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Thermal comfort and productive responses from 7/8 dutch-gir cows submitted to the cooling system

Silva, M.V.[1]; Almeida, G.L.P.[1]; Pandorfi, H.[1]; Moraes, A.S.[2]; Almeida Macêdo, G.A.P.[3]; Batista, P.H.D.[1]; Silva, R.A.B.[1] and Oliveira, M.E.G.[1]

[1] Department of Agricultural Engineering. Rural Federal University of Pernambuco. Recife. Brazil.
[2] Department of Chemistry. Rural Federal University of Pernambuco. Recife. Brazil.
[3] Department of Zootechnics. Rural Federal University of Pernambuco. Recife. Brazil.

ADITIONAL KEYWORDS

Multivariate analysis.
Dairy cattle.
Evaporative cooling system.

SUMMARY

Climatic conditions that are thermally inappropriate for dairy cattle are associated with a reduction in feed consumption, production, and the composition of the final product. The objective of this research was to identify the influence of the evaporative adiabatic cooling system (EACS) on the thermal comfort and productive responses of dairy cattle, through multivariate analysis by principal components, in the summer and winter seasons of the semiarid region of Pernambuco, Brazil. The data came from an experiment that included 16 multiparous lactating cows, randomly distributed in 4 sets, with 4 experimental phases and 4 treatments (0, 10, 20, and 30 min of exposure to EACS). Multivariate analysis was used utilizing principal components for the thermal comfort indexes, physiological variables, milk production, and composition. The highest milk production in the summer season was for animals exposed to the cooling system for 30 min. In the winter season in the morning shift, the use of the evaporative cooling system for 10 min was sufficient for improvements in milk production. The times of exposure to EACS caused changes in the composition of milk, both in summer and in winter. Thermal stress was characterized by a high temperature and humidity index in all treatments in the afternoon shift. The principal component analysis allowed us to identify the positive influence of evaporative cooling on thermal comfort, physiological responses, production, and composition milk of lactating cows.

Comodidad térmica y respuestas productivas de 7/8 vacas holandesas presentadas al sistema de refrigeración

PALABRAS CLAVE

Análisis multivariante.
Ganado lechero.
Sistema de enfriamiento evaporativo.

RESUMEN

Las condiciones climáticas que son térmicamente inapropiadas para el ganado lechero están asociadas con una reducción en el consumo de alimento, la producción y la composición del producto final. El objetivo de esta investigación fue identificar la influencia del sistema de enfriamiento adiabático evaporativo (SEAE) en el confort térmico y las respuestas productivas del ganado lechero, a través del análisis multivariado por componentes principales, en las temporadas de verano e invierno de la región semiárida de Pernambuco, Brasil. Los datos provienen de un experimento que incluyó 16 vacas lactantes multíparas, distribuidas aleatoriamente en 4 grupos, con 4 fases experimentales y 4 tratamientos (0, 10, 20 y 30 minutos de exposición a SEAE). El análisis multivariado se utilizó mediante componentes principales para los índices de confort térmico, variables fisiológicas, producción y composición de leche. La producción de leche más alta en la temporada de verano fue para animales expuestos al sistema de enfriamiento durante 30 minutos. En la temporada de invierno en el turno de la mañana, el uso del sistema de enfriamiento por evaporación durante 10 minutos fue suficiente para mejorar la producción de leche. Los tiempos de exposición al SEAE causaron cambios en la composición de la leche, tanto en verano como en invierno. El estrés térmico se caracterizó por un alto índice de temperatura y humedad en todos los tratamientos en el turno de la tarde. El análisis de componentes principales permitió identificar la influencia positiva del enfriamiento por evaporación en el confort térmico, las respuestas fisiológicas, la producción de leche y la composición de las vacas lactantes.

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Correspondencia a los autores/Contact e-mail:
marcolino_114@hotmail.com

INTRODUCTION

Tropical and subtropical regions generally have high air temperatures that affect the homeotherm of dairy cows, with negative consequences for food consumption, milk production and composition (Garner *et al*. 2017; Fodor *et al*. 2018 and Tresoldi, Schütz and Tucker 2019).

