DOI: 10.5433/1679-0359.2016v37n1p483

Intake, milk yield, and physiological parameters of lactating cows fed on diets containing different quantities of xiquexique (*Pilosocereus gounellei)*

Consumo, produção de leite e parâmetros fisiológicos de vacas em lactação alimentadas com dietas contendo diferentes quantidades de xiquexique (*Pilosocereus gounellei*)

Rafael Nogueira Furtado[1*]; Maria Socorro de Souza Carneiro[2]; Elzânia Sales Pereira[2]; Emilson Costa Moreira Filho[3]; João Avelar Magalhães[4]; Sônia Maria Pinheiro de Oliveira[2]

Abstract

The aim of the present study was to evaluate the effect of substituting Tifton-85 grass hay with different quantities of xiquexique (*Pilosocereus gounellei*) (0, 12, 24, and 36%) on the nutrient intake and physiological responses of lactating dairy cows. Eight multiparous crossbred cows at approximately 100 days in milk, with an average milk yield of 15 kg of milk per day^{-1}, and an average body weight (BW) of 465.20 ± 39.37 kg, were distributed in a 4 × 4 double Latin square design. Each experimental period lasted 16 days, consisting of 10 days for adaptation and 6 days for data collection, giving a total of 64 experimental days. The roughage: concentrate ratio was 60:40, on a dry matter (DM) basis. The DM intake, expressed in kg day^{-1}, was affected quadratically by the levels of xiquexique in the diets. The intakes of DM, expressed in % BW and g kg$^{-0.75}$, and neutral detergent fiber (NDF) in the three units analyzed (kg day^{-1}, % BW, and g kg$^{-0.75}$), as well as the intakes of organic matter (OM), crude protein (CP), ether extract (EE), and total carbohydrates (TC), expressed in kg/day^{-1}, decreased linearly with the levels of xiquexique in the diet. Milk yield (kg day^{-1}) was reduced by the addition of xiquexique into the diet, but feed efficiency was not influenced. Water intake from feed (WI_{Feed}), expressed in kg day^{-1} and % BW, incresed linearly with increasing levels of xiquexique in the total diet, while voluntary water intake, expressed in kg day^{-1} and % BW ($WI_{Voluntary}$), decreased linearly. The total water intake (WI_{Total}) was not affected by experimental treatments. Participation of $WI_{Voluntary}$ in the WI_{Total} linearly reduced with Xiquexique levels in the diet. The respiratory rate and surface temperature during both periods of the day (morning and afternoon), and rectal temperature during the morning were not influenced by the levels of xiquexique in the diet. Therefore, xiquexique can be utilized in the feeding of medium and high producing dairy cows, as a means of reducing nutrient intake, milk yield, and voluntary consumption of water without changing feed efficiency or the animals' physiological responses.

Key words: *Cactaceae*, heat stress, respiratory rate, water intake

[1] Dr. em Zootecnia, Universidade Federal do Ceará, UFC, Fortaleza, CE, Brasil. E-mail: rafaelnfurtado@yahoo.com.br
[2] Prof[as] Dr[as], Dept[o] de Zootecnia, UFC, Fortaleza, CE, Brasil. E-mail: msocorro@ufc.br; elzania@hotmail.com; soniace@ufc.br
[3] Discente do Curso de Doutorado em Zootecnia, UFC, Fortaleza, CE, Brasil. E-mail: emilsonzootecnia@hotmail.com
[4] Dr. Pesquisador, Empresa Brasileira de Pesquisa Agropecuária, EMBRAPA, Centro de Pesquisa Agropecuária do Meio-Norte, Parnaíba, PI, Brasil. E-mail: joao.magalhaes@embrapa.br
[*] Author for correspondence

Recebido para publicação 17/03/15 Aprovado em 17/09/15

Resumo

O presente estudo foi conduzido com o objetivo de avaliar o efeito de diferentes níveis de xiquexique (0, 12, 24 e 36%) em substituição ao feno de capim Tifton 85 sobre o consumo de nutrientes e respostas fisiológicas de vacas leiteiras em lactação. Foram utilizadas oito vacas mestiças pluríparas, com aproximadamente 100 dias em lactação, produção média de 15 kg de leite dia^{-1} e com peso corporal (PC) médio de 465,20 ± 39,37 kg. Os animais foram distribuídos em delineamento em quadrado latino 4x4, duplo. Cada período teve duração de 16 dias, sendo 10 dias de adaptação e 6 dias de coleta de dados, totalizando 64 dias experimentais. A relação volumoso:concentrado foi de 60:40, com base na matéria seca (MS). O consumo de MS, expresso em kg dia^{-1}, foi influenciado de forma quadrática pelos níveis de xiquexique nas rações. O consumo de MS expresso em % PC e g kg$^{-0,75}$ e fibra em detergente neutro (FDN) nas três unidades analisadas (kg dia^{-1}, % PC e g kg$^{-0,75}$), assim como, os consumos de matéria orgânica (MO), proteína bruta (PB), extrato etéreo (EE) e carboidratos totais (CT) expressos em kg dia^{-1}, apresentaram comportamento linear decrescente com os níveis de xiquexique na ração. A produção de leite (kg dia^{-1}) decresceu, mas a eficiência alimentar não foi influenciada pela introdução do xiquexique na ração. O consumo de água via alimento ($CA_{Alimento}$) expresso em kg dia^{-1} e % PC aumentou linearmente com a elevação da participação do xiquexique na ração total, entretanto, o consumo voluntário de água ($CA_{Voluntário}$) expresso em kg dia^{-1} e % PC diminui linearmente. O consumo de água total (CA_{Total}) não foi influenciado pelos tratamentos experimentais. A participação do $CA_{Voluntário}$ no CA_{Total} reduziu linearmente com os níveis de xiquexique na ração. A frequência respiratória e temperatura superficial nos dois turnos (manhã e tarde) e temperatura retal no turno da manhã não foram influenciadas pelos níveis de xiquexique nas rações experimentais. A temperatura retal à tarde foi reduzida com os níveis de xiquexique na ração. O xiquexique pode ser utilizado na alimentação de vacas leiteiras de média e baixa produção, pois, promove redução do consumo de nutrientes, produção de leite e consumo voluntário de água, sem alterar a eficiência alimentar e as respostas fisiológicas.

