IJAS Iranian Journal of Applied Animal Science

Impact of an Agroforestry System on Grazing, Ruminating, and Resting Behaviors of Dairy Cows

Research Article

A.A. Olival[1], F.B. Araújo[1], T.A. Del Valle[2,3*], J.A.C. Osório[4], M. Campana[2] and J.P.G. de Morais[2]

[1] Campus Alta Floresta, Mato Grosso State University, Rodovia MT 208, km 147 s/n, Jardim Tropical, Alta Floresta, Brazil
[2] Department of Biotechnology and Vegetal and Animal Production, Agrarian Science Center, Federal University of São Carlos, Via Anhangera, km 174 s/n, Araras, Brazil
[3] Itaqui Campus, Federal University of Pampa, Luiz Joaquim de Sá Brito Street, Itaqui, Brazil
[4] Department of Animal Science, Maringá State University, Colombo Avenue 5790, Jardim Universitário, Maringá, Brazil

Received on: 2 May 2019
Revised on: 14 Jun 2019
Accepted on: 15 Jun 2019
Online Published on: Mar 2020

*Correspondence E-mail: tiagodelvalle@unipampa.edu.br

Online version is available on: www.ijas.ir

ABSTRACT

The present study aimed to evaluate the effects of agroforestry system on the feeding behavior of dairy cows in the Brazilian Amazon region. Nineteen cross breed dairy cows (14.0±3.30 kg/d of milk yield and 450±40.1 kg body weight) were used. The following treatments were evaluated: A) animals were maintained in opened pasture of *Brachiaria brizantha* during all the day; B) animals were kept in forage peanuts (*Arachis pintoi*) during the morning (between 07:00 and 1200 h) and in muvuca, a type of agroforestry arrangement, afternoon (between 12:00 and 23:00 h); and C) animals were maintained in forage peanuts during the morning (between 07:00 and 11:00 h) and in opened pasture of *Brachiaria brizantha* during the afternoon (between 12:00 and 23:00 h). Behaviors of grazing, ruminating, and resting was monitored every ten minutes, and the hourly index was analyzed as repeated measures in a 3 × 3 latin square design study. Between 07:00 and 09:00 h, animals maintained in opened pasture showed higher grazing and lower ruminating index than those animals kept in forage peanuts. During the hottest period of the day, animals maintained in opened pasture showed a higher grazing index. Animals of A and C treatments showed a higher grazing index than those of B treatment, between 15:00 and 17:00 h. Animals maintained in muvuca had increased grazing index, resulting in lower ruminating and resting, at the end of the day. As a whole, the agroforestry system stabilizes the grazing and ruminating index and increases the grazing index during the hottest period of the day.

KEY WORDS grazing, muvuca, peanut, rumination.

INTRODUCTION

The cattle herds have increased in many parts of the world. Cattle ranches occupy new frontiers to maintain agricultural productivity (McManus *et al*. 2016). Indeed, in Brazil, one of the leading food supplying countries, the expansion of the agrarian frontier threatens forest lands. This condition leads to the detriment of environmental conservation, with alarming rates of deforestation (Nepstad *et al*. 2014; Gibbs *et al*. 2015). From this problematic, new alternatives are being proposed to mitigate the impacts of deforestation in meat and milk production systems (McManus *et al*. 2016). Agroforestry systems are considered essential among sustainable technologies to achieve these goals. Agroforestry systems consist of a combination of various plant and animal species, using different arrangements of components in time and space (Almeida *et al*. 2013). Agroforestry systems are characterized as systems designed to exploit synergies

and emerging properties that result in soil-plant-animal interactions (Moraes *et al.* 2014). The communication begins with the use of solar energy in all strata, the recycling of nutrients from material deposited in the soil, using pruning of woody and perennial species that are present in the agroforestry system. However, these systems are underestimated and underutilized throughout the developing countries, and especially where tree plantations are abundant, such as the Brazilian Amazon region (Devendra, 2014).

