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ANIMAL PRODUCTION

Concentrate intake and performance of dairy calves subjected to programs of supplementary lighting

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ABSTRACT: *This research aimed to assess Girolando calves' concentrate intake and performance when placed in shelters with distinct roofing materials and programs of supplementary lighting during the milk-feeding stage. In order to so, we used a completely randomized design with a 3×3 factorial arrangement, with three replications. Females Girolando calves (n=27) were assigned in individual shelters at random with 3 different roofing materials (fiber cement tile, recycled tile and thatched roofs) and subjected to three lighting programs (12, 16 and 20 hours). No interaction was observed between roofing material and lighting programs, whilst no significant effect (P>0.05) was observed among the roofing materials. The supplementary lighting, by providing greater light exposure time, has stimulated intake and therefore, significantly affected (P<0.05) the concentrate intake and performance of the animals that were subjected to 20 hours of light.*

Key words: *animal performance, dairy cattle, light duration, weight gain.*

Consumo de concentrado e desempenho de bezerras leiteiras submetidas a programas de iluminação suplementar

RESUMO: *Essa pesquisa teve como objetivo avaliar o consumo de concentrado e o desempenho de bezerras da raça Girolando quando colocadas em abrigos com materiais de cobertura e programas de iluminação suplementar distintos, durante a fase de aleitamento. Para tal, nós utilizamos o delineamento experimental inteiramente casualizado em arranjo fatorial 3×3, com três repetições. As bezerras Girolando (n=27) foram distribuídas ao acaso em abrigos individuais, com materiais de cobertura distintos (telha de fibrocimento, telha reciclada e cobertura com palha), e sujeitas a três programas de iluminação (12, 16 e 20h). Não houve interação entre os mateiral de cobertura×programas de iluminação, ao mesmo tempo que não foi observado efeito significativo (P>0,05) para os materiais de cobertura. A iluminação suplementar, proporcionando maior tempo de luz, tem estimulado a ingestão, e, portanto, apresentou efeito significativo (P<0,05) no consumo de concentrado e desempenho dos animais submetidos a 20h de iluminação.*

Palavras-chave: *desempenho animal, bovino leiteiro, duração de luz, ganho de peso.*

INTRODUCTION

Calves' development is one of the most essential activities in dairy farming. It regulates production systems' feasibility, e.g., herd's renewal. More recently, it has been shown that fostering rapid growth early in life may have positive consequences on future milk performance (SOBERON et al., 2012) and survivability to second lactation. To obtain good results for dairy calf performance after weaning, animal consumption of adequate quantities of solid food is imperative before complete milk withdrawal (MILLER-CUSHON et al., 2013).

The behavior of calves is influenced by supplemental lighting at night with effect on feed intake compared to animals without supplemental lighting (OSBORNE et al., 2007). Lactating cows have increased their milk production after being subjected to supplementary lighting (DAHL et al., 2000), in addition to stimulating weight gain in heifers. In studies by RIUS & DAHL (2006) heifers that were exposed to long photoperiods exhibited greater growth and earlier puberty compared to heifers that were exposed to short photoperiods. However, most dairy breeds suffer heat stress in hot regions with high incidence of radiation. When in a hot environment, shade provision can help animals to regulate their body temperature by reducing incoming thermal radiation (CAMPOS et al., 2005).

This research aimed to analyze Girolando calves' concentrate intake and performance placed

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in individual shelters with distinct roofing materials and programs of supplementary lighting during milk-feeding stage.

MATERIALS AND METHODS

This research was conducted in the Várzea Alegre Farm, which is located in the municipality of Pesqueira, Agreste Region, State of Pernambuco, Brazil, at 8º17'10" south latitude, 36º53'03" west longitude and 800m altitude. Mean annual temperature and rainfall are 24.8ºC and 730mm, respectively. The climate is classified as semiarid (Bsh), according to Köppen climate classification.