Palavras-chave: *Cactaceae*, estresse térmico, frequência respiratória, ingestão de água

Introduction

In hot climates, heat stress is one of the main factors limiting cattle production, due to the influence of high temperatures on their food intake, productivity (weight gain and milk production), and reproductive performance (DAMASCENO et al., 1998; AVENDANO et al., 2006; MACEDO et al., 2011). In addition to high temperatures and poor forage quality, water is frequently a factor limiting animal production. In the northeast region of Brazil, dairy-cattle farming has always been of great economic and social importance. In this region, strategic dietary management is essential to increase the productivity of dairy herds, especially during the dry season. This requires local nutritional alternatives, with good nutritional value and a low cost.

Water intake typically comprises the total water contained in the feed, plus the total amount of water consumed voluntarily by the animal. The water requirement of an animal is directly related to its productivity. A lactating cow, for instance, ingests on average 5 to 10 liters (L) of water per kilogram of dry matter consumed, depending on fluctuations in room temperature and milk production. Several studies have shown a reduction in water intake following the inclusion of cacti in the diets of ruminants' (COSTA et al., 2012; LIMA et al., 2003; TEGEGNE et al., 2007). This information is particularly important for semi-arid regions, where the scarcity of water, both in terms of quantity and quality, has been a limiting factor to dairy cattle farming (CARVALHO et al., 2005). Therefore, feeds adapted to these climatic conditions, and which meet the requirements of herds, should be sought to improve the livestock productivity of this region.

Pilosocereus gounellei, commonly known in Brazil as xiquexique, is a cactus widely found across the northeast of Brazil. Its morpho-physiological characteristics, which allows its development in the semi-arid region, makes it useful as a source of nutrients and water for the feeding of herds (SILVA et al., 2011). Thus, research evaluating its use in animal diets is required in order that nutritional strategies can be established that optimize the use of this species in the diets of lactating cows. Therefore, the objective of the present study was to evaluate the nutrient intake, milk yield, and physiological responses of lactating dairy cows fed xiquexique (*Pilosocereus gounellei*) based diets.

Material and Methods

The experiment was conducted between November 2012 to January 2013 at Escola Agrícola Cenecista Francisca Cavalcanti Fialho, located in the District of Barra Nova, in Tauá-CE, Brazil (6°00'11'' S latitude and 40º17'34'' W longitude). The city of Tauá has a tropical, semi-arid dry climate with a rainy season from February to April, with annual precipitation ranging from 550 to 650 mm.

Eight multiparous cows between the second and fifth lactation, with an average production of 15 kg of milk per day^{-1}, and an average body weight of 465.20 ± 39.37 kg, were distributed into four 4 × 4 double Latin squares (4 periods, 4 levels of xiquexique, and 8 animals). Each experimental period lasted 16 days, consisting of 10 days for adaptation and 6 days for data collection, giving a total of 64 experimental days. Animals were kept in individual stalls with a masonry floor and provided with feeders and drinkers to control food and water intake.

The experimental treatments consisted of substituting Tifton-85 grass hay for xiquexique (0, 12, 24, and 36%) in the overall diet, while maintaining a roughage:concentrate ratio of 60:40, on a dry matter basis. The experimental diets were balanced based on the results of a chemical analysis of the ingredients (Tables 1 and 2), in order to meet the nutritional requirements of lactating cows with an average production of 15 kg of milk per day, as recommended by The National Research Council (NRC, 2001). The xiquexique was harvested daily and transported from the Caatinga biome. The thorns were subsequently burned with a gas flamethrower prior to grinding in a forage machine.

Table 1. Chemical composition of the ingredients used in the experimental diets.

Ingredient	DM	OM	CP	EE	NDF	ADF	TC	NFC
	g kg^{-1}	g kgDM^{-1}						
Ground corn	905.12	987.02	66.79	42.02	148.79	44.26	878.21	729.43
Soybean meal	898.92	934.75	431.69	18.64	137.50	70.81	484.41	346.91
Wheat bran	912.53	942.45	150.13	44.04	422.64	110.01	748.28	325.64
Xiquexique	122.06	864.87	38.84	7.41	238.54	158.70	818.61	580.08
Tifton-grass hay	862.66	918.28	96.50	19.24	746.47	332.12	802.54	56.08

DM, dry matter; OM, organic matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fiber; ADF, acid detergent fiber; TC, total carbohydrates; and NFC, non-fiber carbohydrates.

Table 2. The composition and proportion of ingredients used in the experimental diets (g kg DM^{-1}).