The muvuca is a type of agroforestry arrangement, which is used in reforestation in the Amazon, consists of sowing forest species, herbaceous plants with legumes of green manure. It differs from conventional consortium methods by the use of high diversity of plant species and the predominance of direct seeding instead of seedlings. Among the benefits of the agroforestry systems type muvuca, when adapted to pasture areas is to reduce thermal stress, since it provides shade for animals (Checoli *et al.* 2016). High ambient temperatures, associated with high air humidity, leading to changes in the physiological and behavioral reactions of the animals, especially in the reduction of intake, feed efficiency, and production losses (West, 2003). Therefore, we hypothesized that cows kept in the agroforestry system could have higher rumination and grazing indexes, with lower resting rates than traditional management, especially in the hottest hours of the day. This study aimed to evaluate agroforestry system effects on dairy cows feed behavior through the day, in the Brazilian Amazon region.

MATERIALS AND METHODS

Study location

The study was carried out at Terra Nova do Norte, located at latitude, Mato Grosso state, Brazil, in November 2018. According to National Institute of Meteorology (INMET), a rainy tropical climate with two distinct seasons: wet summer and dry winter.

Temperatures were between 20 to 38 ˚C, averaging 26 ˚C. The predominant soils in Terra Nova do Norte are the Red-Yellow Dystrophic Argillosols, occurring as subdominant in most spots, red-yellow latosol, and yellow latosol. The relief compartments of the region corresponding to the Southern Plateau of the South, the Amazon. The morphostructural domains comprise the Phanerozoic Sedimentary Basins and Covers.

The vegetation types that occur in the municipality are the tropical open tropical forest, dense tropical forest, savannas, and areas of ecological tension. Sánchez (1992) described two eco-regions for the vegetation in the north of the State of Mato Grosso: Rainforests of the lowlands and residual mountains and plateaus of northern Mato Grosso (Plateau of the Pareci).

Animals, treatments, and experimental design

Nineteen lactating cows were blocked according to milk yield (14.0±3.30 kg/d) and body weight (450±40.1 kg) and randomly allocated to one of the treatment sequences, according to a 3 × 3 latin square design. Treatments were: A) animals were maintained in opened pasture of *Brachiaria* (syn. *Urocholoa*) *brizantha* during all the day; B) animals were maintained in forage peanuts (*Arachis pintoi*) during the morning (between 07:00 and 11:00 h) and at muvuca afternoon (between 12:00 and 23:00 h); and C) animals were maintained in forage peanuts during the morning (between 07:00 and 11:00 h) and in opened pasture of *Brachiária* (syn. *Urocholoa*) *brizantha* during the afternoon (between 12:00 and 23:00 h). It was used two paddocks with peanuts (0.30 ha), two paddocks of open pasture (1.07 ha), and another one of muvuca (0.81 ha), totaling 2.18 ha of area. Forage samples were collected every sampling period. Samples were assessed for ash (method 942.05, AOAC, 2000), crude protein (N×6.25; method 984.13, AOAC, 2000), ether extract (method 920.39, AOAC, 2000), and neutral detergent fiber (Van Soest *et al.* 1991). Each kg of *Brachiaria* had 935 ± 4.5 g organic matter (OM), 801 ± 10.3 g neutral detergent fiber (NDF), 82.5 ± 18.58 g crude protein (CP), and 8.85 ± 2.664 g ether extract (EE). Average composition of peanuts was: 912 ± 11.2 g/kg OM, 485 ± 10.1 g/kg NDF, 220 ± 13.8 g/kg CP, and 10.8 ± 0.10 g/kg EE. Muvuca had 938 ± 3.4 g/kg OM, 818 ± 7.1 g/kg NDF, 57.7 ± 4.37 CP, and 7.84 ± 1.267 g/kg EE.

Management and ethological evaluation

Cows were milked once daily (06:00 h). After milking, animals were allocated to experimental pastures at 0700 h. Behaviors of grazing, ruminating, and resting of animals was monitored by two trained persons every ten minutes, using ethological fiches (Santos *et al.* 2012). Each of these behaviors was expressed as the hourly mean index calculated for each animal. Animals were managed between 11:00 and 12:00 h to change the pasture and at 23:00 h were removed from the pastures, setting up three periods of analysis: morning: between 07:00 and 11:00; afternoon, between 12:00 and 23:00; and dawn, between 23:00 and 06:00 h (Tables 1, 2 and 3).

