SUN TOLERANCE AND PHYSIOLOGICAL PARAMETERS OF GOATS GRAZING *PANICUM MAXIMUM* CV. TOBIATÃ[1]

R. O. Marques[2], H. C. Gonçalves [2*], P. R. L. Meirelles [2], R. V. Lourençon[2], G. M.Oliveira[2], M. F. Martins[2], H. F. B. Gomes[3], G. I. L. Cañizares[2], E. P. Brito[2], H. L. Correa[2]

[1]Received: 07/08/2018. Accepted: 22/11/2018.
[2]Faculty of Veterinary Medicine and Animal Science – São Paulo State University - Botucatu, SP, Brazil.
[3]Institute of Agricultural and Environmental Sciences – Mato Grosso Federal University, Sinop, MT, Brazil.
*Corresponding author: heraldo.cesar@unesp.br

ABSTRACT: The aim of this study was to evaluate the influence of supplementation on sun tolerance and physiological parameters of goats in grazing. Sixty goats (20 Alpine, 18 Anglo-Nubian and 22 crossbred Boer) primiparous and multiparous, with average body weight of 49.33 ± 1.41 kg were used in this experiment. The goats were kept in rotational pastures of *Panicum maximum* cv. Tobiatã and supplemented with two levels of concentrate: 300 (NS30) and 600 g/ kg (NS60) of the daily dry matter requirements, assessed from pre-breeding season to approximately 110 days of lactation. Visual observations of tolerance of goats in the sun were made monthly, each 15 minutes during the entire period that the animals remained in the pasture. The respiratory rate and rectal temperature were evaluated monthly, being measured at 9 a.m., 1 p.m. and 5 p.m. Temperature and air relative humidity were recorded every hour, on the days of data collection. Breed influenced the respiratory rate and rectal temperature at 1 p.m., and the crossbred Boer animals showed more appropriate physiological parameters, leading to greater heat tolerance. There was no influence of treatment on the physiological variables of the goats. The Anglo-Nubian goats showed higher resistance to direct sun radiation, staying longer in the sun, being the most suitable for the production system in pasture.

Keywords: caprine, rectal temperature, respiratory frequency, THI.

TOLERÂNCIA AO SOL E PARÂMETROS FISIOLÓGICOS DE CABRAS EM PASTAGEM DE CAPIM-TOBIATÃ (PANICUM MAXIMUM CV. TOBIATÃ)

RESUMO: Objetivou-se com este estudo avaliar a influência da suplementação sobre a tolerância ao sol e parâmetros fisiológicos de cabras em pastejo. Foram utilizadas 60 cabras (20 Alpinas, 18 Anglo-Nubianas e 22 mestiças Boer), primíparas e multíparas, com peso corporal médio de 49,33±1,41 kg, mantidas em pastagem rotacionada de *Panicum maximum* cv. Tobiatã e suplementadas com dois níveis de concentrado: 300 (NS30) e 600 g/kg (NS60) das exigências diárias em relação à ingestão de matéria seca, avaliadas desde a pré-estação de monta, até, em média 110 dias de lactação. Foram realizadas mensalmente observações visuais da tolerância das cabras ao sol, a cada 15 minutos, durante todo o período que os animais permaneceram no pasto. A frequência respiratória e a temperatura retal foram avaliadas mensalmente, sendo mensuradas às 09h00, 13h00 e 17h00. A temperatura e a umidade relativa do ar foram registradas a cada uma hora, nos dias de colheita de dados. O grupo racial influenciou a frequência respiratória e a temperatura retal às 13h00, sendo que as mestiças Boer apresentaram parâmetros fisiológicos mais adequados, que levam à maior tolerância ao calor. Não houve influência do tratamento nas variáveis fisiológicas das cabras. As cabras Anglo-Nubianas demonstraram maior resistência à radiação solar direta, permanecendo mais tempo ao sol, sendo as mais indicadas para o sistema de produção em pasto.

Palavras-chave: caprinos, temperatura retal, frequência respiratória, THI.