Centesimal composition	Level of xiquexique			
	0%	12%	24%	36%
Tifton-grass hay	60.00	48.00	36.00	24.00
Xiquexique	0.00	12.00	24.00	36.00
Ground corn	19.02	17.20	15.39	13.64
Soybean meal	13.64	15.76	17.92	20.06
Wheat bran	6.34	6.04	5.69	5.30
Mineral premix	1.00	1.00	1.00	1.00
Chemical composition				
Dry matter (g kg^{-1})	870.22	781.19	692.16	603.13
Organic matter (g kg DM^{-1})	925.95	918.56	911.19	903.83
Crude protein (g kg DM^{-1})	139.00	139.57	140.23	140.80
Ether extract (g kg DM^{-1})	24.87	22.95	21.02	19.09
Neutral detergent fiber (g kg DM^{-1})	521.72	459.72	397.56	335.31
Acid detergent fiber (g kg DM^{-1})	224.32	203.88	183.41	162.91
Total carbohydrates (g kg DM^{-1})	762.08	756.04	749.94	743.94
Non-fiber carbohydrates (g kg DM^{-1})	240.35	296.32	352.38	408.63

During the experiment, the diets were provided at 06h00 and 16h00, and adjusted so that 10% of the total feed supplied remained as orts. Water was permanently available to the animals. Feed intake was determined between the 11th and 16th days of each experimental period by weighing and sampling the material supplied and the orts from each animal daily. Samples were identified and stored in a freezer at -10ºC. At the end of the experiment, samples were thawed and homogenized to form composite samples per animal/period, and an aliquot of approximately 500 g was collected, weighed, and pre-dried in a forced-air oven at 55 ºC, until it reached a constant weight. The samples were processed in knife mills (1 mm) and conditioned in containers previously identified for later analyses. The methodology proposed by AOAC (1990) was used to determine the dry matter (DM), mineral matter (M)), ether extract (EE), and crude protein (CP) levels. To quantify the neutral (NDF) and acid (ADF) detergent fiber, however, the method proposed by Van Soest et al. (1991) was adopted. The quantity of total carbohydrates (TC) and non-fiber carbohydrates (NFC) was obtained as recommended by Sniffen et al. (1992): TC = 100 - (%CP + %EE + %Ash) and NFC = 100 - (%CP + %NDF + %EE + %Ash). Milk production was measured twice daily during all experimental periods. Feed efficiency was calculated as the ratio between the average milk yield and the average dry matter intake.

The temperature of the air and relative humidity of the air was measured using a digital thermohygrometer, with measurements taken both in the sun and in the shade, as well as inside the facilities at 1.2 m above the soil, daily at 07h30 and 14h30 during the 11th and 13th day of each experimental period. The temperature-humidity index (THI) was calculated for each experimental period in the sun and in the shade, by the model defined by Thom (1959): THI = (0.8 × T + (RH (%)/100) × (T - 14.4) + 46.4), where T = room temperature (ºC); and RH = relative humidity of the air (%).

The voluntary water intake of each animal was evaluated daily during each experimental period, by observing markings made on the side of the drinkers twice daily. Water intake from the feed was calculated by the following formula: (Feed supplied (kg fresh matter) - Feed supplied (kg DM)) - (Orts (kg fresh matter) - Orts (kg DM)).

The physiological variables: respiratory rate (RR, mov min^{-1}), rectal temperature, (RT, ºC), and surface temperature (ST, ºC) were measured twice daily (07h30 and 14h00) on the 11th and 13th day of each experimental period. Respiratory rate was measured by visual observation of the lateral movements of the right flank of the animal for 15 seconds, the result was multiplied by four to generate the number of respiratory movements per minute. Rectal temperature was determined by using a veterinary thermometer that was inserted into the rectum of the animal at a depth of 5 centimeters, for 3 minutes. Surface temperature was measured using an infrared thermometer at five different points on the animal's body: the forehead, chest, flank, leg, and udder. At the end of each experimental day, the average temperature of the five points was calculated to obtain the ST.

The data were analyzed according to the following statistical model: $Y_{ijkl} = \mu + T_i + Q_j + P_k + A_{(j)l} + TQ_{ij} + e_{ijkl}$, where:

Y_{ijkl} = experimental response,

μ = general constant,

T_i = effect relative to treatment i,

Q_j = random effect relative to Latin square j,

P_k = random effect relative to period k,

$A_{(j)l}$ = random effect of animal l nested in Latin square j,

TQ_{ij} = random effect of the interaction between treatment j and Latin square I, and

e_{ijkl} = random effect associated with each observation.

The experimental variables were evaluated using analysis of variance and regression analysis, utilizing the GLM procedure of the SAS statistical software (SAS, 2001).

Results and Discussion

The DM intake, when expressed in kg day^{-1}, was affected quadratically by the levels of xiquexique in the diets. The estimated maximum DM intake was 7.38 kg day^{-1}, with 8.19% of xiquexique in the diet. A decreasing linear effect (P<0.05) of the levels of xiquexique was found on DM intake, expressed in % BW and g $kg^{-0.75}$. For every percentage point increase in xiquexique, the DM intake was reduced by 0.02% BW and 0.79 g $kg^{-0.75}$ respectively (Table 3). For all diets, DM intake was greater than the NRC (2001) requirements of 14.2 kg day^{-1} for animals with the same characteristics of weight, lactation stage, and milk yield.

Table 3. Means, coefficients of variation (CV), coefficients of determination (R^2), and p-values (P) for nutrient intake and productivity in relation to the level of xiquexique in the experimental diets.