Statistical analysis

For all response criteria, the cows served as the experimental unit. Data were analyzed as repeated measures, using the mixed procedure of SAS (version 9.4, SAS Institute Inc., Cary, NC), according to the following mathematical model:

$$Y_{ijklm} = \mu + S_i + \alpha_{j:i} + P_k + T_l + w_{ijkl} + H_m + H_{lm} + e_{ijklm}$$

With

$\alpha_{j:i} \approx N(0; \sigma_\alpha^2)$, $\omega_{ijkl} \approx N(0; \sigma_\omega^2)$, and $e_{ijklm} \approx MVN(0; R)$

Where:
Y_{ijklm}: dependent variable.
μ: overall mean.
S_i: fixed effect of the latin square (i=1 and 5).
$\alpha_{j:i}$: random effect of the cow within each latin square (j=1 to 15).
P_k: fixed effect of the experimental period (k=1 to 3).
T_l: fixed effect of treatment (l=1 to 3).
w_{ijkl}: random error associated with experimental units (cow within the experimental period).
H_m: fixed effect of evaluation hour (n=1 to 4 for morning; 1 to 11 for evening, and 1 to 6 for dawn).
$T \times H_{lm}$: interaction effect.
e_{ijklm}: experimental error.
N: normal distribution.
σ_α^2: variance associated with the random animal effect within the Latin square.
σ_ω^2: residual variance associated with experimental units.
MVN: multivariate normal distribution.
R: matrix of variance and covariance used to model repeated measures.

The matrices [CS, CSH, AR (1), ARH (1), TOEP, TOEPH, UN, FA (1) and ANTE (1)] were evaluated, using the Bayesian criterion to identify the most appropriate to the data set. Treatment effects were decomposed orthogonal contrasts.

During the morning, it was compared: 1) opened and peanut pasture (A *vs.* B+C); and difference amount animals in peanut pasture (B *vs.* C). During the afternoon, it was compared 1) muvuca and opened pasture (B *vs.* A+C); and 2) the difference in the behavior of animals that grazed peanut and *Brachiaria* during the morning (A *vs.* C).

RESULTS AND DISCUSSION

During the morning evaluation, there was treatment and time interaction effect (P<0.01) on grazing and ruminating indexes. Herbage intake is an essential variable affecting animal performance in pastoral production systems (Burns and Sollenberger, 2002; Gregorini *et al.* 2013). The animals of the A treatment showed higher (P<0.01) grazing and lower (P≤0.01) ruminating index regarding those animals of B and C treatments, between 07:00 and 09:00 h. A negative relationship between ruminating time and index of temperature and humidity has been previously reported (Moallem *et al.* 2010; Soriani *et al.* 2013).

During this fresh period of the day, animals that were in the opened pasture were able to graze. Besides higher grazing levels of these animals during the morning, A-treated animals showed the highest and the lowest grazing and ruminating average hourly indexes. This finding is associated with lower meal frequency, which could negatively affect animals feed intake, digestion, and performance (Sutton *et al.* 1985). Therefore, higher meal frequency of animals maintained in an agroforestry system could avoid extreme ruminal filling and improved feed digestion, besides changes in feed behavior.

However, between 10:00 and 11:00 h, A-treated animals had lower (P=0.01) grazing ratio than those maintained in forage peanuts. Around noon, temperature increases, and consequently, meal frequency reduces (Gibb *et al.* 1998).

On the other hand, agreeing with our hypothesis, during the morning, animals of opened pasture had higher (P=0.01) resting index than those of peanut, regardless (P=0.22) hour of evaluation.

During the hottest period of the day, animals maintained in the opened pasture (treatment A between 10:00 and 11:00h and treatments A and C between 12:00 and 14:00), showed lower (P≤0.01) grazing index, then those in an agroforestry system. According to Vizzotto *et al.* (2015), during hot days, when deprived of shade, cows reduced the time spent grazing and ruminating, but increased total time spent resting, as well as the number of competition events for shade and water drink. These found to agree with our hypothesis, although no reduction was observed on resting ratio of muvuca-grazing animals, concerning those on opened pasture.

Animals of A and C treatments showed a higher (P≤0.01) grazing index than those of B treatment, between 15:00 and 17:00 h. At these times, we had a lower temperature, and animals of these treatments had a higher positive stimulus, due to lower grazing index observed during hottest periods of the day (12:00 and 14:00 h). According to Gregorini *et al.* (2013), hunger signals stimuli eating behavior after a period of fasting. As these animals are grazing, ruminating index reduces, regarding those animals maintained in muvuca, besides resting index also reduces.