High milk production cows succumb to heat stress before low production animals, due to higher nutritional requirements and metabolic heat production, which significantly alter the energy balance between the animal and the environment (Hu *et al*. 2016). Strategies that minimize this problem include managing the animal in the shade, using an evaporative adiabatic cooling system (EACS) and automating cooling system (Porto, D'emilio and Cascone 2017; Silva and Passini 2018; Tresoldi, Schütz and Tucker 2018 and Tresoldi, Schütz and Tucker 2019).

The characterization of the thermal environment utilizing comfort indexes allows the integrated assessment of more than one meteorological variable associated with the effect of stress and/or comfort on farm animals, such as the temperature and humidity index (THI) commonly used for determining the thermal condition in the housing of dairy cattle. As for phenotypic plasticity, rectal temperature is one of the main physiological variables used to identify thermal stress in dairy cattle, under normal conditions they have a body core temperature of 38.5 °C and the thresholds for environmental fever vary between 39.1 and 39.7 °C (Seerapu *et al*. 2015 and Sousa et al. 2018).

From the large amount of data generated to characterize the cause and effect of environmental thermal stress, one of the statistical methods that make it possible to explain the phenomena that influence milk production is the use of multivariate statistics, which makes it possible to explain a set of two or more variable in time (Macciotta *et al*. 2012). Recent research shows satisfactory results with the use of multivariate analysis, such as evaluation of breed heritability (Yilmaz *et al*. 2011), the influence of nutrients, experimental period in the composition and quality of bovine milk (Gabbi *et al*. 2018).

Given the above, this research was conducted to identify the influence of the evaporative adiabatic cooling system (EACS) on the thermal comfort and productive responses of dairy cattle, through multivariate analysis by principal components, in the summer and winter seasons from the semiarid region of Pernambuco, Brazil.

MATERIAL AND METHODS

The research was developed in one database from an experiment carried out in a dairy unit (**Figure 1**). Located in the Agreste Mesoregion, Vale do Ipojuca Microregion, Pernambuco State dairy basin (8°36'34.82"S and 36°37'33.09"W; 755 m), in the summer (February to March) and winter (July to August).

The average rainfall in the region is 620.3 mm (APAC 2019), with an average annual temperature of 20.3 ºC (INMET 2019). According to the Köppen climate classification, the climate is defined as Bsh - semiarid (Almeida *et al*. 2011). In the summer of 2009, the average temperature based on a historical series of 30 years was 22.8 ºC and in the winter it was 20.3 ºC (INMET 2019).

16 lactating multiparous Girolando cows (7/8 Dutch-Gir) were used, with an average weight of 500 kg and average milk production of 18 kg day^{-1}, randomly distributed in 4 sets (S1, S2, S3, and S4), with 4 experimental phases (P1, P2, P3, and P4) and 4 exposure times of the animals to the evaporative adiabatic cooling - EACS (0, 10, 20 and 30 min).

The experimental period was 56 days for each season, totaling 112 days, with 4 phases of 14 days, with the first seven days of each phase, destined to the adaptation of the animals to the climatization times in the pre-milking of 10, 20 and 30 min under EACS, plus the witness as control (0 min). The other seven subsequent days were used to record the meteorological variables in the waiting pen, physiological responses, and production of lactating cows, with subsequent determination of the composition of the milk.