INTRODUCTION

Dairy goat farming is growing and the consequence of such fact is the need for producers to reduce milk production costs, to remain in the activity. A viable alternative is the use of production systems based on grazing, since it is a low cost forage. However, it is important to consider the animal x environment interactions to obtain efficiency in this operation.

The study of animal behavior target for performance aiming at the understanding of the grazing habits, time of the activities, the relationships of animals with the quality and quantity of available forage and with other environmental factors contribute to the use of management techniques, facilities and adequate feeding, providing welfare and improving the productive and reproductive performance of the animals, as a consequence.

Productive efficiency is enhanced if the animals are in thermal comfort conditions, where there is no need not to trigger thermoregulatory mechanisms to gain or lose heat to the environment (Vieira et al., 2016).

Although goats are considered rustic animals and adapted to harsh environments, the association between high temperature and air humidity can cause heat stress in them. The temperature is the climatic factor with major influence on the physical environment of the animal and atmospheric moisture acts in caloric balance in hot environments, where heat loss by evaporation is crucial to homeothermy (Pereira et al., 2011; Silva et al., 2006).

The temperature and humidity also influence grazing habits, being that in the thermoneutrality, goats have periods spent ingestion of food interspersed with one or more periods of rumination or idleness (Furtado and Crispim, 2015), totaling about ten hours of grazing per day, divided around seven cycles of grazing, with sunrise and sunset being the two most intense grazing periods (Parente et al., 2005).

Animals submitted to thermal stress reduce the number of meals, the duration of meals and the rate of dry matter consumption per meal, with a substitution of food intake and rumination by idleness, in an attempt to reduce the production of metabolic heat (Souza et al., 2012).

There are several criteria to evaluate the reaction of the animal organism to heat, among which the internal temperature and respiratory rate stand out. The internal temperature is usually estimated by rectal temperature, being a result of the animal heat exchange with the environment, essential to judge the attitude of the animal to thermoregulation, while the respiratory rate is more related to the activation of thermoregulatory mechanisms, through water evaporation by respiration.

In extreme cases, in response to heat stress, animals react with behavioral and physiological changes such as increase in heart and respiratory rates (Lucena et al., 2013), reduction in feed intake, increase in the water intake, search for shade (Furtado and Crispim, 2015) and activity decrease at the warmest hours of the day (Furtado et al., 2008).

To achieve success in the animal raising it is necessary to meet some basic requirements on the production system such as the use of specialized animals for the activity and with good adaptability, good nutritional, reproductive and health management, and especially the provision of suitable conditions of thermal comfort to animals.

Therefore, studies are necessary to evaluate what the best breeds and management strategies are to maximize production. Thus, this work was carried out in order to evaluate the influence of concentrate supplementation levels during the pre-breeding season up to on average 110 days of lactation on the tolerance to sun and on the physiological parameters of goats of two pure breeds: Alpine and Anglo-Nubian and crossbred Boer in pasture system under rotational management.

MATERIAL AND METHODS

This study was carried out at UNESP – Faculdade de Medicina Veterinária e Zootecnia, Campus de Botucatu - SP, in the Goat Production Field, located in Fazenda Lageado (22°52'S and 48º26'W at 800 m altitude), from February 2010 to March 2011. The climate in the region is Cwa warm temperate mesothermal according to Koppen classification, with annual rainfall of 1,479 mm (Rolim et al., 2007) and the period considered dry if from May to September (30% of annual

rainfall). The experiment was approved by the local ethics and animal experimentation under the protocol number 20/2010 – CEUA.

Sixty goats were used in the experiment: 20 Alpine, 18 Anglo-Nubian and 22 crossbred Boer (11 ½ Boer + ½ Alpine e 11 ¾ Boer + ¼ Alpine). The animals were primiparous (31) and multiparous (29), with ages ranging from one to five years in proportion to breed and average body weight of 49.33 ± 1.41 kg, maintained together in *Panicum maximum* cv. Tobiatã pastures under rotational system with variable stocking rate and equally divided in two levels of concentrate supplementation. Stocking rates were adjusted every three days by regulating animals of the same breed, which were placed and removed in each paddock according to forage availability.