At the end of the day, once again, animals maintained in muvuca had increased (P≤0.02) grazing index (between 20:00 and 22:00 h), which results in lower (P<0.01) ruminating (between 20:00 and 21:00 h), and resting (between 21:00 and 22:00 h). Besides another increased grazing index, the observed values of animals maintained in an agroforestry system, during the evening, averaged 0.432, ranging from 0.158 to 0.631. On the other hand, A and C-treated animals averaged 0.385 of grazing index, ranging from 0.013 to 0.939.

Table 1 Grazing index of dairy cows managed in open pasture, peanut, and muvuca through the day

Item	Treatments[1]			SEM	P-value						
	A	B	C		Treat	Time	Treat × time	A *vs*. B + C	B *vs*. A + C	B *vs*. C	A *vs*. C
Morning	0.471	0.367	0.398	0.0341	0.04	< 0.01	< 0.01	0.01	-	0.46	-
07:00	0.882	0.744	0.648	0.0633	< 0.01	-	-	< 0.01	-	0.11	-
08:00	0.671	0.302	0.332	0.0580	< 0.01	-	-	< 0.01	-	0.85	-
09:00	0.271	0.197	0.290	0.0399	0.58	-	-	0.68	-	0.34	-
10:00	0.059	0.225	0.321	0.0455	0.02	-	-	0.01	-	0.62	-
Afternoon	0.391	0.432	0.379	0.0284	0.28	< 0.01	< 0.01	-	0.12	-	0.74
12:00	0.013	0.158	0.001	0.0419	0.03	-	-	-	0.01	-	0.98
13:00	0.002	0.184	0.018	0.0206	< 0.01	-	-	-	< 0.01	-	0.54
14:00	0.272	0.465	0.281	0.1083	0.03	-	-	-	0.01	-	0.62
15:00	0.825	0.631	0.842	0.0374	< 0.01	-	-	-	< 0.01	-	0.64
16:00	0.939	0.614	0.974	0.0351	< 0.01	-	-	-	< 0.01	-	0.56
17:00	0.667	0.623	0.640	0.1659	0.87	-	-	-	0.81	-	0.64
18:00	0.377	0.360	0.333	0.0952	0.89	-	-	-	0.80	-	0.68
19:00	0.421	0.351	0.368	0.0579	0.86	-	-	-	0.68	-	0.73
20:00	0.219	0.623	0.219	0.0423	< 0.01	-	-	-	< 0.01	-	0.92
21:00	0.351	0.553	0.333	0.0952	0.07	-	-	-	0.02	-	0.94
22:00	0.211	0.193	0.158	0.0493	0.36	-	-	-	0.84	-	0.16
Night	0.052	0.062	0.042	0.0423	0.39	< 0.01	0.22	-	-	-	-

[1] A: animals maintained in opened pasture of *Brachiaria* (syn. *Urocholoa*) *brizantha* during all the day; B: animals maintained in forage peanuts (*Arachis pintoi*) during the morning (between 07:00 and 11:00 h) and at muvuca afternoon (between 12:00 and 23:00 h); and C: animals maintained in forage peanuts during the morning (between 07:00 and 11:00 h) and in opened pasture of *Brachiária* (syn. *Urocholoa*) *brizantha* during the afternoon (between 12:00 and 23:00 h).
SEM: standard error of the means.

Table 2 Ruminating index of dairy cows managed in open pasture, peanut, and muvuca through the day

Item	Treatments[1]			SEM	P-value						
	A	B	C		Treat	Time	Treat × time	A *vs*. B + C	B *vs*. A + C	B *vs*. C	A *vs*. C
Morning	0.220	0.421	0.355	0.0182	< 0.01	< 0.01	< 0.01	< 0.01	-	0.14	-
07:00	0.042	0.168	0.179	0.0306	0.02	-	-	0.01	-	0.90	-
08:00	0.105	0.632	0.537	0.0714	< 0.01	-	-	< 0.01	-	0.33	-
09:00	0.284	0.463	0.421	0.0604	0.12	-	-	0.06	-	0.72	-
10:00	0.447	0.421	0.281	0.0559	0.14	-	-	0.14	-	0.17	-
Afternoon	0.370	0.340	0.381	0.0120	0.24	< 0.01	< 0.01	-	0.10	-	0.66
12:00	0.625	0.584	0.603	0.0375	0.81	-	-	-	0.57	-	0.74
13:00	0.520	0.290	0.427	0.0367	0.01	-	-	-	< 0.01	-	0.33
14:00	0.266	0.184	0.278	0.0429	0.36	-	-	-	0.20	-	0.55
15:00	0.037	0.062	0.050	0.0206	0.31	-	-	-	0.14	-	0.74
16:00	0.064	0.176	0.024	0.0489	0.01	-	-	-	< 0.01	-	0.51
17:00	0.117	0.237	0.138	0.0739	0.18	-	-	-	0.11	-	0.44
18:00	0.520	0.570	0.594	0.0916	0.55	-	-	-	0.40	-	0.49
19:00	0.450	0.465	0.498	0.0458	0.67	-	-	-	0.47	-	0.59
20:00	0.669	0.255	0.585	0.0547	< 0.01	-	-	-	< 0.01	-	0.64
21:00	0.336	0.263	0.427	0.0787	0.62	-	-	-	0.74	-	0.36
22:00	0.467	0.649	0.568	0.0331	0.33	-	-	-	0.46	-	0.19
Night	0.524	0.526	0.537	0.0199	0.76	< 0.01	0.31	-	-	0.53	0.97