	Level of xiquexique				CV%	R^2	P
	0%	12%	24%	36%			
Intake (kg day^{-1})							
Dry matter[1]	16.81	18.22	15.46	14.52	16.10	0.19	0.0429
Organic matter[2]	15.57	16.48	13.99	13.04	15.64	0.20	0.0098
Crude protein[3]	2.97	2.97	2.39	2.11	15.05	0.47	<0.0001
Ether extract[4]	0.42	0.40	0.30	0.25	14.63	0.68	<0.0001
Neutral detergent fiber[5]	9.71	8.38	6.22	4.97	12.48	0.81	<0.0001
Acid detergent fiber[6]	3.82	3.57	2.70	2.30	14.46	0.66	<0.0001
Total carbohydrates[7]	12.18	13.10	11.30	10.69	15.9	0.13	0.0433
Non-fiber carbohydrates[8]	2.48	4.72	5.08	5.72	24.44	0.53	<0.0001
Intake (% BW)							
Dry matter[9]	3.62	3.94	3.32	3.15	17.53	0.13	0.0464
Neutral detergent fiber[10]	2.10	1.82	1.34	1.08	15.08	0.75	<0.0001
Intake (g kg$^{-0.75}$)							
Dry matter[11]	167.93	182.76	154.09	145.88	16.9	0.14	0.0371
Neutral detergent fiber[12]	97.16	83.97	62.12	49.87	18.4	0.77	<0.0001
Performance							
Milk yield (kg day^{-1})[13]	16.50	16.35	14.68	13.93	14.53	0.19	0.0125
Feed efficiency (kg milk kg DM^{-1})[14]	0.97	0.90	0.98	1.00	19.53	-	NS

NS: not significant; $^{1}\hat{Y}=17.11+0.07X-0.004X^2$; $^{2}\hat{Y}=16.28-0.08X$; $^{3}\hat{Y}=3.09-0.03X$; $^{4}\hat{Y}=0.43-0.01X$; $^{5}\hat{Y}=9.78-0.14X$; $^{6}\hat{Y}=97.84-1.36X$; $^{7}\hat{Y}=12.76-0.05X$; $^{8}\hat{Y}=2.98+0.08X$; $^{9}\hat{Y}=3.81-0.02X$; $^{10}\hat{Y}=2.11-0.03X$; $^{11}\hat{Y}=176.89-0.79X$; $^{12}\hat{Y}=97.84-1.36X$; $^{13}\hat{Y}=16.77-0.08X$; $^{14}\hat{Y}=0.965$.

With increasing levels of xiquexique, the dietary DM contents were reduced from 872.35 to 609.41 g kg^{-1}, and fresh-matter intake dropped from 18.59 to 38.13 kg day^{-1} at xiquexique levels of 0 and 36% respectively. According to the NRC (2001), there is a negative relationship between DM intake and the moisture content of a diet, and DM intake is decreased in diets with a DM content lower than 50%.

In the literature, the effect of the inclusion of cacti on DM intake is controversial. In the present study, the substitution of a roughage with a high DM content (Tifton-grass hay, with 86.27% DM) for xiquexique caused a 30.69% reduction in the DM content of diets that contained 0 to 36% xiquexique, causing a substantial impact on DM intake. Oliveira et al. (2007) also observed a reduction in the DM intake of lactating cows when they replaced corn completely and Tifton-grass hay partially (90.72% DM) with spineless cactus. However, different results were reported by Silva et al. (2005), who substituted sorghum silage with 0, 12.5, 25, 37.5, and 50% of xiquexique without observing any differences in DM intake. This result may be attributed to the DM content of the roughage used (29.73% DM), which provided a reduction of only 13.77% in the DM content of the diets with 0 to 50% xiquexique.

The intakes of organic matter (OM), crude protein (CP), ether extract (EE), and total carbohydrates (TC), expressed in kg day^{-1}, decreased linearly as the levels of xiquexique in the diet were increased. From regression equations, OM values were estimated to range from 16.28 to 13.40 kg day^{-1}, CP from 3.09 to 2.01 kg day^{-1}, EE from 0.43 to 0.25 kg day^{-1}, and TC from 12.71 to

10.88 kg day^{-1}, at levels of 0 to 36% xiquexique respectively. The reduction in the intake of nutrients is associated with the decreasing intake of DM, as the concentrations of OM, CP, EE, and TC in the diets were similar as they were all isoproteic and isoenergetic. The CP intake of all the diets was higher than the 1.97 kg day^{-1} recommended by the NRC (2001) for this animal category.

In line with the results of other studies (OLIVEIRA et al., 2007; PEREIRA et al., 2010; COSTA et al., 2012), which emphasized the richness of species of the family *Cactaceae* in non-fiber carbohydrates (NFC), the NFC content present in xiquexique was 580.08 g kg^{-1} DM, resulting in a linear increase ($P<0.05$) in the intake of this nutrient per kg day^{-1}, even with decreasing DM intake. According to the NRC (2001), the maximum concentration of NFC in the diet must be between 32 to 43% of the DM to prevent acidosis or other metabolic problems. In contrast, increasing levels of xiquexique in the experimental diets reduced the neutral detergent fiber (NDF) intake linearly in the different forms it was expressed (kg day^{-1}, % BW, and g kg$^{-0.75}$), as well as the acid detergent fiber (ADF) intake expressed in kg day^{-1}. This result may be attributed to the reduction in the NDF and ADF contents of the dietary DM, associated with the decrease in DM intake. The NDF intake in % BW decreased by 17.06, 34.12, and 51.18% at xiquexique levels of 12, 24, and 36% respectively (CAVALCANTI et al., 2008).

A reduction was also found in NDF intake, which averaged 1.88, 1.86, 1.53, 1.28, and 1.11 % BW, in lactating crossbred cows fed diets in which Tifton-grass hay was substituted with increasing levels (0, 12.5, 25, 35.5, and 50%) of spineless cactus, with a reduction of 40.95% from substitution levels of 0 to 50%. Even at levels of 36% xiquexique in the diet, the dietary NDF content was 25% higher, on a DM basis, than that recommended by NRC (2001), provided that 19% of this NDF originates from the feed.