Thirteen pasture cycles were performed, with occupancy period of three days and idle period of 27 days (Figure 1). The animals were kept on pasture from 8 a.m. to 6 p.m. The area used was approximately 0.6 ha, divided into 10 paddocks of approximately 500 m^2. Each paddock had automatic drinking fountain and 80 m^2 free access area, provided with artificial shade supplied by shading (75% retention of solar radiation) located in the corridor leading to the paddock.

The goat breeding season began at the end of the summer and lasted until the end of autumn, lasting 90 days, by natural mating, and the goats remained with the billy-goats only at night in the fold. Parturitions occurred between the middle of winter and spring, and the kids were separated from the mothers shortly after birth.

Two levels of concentrate supplementation were evaluated from pre-breeding season until partum: 300 g/kg (NS30) and 600 g/kg (NS60) of the daily nutritional requirements (NRC, 2007), based on consumption of 22 g/kg body weight in dry matter, starting one month before the breeding season and continuing until partum, whose lactation was evaluated.

After partum, the goats were fed concentrate according to milk yield, which was balanced so 1 kg supplied 2.5 kg of produced milk. This amount was corrected every fourteen days.

The pre-partum concentrate was composed of: 450 g/kg maize, 100 g/kg of soybean meal, 410 g/kg of cottonseed meal, 25 g/kg of limestone, 5 g/kg of bicalcium phosphate and 10 g/kg of mineral supplement. The concentrate supplied during lactation was composed of 520 g/kg of maize, 290 g/kg of soybean meal, 150 g/kg wheat bran, 25 g/kg of limestone, 5 g/kg of bicalcium phosphate and 10 g/kg of mineral supplement.

Chemical composition of concentrate diets (Table 1) and of forage (Table 2) was set up in the Laboratório de Bromatologia of Faculdade de Medicina Veterinária e Zootecnia (FMVZ/UNESP) – Botucatu/SP.

After grazing, animals were collected in their collective pens according to breed and

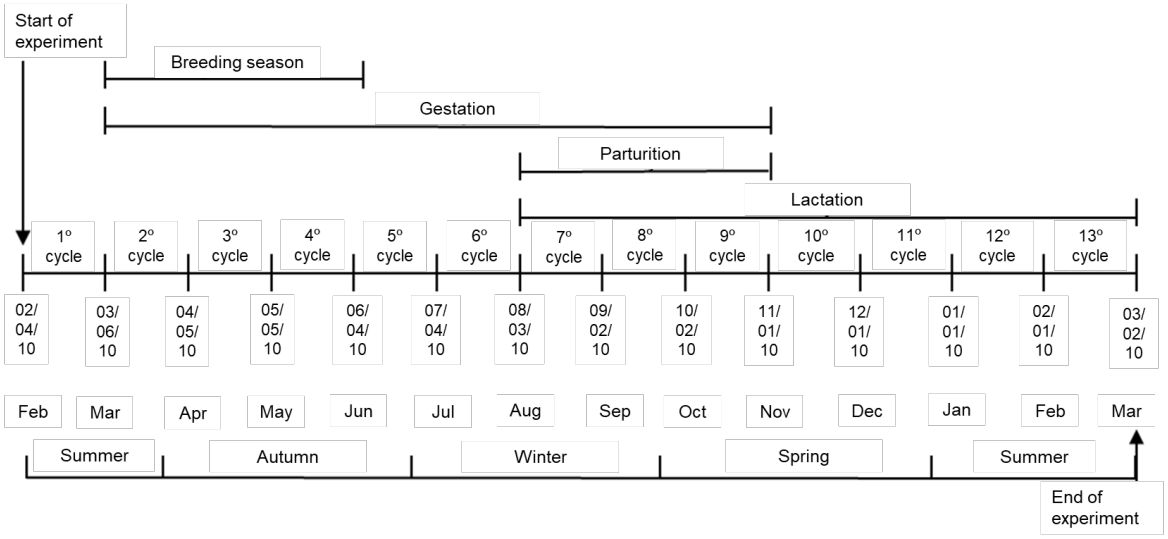

Figure 1 - Scheme representing the stages of reproductive and productive cycles and grazing cycles.