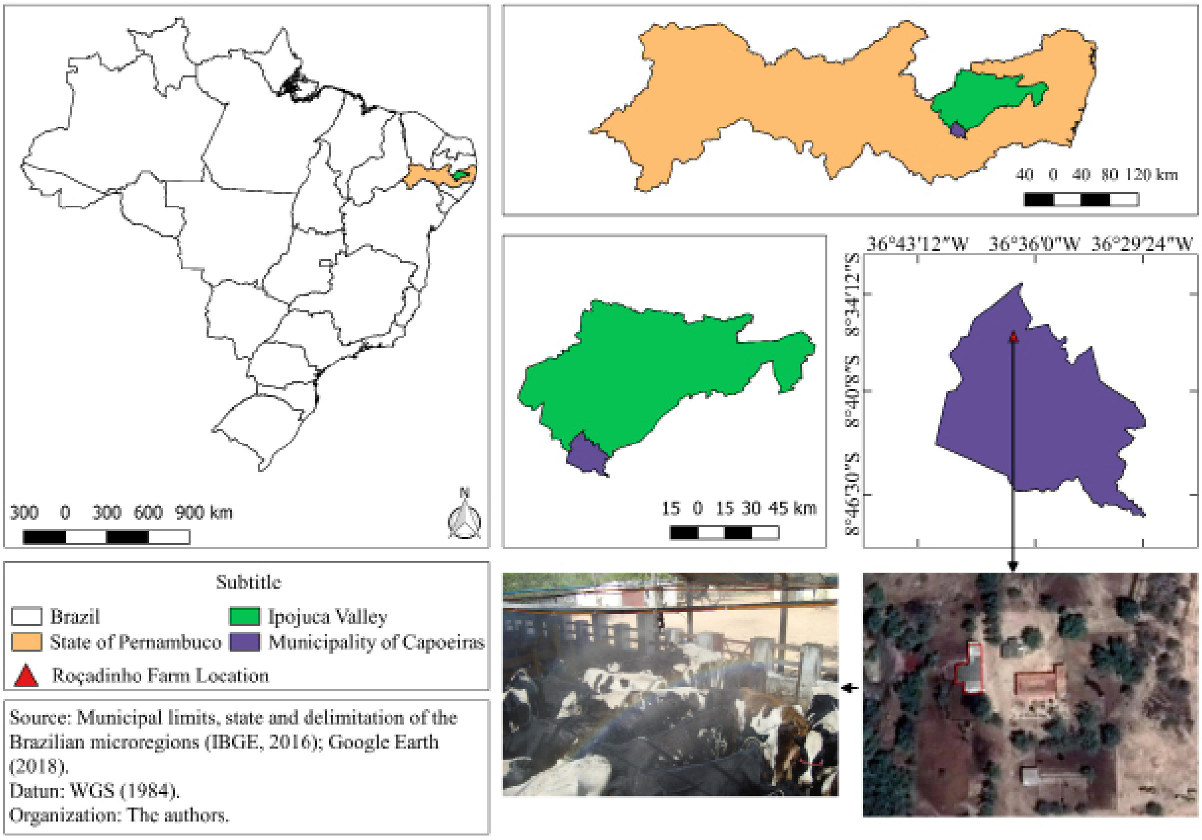
To determine the comfort indexes, the meteorological variables, air temperature (T, ºC), relative air humidity (RH, %) and the temperature of the black globe (Tgn, ºC) were recorded, recorded through dataloggers HOBO Pro Dataloggers HB8 model, with temperature recording interval between - 20 and 70 (± 0.35 °C) and relative humidity between 5 and 100 (± 2.5%). The wind speed (m s^{-1}) was recorded by a propeller anemometer. The sensors were positioned in the geometric center of the waiting corral, 2.5 m from the floor.

The thermal efficiency of the installation was determined by calculating the globe temperature and humidity index (GTHI) proposed by Buffington *et al*. (1981), the temperature and humidity index (THI) by Thom (1959), the radiant thermal load (RTL; W m^{-2}) proposed by Esmay (1982) and the enthalpy (h; KJ kg^{-1}) proposed by Albright (1990, pp. 453).

The physiological variables recorded were rectal temperature (RT; ºC), respiratory rate (RR; mov min^{-1}) and skin temperature (ST; ºC), performed twice a week in pre-milking, after acclimatization, at times from 0500 h (morning shift) and 1400 h (afternoon shift).