Milk yield (MY) decreased linearly with levels of xiquexique, more specifically by 5.72, 11.45, and 17.17% at the levels of 12, 24, and 36% respectively (Table 4). For every percentage point of increase in xiquexique, there was a reduction of 0.08 kg day^{-1} in MY, due to the reduction in the intake of DM and most nutrients, including the plant. Different results were observed by Silva et al. (2005), who did not find an effect of different levels of xiquexique in the diet on MY or on DM intake in lactating dairy cows.

Table 4. Means, coefficients of variation (CV), coefficients of determination (R^2), and p-values(P) for water intake by cows fed diets containing different levels of xiquexique.

	Level of xiquexique				CV%	R^2	P
	0%	12%	24%	36%			
WI_{Feed} (kg day^{-1}) [1]	1.78	12.3	18.92	23.61	27.28	0.82	<0.0001
WI_{Feed} (% BW) [2]	0.38	2.65	4.08	5.12	26.97	0.83	<0.0001
$WI_{Voluntary}$ (kg day^{-1}) [3]	93.06	86.29	77.25	67.34	16.27	0.36	0.0003
$WI_{Voluntary}$ (% BW) [4]	20.14	18.69	16.8	14.78	20.27	0.26	0.0034
WI_{Total} (kg day^{-1}) [5]	94.84	98.59	96.17	90.96	16.37	-	NS
WI_{Total} (% BW)[6]	20.53	21.34	20.88	19.89	19.67	-	NS
$WI_{Voluntary}$/DMI[7]	5.54	4.75	5.07	4.79	17.6	-	NS
WI_{Total}/DMI[8]	5.65	5.43	6.3	6.43	15.55	0.14	0.0353

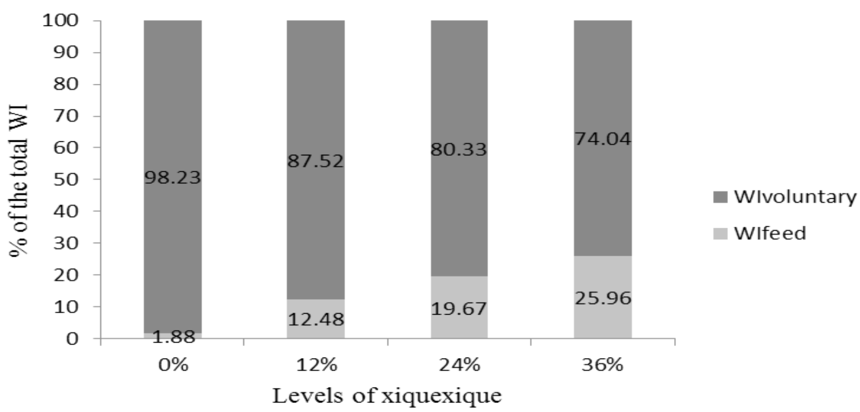
NS: not significant; [1]WI_{Feed}, water intake from the feed, $\tilde{Y}$= 3.33+0.60X; [2]$\tilde{Y}$=0.71+0.13X; [3]$WI_{Voluntary}$, voluntary water intake, $\tilde{Y}$= 93.92-0.72X; [4]$\tilde{Y}$= 20.30-0.15X; [5]WI_{Total}, total water intake, $\tilde{Y}$=95.14; [6]$\tilde{Y}$ =20.66; [7]$WI_{Voluntary}$/DMI, voluntary water intake:dry matter intake ratio, $\tilde{Y}$=5.04; [8]WI_{Total}/DMI, total water intake:dry matter intake ratio, $\tilde{Y}$= 5.47+0.03X.

The levels of xiquexique in the diet had no effect on feed efficiency (FE), which averaged at 0.97 kg milk kg DM^{-1}. The lower MY, with the increasing levels of xiquexique, was compensated for by the lower DM intake, resulting in a similar FE between the treatments. A similar response was reported by Silva et al. (2005), who also did not find changes in FE with increasing levels of xiquexique, obtaining an average FE of 0.88 kg milk kg DM^{-1}. The reduction in DM intake and MY, without alterations in FE, indicates that xiquexique can be used as an ingredient in the diets of medium and low productive animals, but its use should be restricted among animals with a high MY.

The water intake from the feed (WI_{Feed}), expressed in kg day^{-1} and % BW, increased linearly with the proportion of xiquexique in the diet (Table 4). This result is attributed to the increase in the moisture content of the diets containing xiquexique. For every percentage point increase of xiquexique in the diet, WI_{Feed} was increased by 0.60 kg day^{-1} and 0.13% BW, resulting in a WI_{Feed} of 24.93 kg day^{-1} and 5.39% BW in diets containing 36% xiquexique. In contrast, elevations in the level of xiquexique in the diet resulted in a linear reduction in the voluntary water intake ($WI_{Voluntary}$), expressed in kg day^{-1} and % BW. Every percentage point increase in xiquexique in the diet caused $WI_{Voluntary}$ to decrease by 0.72 kg day^{-1} and 0.15% BW. These results are interrelated, as the diets with the highest quantities of xiquexique provide an increase in fresh matter intake, thereby increasing the amount of water absorbed from the feed, consequently requiring a lower $WI_{Voluntary}$. As such, this demonstrates the nutritional importance of this foodstuff in feeding strategies for semi-arid regions. Similar results have been reported in many studies (LIMA et al., 2003; CARVALHO et al., 2005; OLIVEIRA et al., 2007), in which the authors observed a reduction in water intake when spineless cactus was included in the diets of lactating cows.