Table 1 - Chemical composition of concentrate diets.

Chemical composition (g/kg DM)	Pré-partum	Lactation
Mineral matter	78.5	71.3
Crude protein	159.6	198.8
Ether extract	36.6	38.6
Neutral detergent fiber	198.7	184.3
Acid detergent fiber	103.9	91.7
Non-fiber carbohydrates (NFC)[1]	526.6	507.0
Total digestible nutrients (TDN)[2]	749.7	775.0

[1]Achieved from the equation proposed by VAN SOEST et al. (1991): NFC = 100 - (CP + EE + MM + NDF).
[2]Achieved from the equation proposed by NRC (2001): TDN = DCP + DNFC + DNDF + (DFA x 2.25) – 7, where: DCP – truly digestible CP; DNFC – truly digestible CNF; DNDF – digestible NDF; DFA – truly digestible fatty acid.

level of supplementation in the fold of slatted floor, suspended from the soil, with access to cemented floor solarium. Animals received the concentrate in the pens and had water and mineral salt ad libitum.

Forage intake by goats was estimated based on the difference between the availability of forage at the paddocks entrance and remaining forage at exit, performed by double sampling (Haydock and Shaw, 1975). This evaluation consisted in the random launching of a PVC frame with 1 m of side, three times per picket, registering the height of the plant in three points inside the frame and collecting all the fodder up to the height of 5 cm of the ground.

The forage was evaluated in each season for the chemical composition (Table 2). The forage samples were dried at 55°C in forced air oven until constant weight, processed in Willey type mill with 1 mm sieve and packed in plastic containers. In the analyzes, mineral matter (MM), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF) and acid detergent fiber (ADF) corrected for dry matter were determined according AOAC (2012).

In winter, due to low supply of forage in the pasture, the animals were fed corn silage with 73.6 g/kg CP, 494.6 g/kg NDF, 237.2 g/kg ADF and 698.9 g /kg TDN, at night as forage supplementation, being supplied sufficient amount so there would be 100 g/kg of leftover.

Fertilizations were carried out over the experiment in which 20 kg of 20-0-20 NPK mixture in each cycle, totaling 400 kg of nitrogen and potassium per hectare/ year.

At the beginning of the experiment and

Table 2 - Chemical composition of Tobiatã Grass in the pré and post-grazing.

	Pré- grazing			
Chemical composition (g/kg DM)	**Autumn**	**Winter**	**Spring**	**Summer**
Mineral matter	53.0	45.8	54.1	50.8
Crude protein	136.8	130.6	110.6	161.5
Ether extract	20.7	22.0	19.0	26.8
Neutral detergent fiber	643.2	669.3	710.7	627.8
Acid detergent fiber	410.6	419.8	417.5	402.8
Non-fiber carbohydrates (NFC)[1]	146.4	132.3	105.7	133.2
Total digestible nutrients (TDN)[2]	625.5	605.0	602.0	630.4
Post-grazing				
Mineral matter	84.0	76.8	89.1	81.8
Crude protein	99.0	94.5	79.1	115.6
Ether extract	27.7	26.8	17.0	30.1
Neutral detergent fiber	783.2	794.4	784.6	768.6
Acid detergent fiber	426.1	444.6	460.5	431.7
Non-fiber carbohydrates (NFC) [1]	61.0	75.0	30.3	39.0
Total digestible nutrients (TDN) [2]	566.0	563.8	540.3	570.2

[1]Achieved from the equation proposed by VAN SOEST et al. (1991): NFC = 100 - (CP + EE + MM + NDF).
[2]Achieved from the equation proposed by NRC (2001).

after parturition, the animals received a dose of endectocide (1% ivermectin subcutaneously via, 1 ml per 50 kg body weight).

Physiological parameters of goats were evaluated in the pasture three times a day (9 a.m., 1 p.m. and 5 p.m.) every 30 days, twice in each season, totaling eight collections. Respiratory rate (RR) was measured, achieved by counting the number of movements of the flanks with the aid of a timer for a period of one minute (movement / minute), and rectal temperature (RT) was measured by digital clinical thermometer (C°) inserted into the rectum of the animal to a depth of about 3.5 cm and maintained for about three minutes.