This experiment was carried out from January to March 2012 and lasted 55 days. Twenty-seven female Holstein × Gir calves that were 2nd week old and weighed 40.24kg and heart girth 0.79m were used in this study. Calves were placed in individual shelters throughout the experimental period that were 1.80m long and 1.50m wide, had a mean height of 1.45m; the shelters had a sand bed on the soil surface and no side closure. Covers were fixed onto shelters with three degrees of tilt and longitudinal orientation in the east-west direction.

Three types of roofing materials were studied: 4-mm thick fiber cement tile, 6-mm thick recycled tile and 50-mm thick thatched roofs (palm, *Syagrus coronata*). Association between roof type and the following programs of supplementary lighting were also considered: natural light + 4h of supplementary lighting (16h of light), natural light + 8h of supplementary lighting (20h of light), and natural light (12h of light).

Shelters were equipped with 40-W incandescent lamps with a 415-lumen luminous flux and 450 to 850-nm wavelength that were placed 1.40m aboveground, a position that enables proper illumination of animal surroundings without producing heat for calves. Lamps were lit daily at 18h00 (local time) and were left on with no discontinuance until illumination program was over with the aid of a programmed timer for each treatment.

In the first three days of life, calves received 4L of colostrum in individual buckets divided into two meals daily, half in the morning (05h00) and half in the afternoon (17h00), according to the farm management. After the colostrum phase, the same amount of whole milk (4L) was supplied to animals, also divided into two meals per day (2L - morning and 2L - afternoon) until weaning (70 days old). There were no leftovers of the milk given to the animals. Every animal has consumed the same quantity of milk daily. The milk given to the animals was accounted in the dry matter intake. During this phase the animals did not receive other type of solid food.

Calves had ad libitum access to pelleted concentrate with the following nutritional composition: dry matter (87.0%), crude protein (18.0%), ether extract (2.5%), fibrous matter (7.0%), mineral matter (8.0%), maximum calcium (1.2%), minimum calcium (0.96%), minimum phosphorus (0.5%), maximum FDA (7.6%); vitamin A (4,000.00IU kg^{-1}), vitamin D3 (1,000.00IU kg^{-1}), vitamin E (60.00IU kg^{-1}), zinc (7.6%), manganese (8.5%), cobalt (0.04%), iodine (0.01%), copper (1.8%), selenium (0.05%), monensin sodium (3.6%), and antioxidants (0.041%). During the study, animals were given, individually, pelleted concentrate, milk and water in buckets.

To quantify the day and night concentrate consumption, the food remains were weighed at 06h00 and 18h00 prior to each new supply with the aid of a digital scale (15.0kg x 0.002kg). The remains of the diets were weighed and discarded.

Measurements of calves' weights and heart girth were performed weekly in the morning prior to milk supply, beginning at 3rd week of age and ending at 10th week of age, to calculate the weight gain. An electronic scale (300.0kg x 0.100kg) with a fixed chute-type containment structure was used.

Dry bulb temperature (DBT, °C) and relative humidity (RH, %) were hourly recorded inside and outside of individual houses through data loggers model HOBO U12-12 (Onset Computer Corporation Bourne, MA, USA). The data loggers were placed inside the shelters at the geometric center of the facility 1.40m aboveground. In the external environment, the device was place in the meteorological shelter 1.50m aboveground.

A completely randomized design was used following a 3×3 factorial arrangement. Twenty-seven female calves were used and were distributed at random in individual shelters with three roofing materials and three periods of artificial lighting; three animals were exposed to each treatment (three replications).

Analysis of variance was performed for concentrate intake, dry matter intake, body weight, weight gain, heart girth and feed efficiency using Statistical Analysis System (SAS, version 8), using the model $Yij = \mu + Ri + LDj + (R \times LD)ij + Eij$, Yij is the value of each variable, μ is general mean, Ri is the roof effect (I = 1, 2, 3), LDj is effect of light duration j (j = 1, 2, 3), (R × LD) ij is the interaction effect of roof i and light duration j, and Eij is the effect of the error associated with each observation.

Inferences were assessed using the Tukey method for a significance level of 95%.