The levels of xiquexique in the diet had no effect on the total water intake (WI_{Total}), which averaged 95.14 kg day^{-1} (Table 4). This is attributed to the interaction between WI_{Feed} and $WI_{Voluntary}$ discussed above. Water requirements can be met by three different sources, specifically: voluntary water intake, water intake from the feed, and water from the metabolism of nutrients in the body, the first two sources being the most important (NRC, 2001). According to the NRC (2001), 70 to 97% of the total water consumed by cattle comes from $WI_{Voluntary}$. In the present study, the contribution of $WI_{Voluntary}$ to the WI_{Total} varied between 74.04 and 98.12% in diets containing xiquexique of 36% and 0% respectively (Figure 1). Costa et al. (2012) found the contribution of $WI_{Voluntary}$ to WI_{Total} varying between 95.48 and 40.66% in diets containing 0 and 100% of spineless cactus, respectively, when used to replace corn in sheep diets.

Figure 1. The distribution of total water intake by lactating dairy cows fed diets containing different levels of xiquexique.



The air temperature (AT) in the morning, in the shade, remained below the upper limit of the thermoneutral zone for crossbred cows, with values ranging from 25.8 to 26.5 ºC during the four experimental periods (Table 5). In the morning, in the sun, an AT above the thermal comfort zone was only observed in the third experimental period (32.7 ºC). In the afternoon, both in the shade and in the sun, AT was always above the thermoneutral zone for crossbred cows, which varies from 5 to 31% (PEREIRA, 2005). During these experimental periods, the animals were subjected to temperatures higher than those considered comfortable, characterizing these conditions as heat stress, with mean values of 33.2 and 37.3 ºC in the shade and in the sun respectively.

Table 5. Mean values for air temperature (AT), relative humidity of the air (RH), and temperature-humidity index (THI) in the shade and in the sun, both in the morning and afternoon, during the experimental periods.

Period	Period of the day	AT (°C)		RH (%)		THI (%)	
		Shade	Sun	Shade	Sun	Shade	Sun
1	Morning	25.8	28.7	61.5	53.0	74.05	76.94
	Afternoon	33.5	36.9	39.0	34.7	80.65	83.73
2	Morning	26.1	29.9	60.0	47.0	74.30	77.61
	Afternoon	31.9	33.9	34.0	33.0	77.87	79.96
3	Morning	26.5	32.7	62.0	51.5	75.10	81.98
	Afternoon	34.1	39.2	34.0	31.0	80.38	85.45
4	Morning	26.4	27.2	64.5	62.0	75.26	76.10
	Afternoon	33.3	39.2	41.0	30.0	80.79	85.20
Mean	Morning	26.2	29.6	62.0	53.4	74.68	78.20
	Afternoon	33.2	37.3	37.0	32.2	79.92	83.61

The mean values for relative humidity (RH) responded inversely to AT, with higher values occurring in the morning and lower values in the afternoon. In the morning, in the shade, RH varied from 60 to 64.5%, while in the sun it had a larger amplitude, varying from 47 to 62%. The lowest RH values were recorded during the experimental periods in the afternoon, ranging from 34 to 41% in the shade and 30 to 34.7% in the sun. According to Armstrong (1994), the environment does not cause heat stress in cattle when the temperature-humidity index (THI) is below 72. Heat stress is considered mild from 72 to 78, moderate from 79 to 88, and severe from 89 to 98. In the present study, the values obtained for the THI indicated more stress in the sun than in the shade, both in the morning and afternoon. The THI values in the morning experimental periods were characterized as mild stress, both in the shade and in the sun, with average THI values of 74.7 and 78.2 respectively. In the afternoon experimental periods, the average THI values were 79.9 and 83.6 in the shade and in the sun, respectively, which characterized this experimental period as moderate heat stress. Similar results were reported by Rocha et al. (2012), who also found differences between times of day, with higher THI values found in the afternoon. The authors attributed this to the increased AT throughout the day, with a positive correlation detected between AT and THI (r = 0.89).

Respiratory rate (RR) was not influenced by the inclusion of xiquexique in the experimental diets (Table 6) in the morning (RRm) or the afternoon (RRa), averaging 35.75 and 43.29 mov. min^{-1} respectively. In the afternoon, RR was higher than the normal values for adult cattle, which varies between 24 and 36 respiratory movements per minute (STÖBER et al., 1993). This shows that during this period of the day the animals had greater difficulty maintaining homeothermy. Similarly, Ferreira et al. (2006) characterized the physiological responses of male and female cattle of 14 to 20 months of age and found an elevation in RR during the afternoon (a period of heat stress). Carvalho et al. (2005) observed an increase in the RR of animals subjected to the treatments containing the highest levels of cactus.

Table 6. Means, regression equations (RE), p-values (P), and coefficients of variation (CV) for respiratory rate in the morning (RRm) and afternoon (RRa), surface temperature in the morning (STm) and afternoon (STa), and rectal temperature in the morning (RTm) and afternoon (RTa) in relation to the level of xiquexique in the experimental diets.

	Level of xiquexique				RE	P	CV%
	0%	12%	24%	36%			
RFm	36.00	36.25	35.50	35.25	Y=35.75	NS	14.68
RFa	46.00	40.88	46.75	39.5	Y=43.29	NS	18.24
STm	32.89	32.82	32.45	32.41	Y=32.64	NS	3.13
STa	37.04	36.73	36.83	36.96	Y=36.89	NS	2.86
RTm	38.04	37.98	37.9	37.31	Y=37.81	NS	2.77
RTa	38.73	38.63	38.23	38.26	$\tilde{Y}$=38.73-0.015X	0.0111	1.09

NS: not significant.