Tolerance of goats to the sun at different physiological stages was assessed by means of observations of the 60 experimental animals, every 30 days by the method of instantaneous scan, according to Martin and Bateson (2007), every 15 minutes, on different days of data collection of the physiological parameters, and counted the number of animals in the sun or in the shade during the period in which they remained in the pasture. On days of observation the time was sunny, without rain or clouds covering the sky.

To evaluate the effects of environmental conditions on thermal comfort of the animals, data on the temperature and humidity of the air were collected on the days of observation and measurement of physiological parameters to calculate the index of temperature and humidity (THI), using the formula mentioned by Kelly and Bond (1971), cited by Baccari Junior (2001).

THI = Ts – 0.55 (1-RH) (Ts – 58), where:

Ts = temperature of the dry bulb thermometer in ^{o}F;

RH = relative humidity of the air expresses as decimal number.

The experiment was conducted in a completely randomized design. Physiological parameters were analyzed by analysis of variance in split-split plot, in which the combination of the three breeds and two levels of concentrate were the main plots and the subplots were assessment times and controls. Means were compared by Tukey test ($P<0.05$). The permanence on the pasture by breed was evaluated by χ^2 test, in each evaluation time in the four seasons of the year. Statistical analyses were performed by using SAS software (SAS, 1999).

RESULTS AND DISCUSSION

The respiratory rate and rectal temperature of goats were influenced by the breed and collection time, with values ranging from 12 to 25 movements/minute and 38.5 to 39.7°C, respectively (Table 3), considered normal for goats, according to Silva et al. (2010).

Respiratory rate was influenced by breed only at 1 p.m. The crossbred Boer animals showed higher values than the Anglo-Nubian, and did not differ from the Alpine goats. An increase in the respiratory rate at 1 p.m. was found in all racial groups due to the raise in the

Table 3 - Respiratory rate and rectal temperature of goats according to racial group and collection time.

Time	Mean	Racial group			CV [1]
		Alpine	Anglo-Nubian	Crossbred Boer	%
Respiratory frequency (mov/min)					
9 a.m.		16.06	17.30	16.22	
1 p.m.	19.56	23.78 ab	21.84 b	25.98 a	20.00
5 p.m.		18.06	17.20	19.55	
Rectal temperature (°C)					
9 a.m.		39.09	39.03	39.15	
1 p.m.	39.12	39.20 a	39.23 a	38.75 b	0.91
5 p.m.		39.17	39.22	39.13	

[1] Coefficient of variation. [2]Number of animals. Means followed by different lower case letters (a,b) in the rows are different from each other ($P<0.05$) by the Tukey test.

temperature, and consequently, an increase in THI (Table 4) higher than 70, a rate considered critical to the thermal comfort of the goats, according to the classification of Hahn (1993). Several authors (Brasil et al., 2000; Gomes et al., 2008; Souza et al., 2010; Souza et al., 2013; Roberto et al., 2014) worked with several breeds and found higher respiratory rates in the afternoon. Souza et al. (2010) found lower values of respiratory rate for ½ Saanen + ½ Boer crossbread animals than pure Saanen in the afternoon, showing greater adaptability of crossbred animals.

Table 4 - Mean values of temperature, air relative humidity and temperature and humidity index (THI) according to collection time.

Time	Air temperature (°C)	Air humidity (%)	THI [1]
9 a.m.	21.19	55.53	67.17
1 p.m.	26.86	33.03	72.15
5 p.m.	25.70	34.64	70.74

[1] Values achieved from the equation proposed by KELLY and BOND (1971), cited by BACCARI JUNIOR (2001).