RESULTS AND DISCUSSION

There was little thermal difference among internal environment of the individual shelters covered with each type of roofing material and the external environment, as of temperature and the relative humidity. There was little variation in the maximum mean air temperature values among the roofing materials, being 30.5, 31.0, 31.8 and 30.6°C for the recycled tile, thatched roof, and fiber cement tile covered shelters and external environment, respectively, at 13h00. The minimum relative humidity was approximately 40% for all shelters and external environment (Figure 1).

This little variation occurred due to the lack of side locks, which in turn favors a greater circulation of inside air. Within the studied period, the air temperature exceeded 26°C between 09h00 and 17h00, and this time of day is regarded as critical for young cattle (BAÊTA & SOUZA, 2010).

There is little knowledge on the proper material to roofing of shelters for dairy calves under Brazilian semiarid region, because fiber cement tiles was a tradition in the region. However, other materials are becoming an alternative to substitute the fiber cement, as recycled tile and thatched roof in the region, since these have good thermal properties, with lower influence of the absorbance and thermal conductivity. Recently the straw is being used a lot to cover the shelters, due to the ease of acquisition, because the Northeast is the largest producer of coconut of the Brazil and have available high amount of this material.

Roof type did not present a significant effect on concentrate intake (fiber cement tile = 0.585±0.307kg d^{-1}, recycled tile = 0.549±0.269kg d^{-1}, thatched roof = 0.438±0.145kg d^{-1}), dry matter intake (fiber cement tile = 1.015±0.331kg d^{-1}, recycled tile = 0.983±0.240kg d^{-1}, thatched roof = 0.885±0.128kg d^{-1}), daily weight gain (fiber cement tile = 0.604±0.233kg $animal^{-1}$, recycled tile = 0.624±0.142kg $animal^{-1}$, thatched roof = 0.570±0.112kg $animal^{-1}$), feed efficiency (fiber cement tile = 0.595±0.084kg kg^{-1}, recycled tile = 0.635±0.039kg kg^{-1}, thatched roof = 0.644±0.057kg kg^{-1}) and heart girth (fiber cement tile = 0.950±0.070m, recycled tile = 0.939±0.060m, thatched roof = 0.943±0.030m), and there was no interaction (P>0.05) between roofing materials and supplementary lighting programs for the same variables.

No significant differences (P>0.05) were observed in concentrate intake by calves during