In terms of surface temperature (ST), no effect of the diets was found during morning (STm) or afternoon (STa) experimental periods, with averages of 32.64 and 36.89 ºC respectively. According to Baccari Júnior (2001) there is a thermal gradient in the body, within which the temperature is higher in its interior and decreases in its periphery (skin and hair). Variations in body surface temperature between 31.6 to 34.7 ºC are considered to indicate that the animal is not under heat stress (MARTELLO et al., 2004). Thus, the results obtained for this parameter indicate that heat stress is experienced by the animals during the afternoon. According to McDowell (1976), body temperature, respiratory rate, and heart rate are direct measurements of alteration in homeothermy in animals subjected to high temperatures and relative humidity of the air. As a result, the RRa and STa can be attributed to the high air temperature in the afternoon.

The rectal temperature (RT) recorded in the animals was not influenced by the inclusion of xiquexique in the experimental diets during the morning period (RTm), averaging 37.81 ºC. However, the RT measured in the afternoon (RTa) decreased ($P<0.05$) in the animals receiving the highest levels of xiquexique in their diets. The regression equation obtained ($\tilde{Y}=38.73-0.015X$) shows that the decline in RTa was 0.015 ºC for every percentage point of xiquexique added. This result is associated with the reduction in DM in the diets containing the highest levels of xiquexique, which provide a lower heat increment originating from the activities of digestion, rumen fermentation, absorption of nutrients, and endogenous metabolism. The normal RT for dairy animals, according to Robinson (1999) ranges from 38.0 ºC to 39.3 ºC, and so the values obtained in the present study were within the physiological limits for this species. These results demonstrate that, in this study, the animals displayed physiological adaptations to the environment, as the maintenance of RT within the physiological limits indicates that the heat-releasing mechanisms were sufficient to maintain homeothermy. According to Azevedo et al. (2005), homeostatic mechanisms, including the increase in RF, may prevent a considerable increase in RT before the THI reaches a critical point.

Conclusions

Xiquexique can be utilized in the diets of medium to high yield lactating cows, in a semi-arid climate, without changing the feed efficiency or physiological responses of the animals. Xiquexique reduces the voluntary intake of water by dairy cows, and is an important alternative foodstuff in semi-arid regions where this resource is limited.

Acknowledgments

The authors thank Banco do Nordeste for the financial aid provided for the development of this study.

References

ARMSTRONG, D. V. Heat stress interaction with shade and cooling. *Journal of Dairy Science*, Champaign, v. 77, n. 7, p. 2044-2050, 1994.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS - AOAC. Official methods of analysis of the association of official analytical chemists. 15th ed. Washington, DC: Association of Official Analytical Chemistry, 1990. 1117 p.

AVENDANO, R. L.; ALVAREZ, V. F. D.; CORREA, C. A.; SAUCEDO, Q. J. S.; ROBINSON, P. H.; FADEL, J. G. Effect of cooling Holstein cows during the dry period on postpartum performance under heat stress conditions. *Livestock Science*, London, v. 105, n. 1, p. 198-206, 2006.

AZEVEDO, M.; PIRES, M. F. A.; SATURNINO, H. M.; LANA, A. M. Q.; SAMPAIO, I. B. M.; MONTEIRO, J. B. N.; MORATO, L. E. Estimativa de níveis críticos superiores do índice de temperatura e umidade para vacas leiteiras 1/2, 3/4 e 7/8 Holandês-Zebu em lactação. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 34, n. 6, p. 2000-2008, 2005.

BACCARI JÚNIOR, F. *Manejo ambiental da vaca leiteira em climas quentes.* Londrina: UEL, 2001. 142 p.

CARVALHO, M. C.; FERREIRA, M. A.; CAVALCANTE, C. V. A.; VÉRAS, A. S. C.; SILVA, F. M. da; AZEVEDO, M. Substituição do feno de capim Tifton (*Cynodon* spp cv 85) por palma forrageira (*Opuntia ficus indica* Mill) e comportamento ingestivo de vacas da raça holandesa. *Acta Scientiarum. Animal Sciences,* Maringá, v. 27, n. 4, p. 505-512, 2005.

CAVALCANTI, C. V. A.; FERREIRA, M. A.; CARVALHO, M. C.; VÉRAS, A. S. C.; SILVA, F. M. da; LIMA, L. E. Palma forrageira enriquecida com uréia em substituição ao feno de capim Tifton 85 em rações para vacas da raça Holandesa em lactação. *Revista Brasileira de Zootecnia,* Viçosa, MG, v. 37, n. 4, p. 689-693, 2008.

COSTA, R. G.; HERNÁNDEZ, T. I.; MEDEIROS, G. R.; MEDEIROS, A. N.; AZEVEDO, P. S.; PINTO, T. F.; DELGADO, J. V. Consumo de agua de ovinos alimentados con diferentes niveles de nopal (*Opuntia Ficus Indica*) en Brasil. *Archivos de Zootecnia,* Córdoba, v. 61, n. 234, p. 301-304, 2012.

DAMASCENO, J. C. F.; BACCARI JÚNIOR, F.; TARGA, L. A. Respostas fisiológicas e produtivas de vacas holandesas com acesso à sombra constante ou limitada. *Revista da Sociedade Brasileira de Zootecnia,* Viçosa, v. 27, n. 3, p. 595-602, 1998.

FERREIRA, F.; PIRES, M. F. A.; MARTINEZ, M. L.; COELHO, S. G.; CARVALHO, A. U.; FERREIRA, P. M.; FACURY FILHO, E. J.; CAMPOS, W. E. Parâmetros fisiológicos de bovinos cruzados submetidos ao estresse calórico. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia,* Belo Horizonte, v. 58, n. 5, p. 732-738, 2006.