Rectal temperature followed the pattern, being significant at 1 p.m., when the Alpine and Anglo-Nubian goats had higher rectal temperatures than crossbred Boer animals. Such result can be explained by a better adaptation of this breed to high temperatures due their African origin. Being the breath one of the regulatory mechanisms of body temperature, crossbred Boer goats raised respiratory rate to promote greater heat dissipation through the evaporation of water during respiration, aimed at maintaining homeothermy, and presented lower rectal temperature as a consequence. Brasil et al. (2000), Gomes et al. (2008), Sousa Junior et al. (2008); Souza et al. (2010); Souza et al., 2013 and Roberto et al., 2014 achieved results that corroborate with this study, in relation to higher rectal temperatures in the afternoon, with different goat breeds.

There was no influence of the treatment on the respiratory rate and rectal temperature. It would be expected that the animal treatment NS30 whose animals consumed less concentrated before parturition should consume a larger volume of material, and therefore have higher values in the physiological parameters, because according to Chandler (1987), the greater the share of roughage in the diet, the greater the heat production due to the fermentation and digestion. The opposite was shown by Gomes et al. (2008), who assessed levels of supplementation in Moxotó goats and concluded that the higher amount of concentrate, promoted higher values of respiratory rate and rectal temperature.

Graphs of percentages of goats in the Sun in function to breed and evaluation time in the four seasons are presented in Figure 2.

Early in the morning, all breeds remained in the sun (Figure 2), looking for shades from the time that the temperature had risen (Table 5). It is clear that this reaction by the goats can be correlated to the increase in the value of THI (Table 5), which presents critical values to thermal comfort, between 71 and 78 (Hahn, 1993), from 1 p.m. to 2 p.m. in autumn, from 11 a.m. in winter, 10 p.m. in the spring and throughout the period that the goats remained in pasture in the summer.

The graph representing the fall (Figure 2) shows the influence of the breed. In the period from 10:45 a.m. to 5:15 p.m., the Anglo-Nubian goats remained in the sun for longer than Alpine goats did. However, in the graphs representing winter, spring and summer, breed had an influence at 8:45 a.m. to 5:45 p.m., from 9:30 a.m. to 4: 45 p.m. and from 9:15 a.m. to 5:15 p.m., respectively. These results can be attributed to the low forage supply and milder temperatures for the winter and spring months, forcing the animals to graze in the sun for longer time.

The results of this experiment corroborate with Medeiros et al. (2008) and Silva et al. (2014), who reported that the Anglo-Nubian goats showed greater resistance to direct solar radiation, when compared to Saanen and Alpine, respectively.

CONCLUSIONS

The crossbred Boer goats maintained lower rectal temperature by means of increasing respiratory rate, when compared to the other breeds, embora outros mecanismos possam estar envolvidos, mas não foram avaliados, although other mechanisms may be involved but have not been evaluated.

Table 5 - Mean values of temperature (ºC), air relative humidity (RH %) and THI in the four seasons.

Time	Season of the year											
	Autumn			Winter			Spring			Summer		
	T°C	RH%	THI[1]	T°C	RH%	THI[1]	T°C	RH%	THI[1]	T°C	RH%	THI[1]
8 a.m.	19.3	58.0	62.98	17.8	68.6	64.28	22.0	71.0	69.32	23.5	64.6	70.60
9 a.m.	21.6	48.3	65.39	19.6	61.6	66.89	22.7	64.5	69.78	25.3	60.9	72.79
10 a.m.	23.6	39.3	67.21	21.5	50.3	68.65	24.5	56.0	71.32	26.6	57.0	74.16
11 a.m.	25.3	35.8	68.73	23.0	45.3	70.07	26.0	53.7	72.95	27.8	52.0	75.35
12 a.m.	28.3	29.0	69.36	24.0	38.8	72.73	26.2	51.0	72.68	28.7	48.2	76.05
1 p.m.	29.8	23.3	70.13	25.0	34.3	73.71	26.5	52.5	73.03	29.6	45.8	76.81
2 p.m.	30.6	20.3	70.10	25.1	31.8	74.10	27.0	55.5	73.61	29.9	41.9	76.63
3 p.m.	31.0	19.0	69.97	25.3	28.6	74.11	25.5	50.0	71.07	30.0	41.2	76.65
4 p.m.	30.3	19.8	67.72	23.3	28.3	73.61	25.5	35.0	69.97	28.0	52.1	74.98
5 p.m.	29.5	19.1	66.73	22.3	30.0	72.55	25.5	38.0	70.36	27.9	51.3	74.76
6 p.m.	26.6	22.3	65.36	21.0	32.0	70.02	25.2	41.0	70.43	27.7	48.8	74.37

[1] Values achieved from the equation proposed by KELLY and BOND (1971), cited by BACCARI JUNIOR (2001).