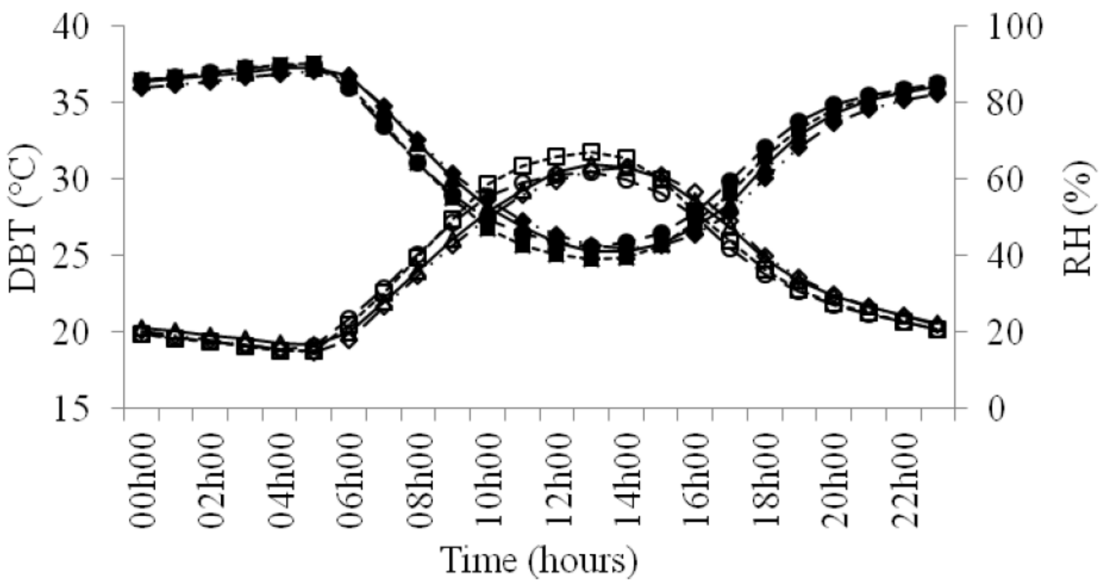

Figure 1 - Mean hourly temperature and relative humidity inside the individual shelters and in the external environment during the days of the experiment. DBT = dry bulb temperature: fiber cement tile (□), recycled tile (○), thatched roof (Δ) and external environment (◊); RH = relative humidity: fiber cement tile (■), recycled tile (●), thatched roof (▲) and external environment (♦).

the day and during the night between the programs of lighting until the 7th weeks of age. However, calves under 20h of light significantly increased their concentrate intake ($P<0.05$) during the night compared with those that had no additional lighting (12h of light) after 7th week of age (Table 1).

The animals have been fed milk in the late afternoon (17h00) and would not ingest concentrate in the early night. However, the animals later returned to consume concentrate, and there was no supplemental lighting at 12 and 16h of light; therefore, the concentrate intake by these calves was reduced. In contrast, the calves under the 20h of light had more available light and were thus encouraged to ingest more concentrate.

To obtain satisfactory results regarding dairy calves' performance after weaning, adequate solid food consumption needs have to be met, even during the milk-feeding stage, before completely withdrawing the milk (MILLER-CUSHON et al., 2013). One method for stimulating concentrate intake by calves prior to weaning is a gradual reduction of the milk supply for a period of time until complete weaning; this requires more management attention and workmanship. Another method for stimulating feed intake is group social facilitation. Therefore, calves' housing in individual shelters with supplemental artificial light is a practice that can be used to stimulate the concentrate intake of calves during milk-feeding stages (OSBORNE et al., 2007).

From the 3rd to the 10th week of age, the daily mean consumption of the calves without illumination (0.418kg) and that of the calves under 16h of light (0.460kg) were close to the 0.440kg that was observed from the 2nd to the 8th week of age by CUNHA et al. (2007). However, the animals in this research under 20h of light (12h+8h of supplementary light) consumed a daily mean of 0.694kg of concentrate from the 3rd to the 10th week. Importantly, calves at 8 weeks of age under 20h of light consumed 0.952kg of concentrate (Table 1), which was much greater than the 0.800kg day^{-1} recommendation of LOPES et al. (2010) as a criterion for weaning. According to ALMEIDA et al. (2015) the increasing daily lighting period stimulated the consumption of concentrate and allowed weaning of calves in shorter period, promoting a reduction of 20% in the cost of rearing animals during milk feeding stage. Therefore, it is evident that age at first childbirth in cow has a great involvement in stablishing cattle livestock structure. If the age at first birth were high, areas designated to such activity would be jeopardized, thereby compromising calves during lactation. Therefore, the use of a lighting system for dairy calves becomes feasible, promoting satisfactory weight gains. Consequently, age at first birth is reduced and the animals will produce faster, hence generating income to the farmer.

Table 2 shows the mean consumption of concentrate and dry matter from the 3rd to 6th weeks and from 7th to 10th weeks of age, the initial and final weights at 3rd and 10th week of age, daily gain and total weight over the 55 days corresponding to the experimental period, and feed efficiency of the calves between the programs of lighting (12, 16 and 20h of light).

Table 1 - Mean values and standard deviation of the concentrate intake during the daytime and nighttime periods of the animals subjected to different light durations during the milk-feeding stage from the 3rd to the 10th week of age.

