letters, differed by Student's *t* test ($P < 0.05$)

There was no effect of pre- or post-partum supplementation or their interaction on the afternoon/morning proportion of MF, MP, ML, and TS ($P > 0.05$; Table 3), demonstrating that all components analyzed were similar in the morning and afternoon milking. The MP increased with advancing stage of lactation ($P < 0.05$; Fig. 3a). The MF presented similar values in the early and middle third ($P > 0.05$), and these were lower than the mean value obtained in the late third ($P < 0.05$; Fig. 3b).

In the early third of lactation, ML was higher than observed in the middle and late lactation ($P < 0.05$; Fig. 3c). There was no difference between the values of ML found in the middle and late lactation ($P > 0.05$). Regarding the TS, lower values were observed in the third of early and middle lactation compared to those observed in the late third ($P < 0.05$). There was no difference between the values found in the early and middle third ($P > 0.05$; Fig. 3d).

Discussion

Paulino et al. (2008), in order to associate production per animal and per area, suggested a herbage allowance between 4 and 5% of BW in pdDM (between 40 and 50 g of pdDM/kg of BW) of pasture for satisfactory animal performance of the animals under grazing conditions. In this study, the mean weight of pdDM was 91.7 and 72.7 g/kg BW in pre- and post-partum, respectively, values above that recommended by Paulino et al. (2008), demonstrating that the amount of forage did not compromise animal performance. The percentage of CP of forage (Table 1), in the pre- and post-partum period, was above the minimum value of 7% CP in the basal diet, reported by Lazzarini et al. (2009) as necessary for adequate utilization of the neutral detergent fiber (NDF) of basal forage, which is the main source of energy for grass-fed animals. In this sense, milk yield was not altered with supplementation, and this happened, basically, because the supply in quantity and quality of forage was enough for the cows to express their productive genetic limit.

Milk yield in the morning and afternoon also followed the same behavior of total MY, with higher values in the first third of lactation, intermediate values in the second third, and lower yields in the third (Fig. 1). This gradual reduction of milk yield with the advancement of lactation is a natural process and has been reported in studies with beef cows (Rodrigues et al. 2014) and dairy cows (Tekerli et al. 2000) in confinement and outdoor systems.

In agreement with our hypothesis, the afternoon/morning proportion followed a relationship similar to that observed in dairy cows. Afternoon milk yield was not same as morning yield (Figs. 1 and 2), suggesting that the methods that double morning milk yield to obtain total milk yield do not accurately estimate total milk yield. These differences observed between

Table 3 Effects of supplementation on pre-, post-partum, or interaction on milk components in the morning and afternoon milking and afternoon/morning proportion

Item	*P* value[a]						
	Pre	Pos	Pre × Pos	Third	Pre × Third	Pos × Third	Pre × Pos × Third
Fm	0.679	0.125	0.183	0.006	0.087	0.938	0.145
Fa	0.647	0.475	0.162	0.006	0.297	0.763	0.497
F a/m	0.870	0.079	0.667	0.591	0.092	0.398	0.117
Pm	0.108	0.004	0.677	0.001	0.654	0.523	0.834
Pa	0.077	0.003	0.675	0.001	0.208	0.571	0.124
P a/m	0.440	0.464	0.559	0.497	0.114	0.755	0.113
Lm	0.829	0.329	0.083	0.001	0.402	0.133	0.873
La	0.281	0.406	0.101	0.001	0.494	0.096	0.976
L a/m	0.111	0.330	0.858	0.002	0.305	0.395	0.764
TS m	0.719	0.022	0.515	0.001	0.151	0.822	0.329
TSa	0.490	0.092	0.413	0.001	0.267	0.657	0.697
TS a/m	0.472	0.082	0.202	0.179	0.085	0.542	0.083

Fm, milk fat at milking in the morning; *Fa*, milk fat at milking in the afternoon; *F a/m*, afternoon/morning proportion of milk fat; *Pm*, milk protein at milking in the morning; *Pa*, milk protein at milking in the afternoon; *P a/m*, afternoon/morning proportion of milk protein; *Lm*, milk lactose at milking in the morning; *La*, milk lactose at milking in the afternoon; *L a/m*, afternoon/morning proportion of milk lactose; *TSm*, milk total solids at milking in the morning; *TSa*, milk total solids at milking in the afternoon; *TS a/m*, afternoon/morning proportion of milk total solids

[a] /Probability values for the effects of pre-partum supplementation (Pre), post-partum supplementation (Pos), interaction between pre-partum supplementation and post-partum supplementation (Pre × Pos), lactation third (Third), interaction between pre-partum supplementation and lactation third (Pre × Third), interaction between post-partum supplementation and lactation third (Pos × Third), and interaction between pre-partum supplementation, post-partum supplementation and lactation third (Pre × Pos × Third)

morning and afternoon milk production are a result of the circadian system, which affects daily milk production (Harvatine 2012; Plaut and Casey 2012). There is evidence in dairy cows that have higher incidence of nocturnal grazing, and a longer cooling period at night may contribute to explain the greater morning yield of grazing beef cows (Kendall et al. 2006) observed in this study. However, the lower milk yield observed in afternoon milking is a reflection of diurnal rhythm (Klopcic et al. 2013), influenced mainly by high temperatures in the tropical regions (Spiers et al. 2004).