[1] A: animals maintained in opened pasture of *Brachiaria* (syn. *Urocholoa*) *brizantha* during all the day; B: animals maintained in forage peanuts (*Arachis pintoi*) during the morning (between 07:00 and 11:00 h) and at muvuca afternoon (between 12:00 and 23:00 h); and C: animals maintained in forage peanuts during the morning (between 07:00 and 11:00 h) and in opened pasture of *Brachiária* (syn. *Urocholoa*) *brizantha* during the afternoon (between 12:00 and 23:00 h).
SEM: standard error of the means.

As previously discussed, higher meal frequency could stabilize feed intake during the day, resulting in improved digestive process (Sutton *et al*. 1985). There was no carry-over effect of diurnal pasture management on dawn animal's behavior, different that was expected. During the night, there was no treatment effect (P≥0.39) on grazing, ruminating, and resting indexes, regardless (P≥0.22) time of evaluation.

Table 3 Resting index of dairy cows managed in open pasture, peanut, and muvuca through the day

Item	Treatments[1]			SEM	P-value						
	A	B	C		Treat	Time	Treat × time	A *vs*. B + C	B *vs*. A + C	B *vs*. C	A *vs*. C
Morning	0.273	0.190	0.233	0.1106	0.01	< 0.01	0.22	0.01	-	0.11	-
Afternoon	0.230	0.217	0.229	0.0208	0.88	< 0.01	< 0.01	-	0.60	-	0.99
12:00	0.364	0.259	0.382	0.0432	0.26	-	-	-	0.11	-	0.80
13:00	0.465	0.526	0.535	0.0365	0.62	-	-	-	0.63	-	0.40
14:00	0.439	0.333	0.439	0.0787	0.18	-	-	-	0.12	-	0.30
15:00	0.141	0.298	0.088	0.0288	< 0.01	-	-	-	< 0.01	-	0.76
16:00	0.006	0.184	0.001	0.0205	< 0.01	-	-	-	< 0.01	-	0.94
17:00	0.211	0.140	0.219	0.0944	0.27	-	-	-	0.12	-	0.77
18:00	0.105	0.070	0.070	0.0205	0.43	-	-	-	0.22	-	0.65
19:00	0.123	0.184	0.132	0.0354	0.82	-	-	-	0.53	-	0.82
20:00	0.114	0.123	0.193	0.0368	0.34	-	-	-	0.28	-	0.32
21:00	0.272	0.114	0.219	0.0452	0.15	-	-	-	0.13	-	0.21
22:00	0.290	0.158	0.246	0.0462	0.21	-	-	-	0.17	-	0.77
Night	0.421	0.410	0.423	0.0876	0.96	0.27	0.42	-	-	0.78	0.88

[1] A: animals maintained in opened pasture of *Brachiaria* (syn. *Urocholoa*) *brizantha* during all the day; B: animals maintained in forage peanuts (*Arachis pintoi*) during the morning (between 07:00 and 11:00 h) and at muvuca afternoon (between 12:00 and 23:00 h); and C: animals maintained in forage peanuts during the morning (between 07:00 and 11:00 h) and in opened pasture of *Brachiária* (syn. *Urocholoa*) *brizantha* during the afternoon (between 12:00 and 23:00 h).
SEM: standard error of the means.