Mean concentrate intake, kg	Light duration[1]							
	Daytime[2]				Nighttime[3]			
	12h	16h	20h	*P*-value	12h	16h	20h	*P*-value
3rd week	0.125ᵃ±0.057	0.069ᵃ±0.042	0.121ᵃ±0.057	0.160	0.058ᵃ±0.043	0.058ᵃ±0.038	0.088ᵃ±0.045	0.382
4th week	0.143ᵃ±0.121	0.092ᵃ±0.050	0.152ᵃ±0.113	0.459	0.112ᵃ±0.090	0.072ᵃ±0.039	0.148ᵃ±0.089	0.334
5th week	0.166ᵃ±0.163	0.125ᵃ±0.072	0.196ᵃ±0.135	0.547	0.154ᵃ±0.100	0.108ᵃ±0.067	0.211ᵃ±0.125	0.287
6th week	0.153ᵃ±0.124	0.179ᵃ±0.123	0.213ᵃ±0.125	0.673	0.121ᵃ±0.116	0.150ᵃ±0.128	0.209ᵃ±0.135	0.481
7th week	0.171ᵃ±0.115	0.164ᵃ±0.096	0.257ᵃ±0.150	0.410	0.125ᵃ±0.110	0.144ᵃ±0.116	0.267ᵃ±0.150	0.281
8th week	0.232ᵃ±0.164	0.263ᵃ±0.133	0.472ᵃ±0.180	0.141	0.199ᵃ±0.146	0.254ᵃᵇ±0.145	0.480ᵇ±0.212	0.045
9th week	0.428ᵃ±0.260	0.448ᵃ±0.186	0.643ᵃ±0.224	0.124	0.313ᵃ±0.182	0.397ᵃᵇ±0.198	0.661ᵇ±0.251	0.012
10th week	0.530ᵃ±0.212	0.621ᵃ±0.211	0.674ᵃ±0.203	0.396	0.351ᵃ±0.202	0.535ᵃᵇ±0.223	0.757ᵇ±0.276	0.009

Means followed by the same letter in the same row in the same period of the day are not statistically different ($P>0.05$) by the Tukey test.
[1]Light duration: 12h = 12 hours of natural light; 16h = 12 hours of natural light + 4 hours of supplementary light; 20h = 12 hours of natural light + 8 hours of supplementary light; 2Concentrate intake during the daytime (06h00 to 18h00); 3Concentrate intake during the nighttime (18h00 to 06h00).

Table 2 - Mean values and standard deviations of concentrate and dry matter intake, weight gain, feed efficiency and heart girth in the calves exposed to different light durations.

Calves performance	-----------------------------Light duration[1]-----------------------------			
	12h	16h	20h	P-value
Mean concentrate intake from the 3rd to the 6th week of age (kg d^{-1})	0.249^{a}±0.210	0.213^{a}±0.112	0.334^{a}±0.249	0.465
Mean concentrate intake from the 7th to the 10th week of age (kg d^{-1})	0.587^{a}±0.319	0.706^{ab}±0.278	1.052^{b}±0.480	0.048
Mean dry matter intake from the 3rd to the 6th week of age (kg d^{-1})	0.719^{a}±0.251	0.688^{a}±0.281	0.794^{a}±0.331	0.465
Mean dry matter intake from the 7th to the 10th week of age (kg d^{-1})	1.017^{a}±0.185	1.122^{ab}±0.099	1.427^{b}±0.219	0.048
Final body weight (kg animal^{-1})	66.800^{a}±6.737	71.567^{ab}±7.832	81.233^{b}±8.123	0.018
Daily weight gain, kg animal^{-1})	0.499^{a}±0.106	0.571^{ab}±0.119	0.726^{b}±0.183	0.007
Total weight gain (kg animal^{-1})	27.489^{a}±5.840	31.444^{ab}±6.522	39.933^{b}±7.898	0.007
Feed efficiency (kg kg^{-1})	0.575^{a}±0.097	0.631^{a}±0.081	0.654^{a}±0.061	0.056
Final heart girth (m)	0.901^{a}±0.030	0.940^{ab}±0.040	0.991^{b}±0.060	0.002

Means followed by the same letter in the same row are not statistically different (P>0.05) by the Tukey test. [1]Light duration: 12h = 12 hours of natural light; 16h = 12 hours of natural light + 4 hours of supplementary light; 20h = 12 hours of natural light + 8 hours of supplementary light.