According to Gantner et al. (2009), late third of lactation is an important source of variation in the daily production estimation of dairy cows. In this study, the difference observed in the afternoon/morning proportion (0.45 for the early third and 0.41 for the middle and late third), showed that there is a variation in the lactation third for beef cows as well. Additionally, Kendall et al. (2006) observed a 36.1% of afternoon/total proportion for dairy cows in the first third of lactation, which is relative similar to those found in this study (31.0%) for beef cows.

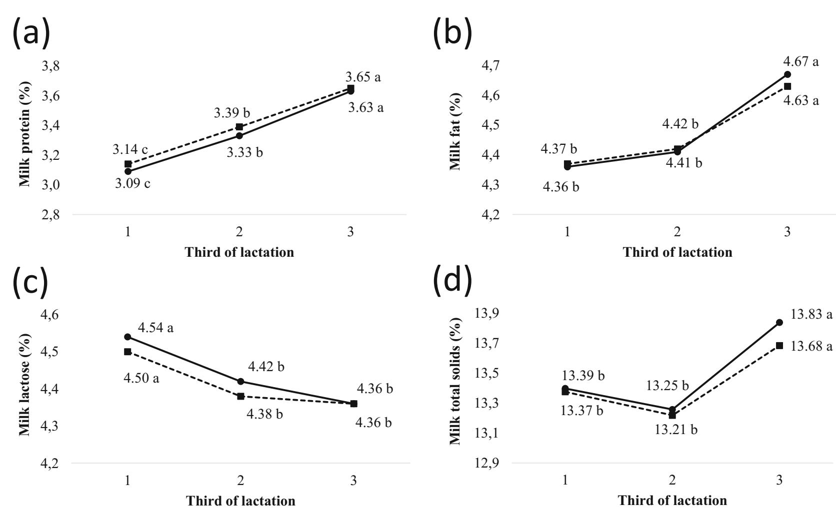

Fig. 3 Percentage values for protein (**a**), fat (**b**), lactose (**c**), and total solids (**d**) of morning (—●—) and afternoon (--■--) milkings. a, b, c; means followed by different letters, differed by Student's *t* test ($P < 0.05$)

There was no difference in milk composition between morning and afternoon milking (Table 3). Possibly, these lower volumes produced by beef cows were not sufficient to promote variations in milk composition. In addition, similar values found for milk components reinforce the importance of afternoon/morning and afternoon/total proportion found in this work to estimate milk yield in Nellore cows.

Protein is a milk component that may vary considerably as it can differ between genetic groups of cows and between cows of the same genetic group. Beneficial effects of crossbreeding utilizing zebu cattle on protein concentration in milk were also observed by Cerdótes et al. (2004). According to NRC (2001), milk protein can range from 3.11 to 3.65%. This study found mean values of morning and afternoon milking between 3.12% in the early third and 3.64% in the late third (Fig. 3a). Considering MF and ML, these values are within the NRC (1996) range, between 2.79 and 5.27% for MF and 3.84 and 5.66% for ML (Fig. 3b, c). Fat has been found to be the most variable milk component, increasing gradually through the lactation, and generally being negatively correlated with the level of milk production (Chilliard et al. 2003). Rodrigues et al. (2014) also reported decreased lactose concentration and increased in TS concentration with the advancement of lactation (Fig. 3d).

In summary, our data support a conclusion that it is not accurate to multiply a once daily milking amount times two in order to calculate daily milk production. The relative proportions of milk produced in the afternoon vs. morning milkings in this study were 0.45 early in lactation and 0.41 in the middle and late lactation. Because proportions are affected by environment, those determined at one location may not necessarily apply to other locations. Additional research is needed to assess these relationships at more locations in the tropics and in different climatic regions.

This article is based on parts of the first author´s doctoral thesis http://www.locus.ufv.br/bitstream/handle/123456789/10524/texto%20completo.pdf?isAllowed=y&sequence=1 (Almeida 2017).

Acknowledgements We are grateful to Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG), and Instituto de Ciência e Tecnologia de Ciência Animal (INCT-CA) for supporting this study.

Compliance with ethical standards

All animal care and handling procedures were approved by the Animal Care and Use Committee of the Universidade Federal de Viçosa, Brazil (protocol CEUAP-UFV 0008).

Conflicts of interest The authors declare that they have no conflict of interest.

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