Anglo-Nubian goats presented higher resistance to direct sun radiation, remaining longer in the sun, being more suitable for pasture production system.

Despite the changes in environmental variables, the animals showed values of physiological parameters within normal limits for the goats.

Concentrate supplementation did not affect the physiological parameters and tolerance to

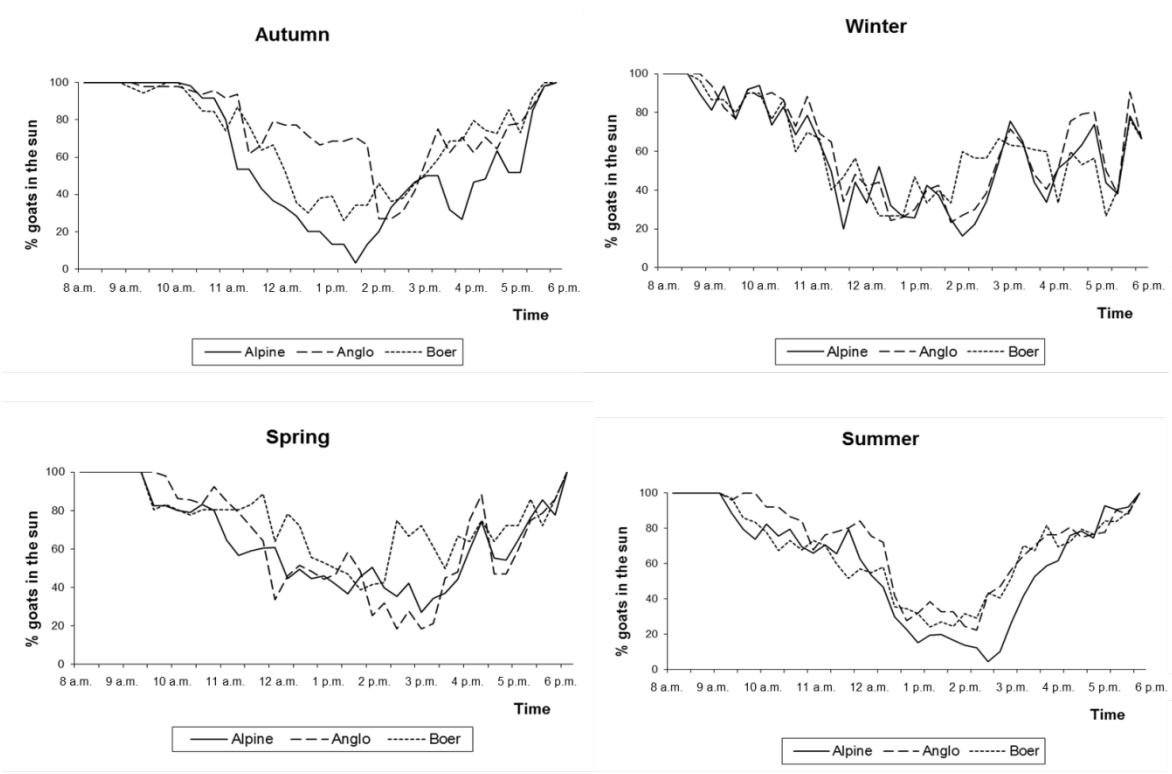

Figure 2 - Percentages of goats in the Sun, evaluated by χ^2 test in function of the racial group and evaluation time in the four seasons of the year.

direct sun radiation of the goats.

ACKNOWLEDGEMENTS

We thank Fundação de Amparo à Pesquisa do Estado de São Paulo for granting the scholarship (Processo Nº 2010/04566-0).

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