LIMA, R. M. B.; FERREIRA, M. A.; BRASIL, L. H. A.; ARAÚJO, P. R. B.; VÉRAS, A. S. C.; SANTOS, D. C.; CRUZ, M. A. O. M.; MELO, A. A. S.; OLIVEIRA, T. N.; SOUZA, I. S. Substituição do milho por palma forrageira: comportamento ingestivo de vacas mestiças em lactação. *Acta Scientiarum. Animal Sciences*, Maringá, v. 25, n. 2, p. 347-353, 2003.

MACEDO, G. G.; ZUCCARI, C. E. S. N.; ABREU, U. G. P.; NEGRAO, J. A.; SILVA, E. V. C. Human-animal interaction, stress, and embryo production in *Bos indicus* embryo donors under tropical conditions. *Tropical Animal Health and Production*, Edinburgh, v. 43, n. 6, p. 1175-82, 2011.

MARTELLO, L. S.; SAVASTANO JÚNIOR, H.; SILVA, S. D. L.; TITTO, E. A. L. Respostas fisiológicas e produtivas de vacas holandesas em lactação submetidas a diferentes ambientes. *Revista Brasileira de Zootecnia,* Viçosa, MG, v. 33, n. 1, p. 181-191, 2004.

MCDOWELL, R. E. *Bases biológicas de la producción animal en zonas tropicales*. Zaragoza: Acribia, 1976. 692 p.

NATIONAL RESEARCH COUNCIL (US) - NRC. Nutrient requirement of the dairy cattle. 7. ed. Washington, DC: National Academy Press, 2001. 381 p.

OLIVEIRA, V. S.; FERREIRA, M. A.; GUIM, A.; MODESTO, E. C.; ARNAUD, B. L.; SILVA, F. M. Substituição total do milho e parcial do feno de capim Tifton por palma forrageira em dietas para vacas em lactação. Consumo e digestibilidade. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 36, n. 5, p. 1419-1425, 2007.

PEREIRA, C. C. J. *Fundamentos de bioclimatologia aplicados à produção animal.* Belo Horizonte: Ed. da FEPMVZ, 2005. 195 p.

PEREIRA, E. S.; PIMENTEL, P. G.; DUARTE, L. S.; MIZUBUTI, I. Y.; ARAÚJO, G. G. L.; CARNEIRO, M. S. S.; REGADAS FILHO, J. G. L.; MAIA, I. S. G. Determinação das frações proteicas e de carboidratos e estimativa do valor energético de forrageiras e subprodutos da agroindústria produzidos no Nordeste Brasileiro. *Semina: Ciências Agrárias*, Londrina, v. 31, n. 4, p. 1079-1094, 2010.

ROBINSON, E. N. Termorregulação. In: CUNNINGHAM, J. G. *Tratado de fisiologia veterinária*. 2. ed. Rio de Janeiro: Guanabara Koogan, 1999. p. 427-435.

ROCHA, D. R.; SALLES, M. G. F.; MOURA, A. A. A. N.; ARAÚJO, A. A. Índices de tolerância ao calor de vacas leiteiras no período chuvoso e seco no Ceará. *Revista Acadêmica: Ciência Animal*, Curitiba, v. 10, n. 4, p. 335-343, 2012.

SILVA, J. G. M.; MELO, A. A. S.; RÊGO, M. M. T.; LIMA, G. F. C.; AGUIAR, E. M. Cactáceas nativas associadas a fenos de flor de seda e sabiá na alimentação de cabras leiteiras. *Revista Caatinga*, Mossoró, v. 24, n. 2, p. 158-164, 2011.

SILVA, J. G. M.; SILVA, D. S.; FERREIRA, M. A.; LIMA, G. F. C.; MELO, A. A. S.; DINIZ, M. C. N. M. Xiquexique (*Pilosocereus gounellei* (A. Weber ex K. Schum.) Bly. ex Rowl.) em substituição à silagem de sorgo (*Sorghum bicolor* L. Moench) na alimentação de vacas leiteiras. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 34, n. 4, p. 1408-1417, 2005.

SNIFFEN, C. J.; O'CONNOR, J. D.; VAN SOEST, P. J.; FOX, D. G.; RUSSELL, J. B. A net carbohydrate and protein system for evaluating cattle diets. II Carbohydrate and protein availability. *Journal of Animal Science*, Champaign, v. 70, n. 10, p. 3562-3577, 1992.

STATISTICAL ANALYSIS SYSTEM - SAS. Statistical analysis system user's guide: statistics. Version 8. 2, Cary: SAS Institute, 2001. 1686 p.

STÖBER, M.; DIRKSEN, G.; GRÜNDER, H. D.; STÖBER, M. *Identificação, anamnese, regras básicas da técnica do exame clínico geral*. *Exame clínico dos bovinos*. 3. ed. Rio de Janeiro: Guanabara Koogan, 1993. 419 p.

TEGEGNE, F.; KIJORA, C.; PETERS, K. J. Study on the optimal level of cactus pear (*Opuntia ficus-indica*) supplementation to sheep and its contribution as source of water. *Small Ruminant Research*, Amsterdam, v. 72, n. 2, p. 157-164, 2007.

THOM, E. C. The discomfort index. *Weatherwise*, Washington, v. 12, n. 2, p. 57-61, 1959.

VAN SOEST, P. J.; ROBERTSON, J. B.; LEWIS, B. A. Methods for dietary fiber, neutral detergent fiber, and nonstarch polyssacharides in relation to animal nutrition. *Journal of Dairy Science*, Madison, v. 74, n. 10, p. 3583-3597, 1991.