Calves' concentrate intake did not differ (P>0.05) among treatments with artificial lighting and those without supplementary light during the first four experimental weeks, both of which showed mean consumption of 0.265kg d^{-1}. However, the concentrate intake was higher (P<0.05) for the animals under 20h of light from the 7th week until the end of the experiment, with differences of 0.465 and 0.346kg compared to the calves under 12 and 16h of light, respectively (Table 2). The addition of solid food to the liquid diet of calves from the second week of age, when the animals are able to digest significant amounts of solid food, is important; however, this amount is regulated by the volume, metabolic activity, rumen motility and quality of the food provided (KHAN et al., 2011). Physiologically, dark periods activate melatonin secretion, this hormone is synthetized and secreted by pineal gland, whose neural control depends on light-dark cycle. Thus, melatonin influences the reduction of the digestive system motility and thyroid hormones. This physiological response reduces animals' feed intake and metabolism (AMARAL et al., 2014). So, cattle exposed to long periods of lighting showed greater dry matter ingestion when compared to those without long lighting exposure (DAHL et al., 2000).

The mean daily mean gain and total weight gain for the calves exposed to 0, 4 and 8h of supplementary light are presented in table 2. These resulted confirmed those of OSBORNE et al. (2007), who reported that 84% of the variation in the weight gain of calves occurred before 56 days of age, which is justified by the amount of intake. The difference between the daily mean gain (0.226kg), and total weight gain, (12.444kg) of calves exposed to 20 and 12h of light accounts for intake of the animals (Table 1).

The final body weight 10th week of age (70 days) of the calves exposed to 8h of supplementary light was 14.433 and 9.666kg, respectively highest compared with calves exposed to 0 and 4h of supplementary light (Table 2). The highest body weight at 10th week of age observed in the former animals (Table 2), demonstrate the efficiency of supplemental artificial light in stimulating concentrate consumption by calves during the milk-feeding stage; increased concentration consumption can result in early weaning, which is characterized by daily consumption of concentrate (0.800kg d^{-1}), according to LOPES et al. (2010). In fact, the greatest weight gain observed in this study was in the calves under 20h of light, whose weight gain was significantly superior (P<0.05) in comparison with the weight gain of calves without supplemental lighting (Table 2), as evidenced by the highest concentrate intake (Table 1). Thus, supplemental lighting can be adopted to stimulate concentrate consumption in calves during the milk-feeding stage so that calves develop normally post weaning.

The daily gain, total weight gain and final body weight values verified in the present study agree with those of OSBORNE et al. (2007), who observed higher means for animals subjected to a long light duration, with mean daily weight gain values of 0.560 and 0.746kg, total weight gain values of 30.2 and 39.2kg and live and final weights of 73.4 and

80.5kg for calves without additional lighting and with supplementary light, respectively, until 56 days of age.

Feed efficiency did not significantly differ (P>0.05) among calves subjected to the various light durations from the 3rd to 10th weeks of age because the mean weight gain was proportional to dry matter intake. The mean feed efficiency was 0.620kg weight gain per kg consumed dry matter (Table 2). Feed efficiency (0.620kg kg^{-1}) in this study was greater than that (0.554) reported by CUNHA et al. (2007), who reported no difference in Girolando calves' feed efficiency during the milk-feeding stage, also because weight gain was proportional to concentrate intake.

The average increase in heart girth of the calves subjected to the greatest amount of supplementary lighting was 0.09m (P<0.05) compared to that animals that had access to 12h of light (Table 2). Heart girth was highly (r=0.79, P<0.001) correlated with average daily weight gain, which in turn was related to dry matter intake; these results corroborated those obtained by OSBORNE et al. (2007).

CONCLUSION

The roofing materials did not affect the concentrate intake and performance of dairy calves during the milk-feeding stage. Calves' concentrate intake during the aforementioned stage was higher during night period for animals with 20h of light, after the seventh week old. The 20h of light positively influenced calves' daily weight gain, live weight and heart girth increase during milk-feeding stage, compared to animals which had access to natural light.

BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

This experiment was approved by the Ethics Committee on Animal Use of the Universidade Federal de Pernambuco (UFRPE) – Recife (CEUA - #019/2014).

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