CONCLUSION

Peanut increases ruminating and reduces grazing and resting index. Agroforestry system (peanut and muvuca) increases grazing index during the hottest period of the day, with no effects on animals feed behavior during the night, stabilizing grazing and ruminating indexes through the day.

ACKNOWLEDGEMENT

The authors thanks to Ouro Verde Institute for the support durnig the trial.

REFERENCES

Almeida R.G., Andrade C.M., Paciullo D., Fernandes P.C., Cavalcante A.C., Barbosa R. and Valle C.B. (2013). Brazilian agroforestry systems for cattle and sheep. *Trop. Grassl.* **1,** 175-183.

AOAC. (2000). Official Methods of Analysis. 17th Ed. Association of Official Analytical Chemists, Arlington, Washington, DC., USA.

Burns J. and Sollenberger L. (2002). Grazing behavior of ruminants and daily performance from warm-season grasses. *Crop Sci.* **42,** 873-881.

Checoli C.H., Shiraiwa S., Silva M.C. and Silva N.M. (2016). Gestão participativa na recuperação de área degradada pela agricultura. *Soc. Nat.* **28,** 117-130.

Devendra C. (2014). Perspectives on the potential of silvopastoral systems. *Agrotechnology.* **3,** 117-225.

Gibb M., Huckle C. and Nuthall R. (1998). Effect of time of day on grazing behaviour bylactating dairy cows. *Grass Forage Sci.* **53,** 41-46.

Gibbs H.K., Munger J., L'Roe J., Barreto P., Pereira R., Christie M., Amaral T. and Walker N. (2015). Did ranchers and slaughterhouses respond to zero-deforestation agreements in the Brazilian Amazon? *Conserv. Lett.* **9,** 32-34.

Gregorini P., Beukes P.C., Romera A.J., Levy G. and Hanigan M.D. (2013). A model of diurnal grazing patterns and herbage intake of a dairy cow, MINDY: Model description. *Ecol. Model.* **270,** 11-29.

McManus C., Barcellos J.O.J., Formenton B.K., Hermuche P.M., Carvalho O.Ad., Guimarães R., Gianezini M., Dias E., Lampert V., Zago D. and Neto J.B. (2016). Dynamics of cattle production in Brazil. *Plos One*. **11,** e0147138.

Moallem U., Altmark G., Lehrer H. and Arieli A. (2010). Performance of high-yielding dairy cows supplemented with fat or concentrate under hot and humid climates. *J. Dairy Sci.* **93,** 3192-3202.

Moraes A., Carvalho P.C., Lustosa S.B.C., Lang C.R. and Deiss L. (2014). Research on Integrated crop-livestock systems in Brazil. *Rev. Ciênc. Agron.* **45,** 1024-1031.

Nepstad D., McGrath D., Stickler C., Alencar A., Azevedo A., Swette B. and Bezerra T. (2014). Slowing Amazon deforestation through public policy and interventions in beef and soy supply chains. *Science.* **344,** 1119-1123.

Sánchez R.O. (1992). Zoneamento Agroecológico do Estado de Mato Grosso: Ordenamento Ecológico-Paisagístico do Meio Natural e Rural. Fundação de Pesquisas Cândido Rondon. Cuiabá, Mato Grosso, Brazil.

Santos M.V., Kozloski G.V., Quadros F.L.F., Pires C.C., Wommer T.P. and Mônego C.O. (2012). Animal production and canopy attributes of Cynodon pasture managed under continuous stocking with wethers at three levels of forage allowance. *R. Bras. Zootec.* **41,** 181-187.

Soriani N., Panella G. and Calamari L. (2013). Rumination time during the summer season and its relationships with metabolic conditions and milk production. *J. Dairy Sci.* **96,** 5082-5094.

Sutton J.D., Broster W.H., Napper D.J. and Siviter J.W. (1985). Feeding frequency for lactating cows: Effects on digestion, milk production and energy utilization. *Br. J. Nutr.* **53,** 117-130.

Van Soest P.J., Robertson J.B. and Lewis B.A. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* **74,** 3583-3597.

Vizzotto E.F., Fischer V., Thaler N.A., Abreu A.S., Stumpf M.T., Werncke D. and McManus C.M. (2015). Access to shade changes behavioral and physiological attributes of dairy cows during the hot season in the subtropics. *Animal*. **9,** 1559-1566.

West J.W. (2003). Effects of heat-stress on production in dairy cattle. *J. Dairy Sci.* **86,** 2131-2144.