The verification of the RR occurred from the count of the number of movements of the flank region performed by the animal, in the interval of 1 min. After registration, RT measurements were performed, with the aid of a digital veterinary thermometer (a scale between 20 and 50 ºC), introduced into the rectum of the animals, during the time of 1 min for stabilization and obtaining the temperature value. The recording of ST was performed using an infrared thermometer, based on the temperature records of the head, back, shin and udder of each animal studied, for later determination of the average temperature of the fur according to the methodology established by Pinheiro et al. (2000).

Milk production (Prod) was determined individually, in the evaluated seasons, for the two daily milking shifts. The chemical composition (fat - Fat, protein -



Source: Municipal limits, state and delimitation of the Brazilian microregions (IBGE, 2016); Google Earth (2018).
Datun: WGS (1984).
Organization: The authors.

Figure 1. Location of the property in the municipality of Capoeiras, State of Pernambuco, Brazil (Ubicación del inmueble en el municipio de Capoeiras, Estado de Pernambuco, Brasil).

Pro, lactose - Lac and total solids - Sol) occurred in two collections for each phase, with individual samples of the milk of each animal, in their respective treatments and analyzed in the Programa de Gerenciamento de Rebanhos Leiteiros do Nordeste (PROGENE), of the Department of Zootechnics at UFRPE.

The data were submitted to descriptive statistical analysis to obtain the mean, median and coefficient of variation (CV), classified as low when the CV < 12%; medium when 12% < CV < 24% and high when CV > 24% (Warrick and Nielsen 1980, pp. 319-344). The Kolmogorov-Smirnov normality test ($p \leq 0.01$) was also applied.

For the use of principal component analysis, 12 variables (h, THI, GTHI, RTL, RR, RT, ST, Prod, Fat, Pro, Lac, Sol) were admitted for each season of the year (summer/winter), totaling 24 variables. From the principal components extracted from the data sets in the summer and winter seasons, the covariance matrix was obtained, in which the eigenvalues that originated the eigenvectors were extracted (Kaiser 1958).

This analysis was performed to identify parameters that explained most of the influence of the variables. For this, the Kaiser criterion was used, which considers eigenvalues above 1, because they generate components with a relevant amount of information contained in the original data, with the disposal of components that presented eigenvalues below 1 (Kaiser 1958).

RESULTS AND DISCUSSION

MORNING SHIFT

Descriptive statistics for the morning shift, in both seasons, are described in **Table I**. According to Warrick and Nielsen (1980, pp. 319-344) the coefficient of variation (CV) was low for all variables studied, except milk fat (Fat) in winter, from animals submitted to 10 min of cooling in pre-milking; enthalpy (h) in winter, for cooling times of 10 and 20 min and, for respiratory rate (RR) in summer, for control animals (0 min), which presented average CV (12% < CV < 24 %).

The low values of the coefficient of variation indicate that the use of the evaporative adiabatic cooling system (EACS), proved to be efficient in homogenizing the environment in which the animals were. The THI values in both seasons, in the morning shift, were lower than 72, characterized as a condition of comfort for the animals, as established by Armstrong (1994).

Table II shows the principal components (PC) obtained through multivariate analysis, for comfort indexes, physiological variables, production, and composition milk of cows in the morning shift (summer/winter). Components 1 (PC1) and 2 (PC2), presented an eigenvalue greater than 1, according to the criterion established by Kaiser (1958), with eigenvalues of the order of 16.732 and 5.590, respectively. PC1 and PC2 presented a total variance of the order of 93.00% for PC2.

Table I. Descriptive statistics of milk production (Prod, liters), fat (Fat, %), protein (Pro, %), lactose (Lac, %), total solids (Sol, %), enthalpy (h, KJ kg-1), black globe temperature and humidity index (GTHI), temperature and humidity index (THI), radiant thermal load (RTL, W m-2), rectal temperature (RT, °C), respiratory rate (RR, mov min-1) and temperature of the coat (ST, °C) in the morning shift in both seasons (Estadística descriptiva de la producción de leche (Prod, litros), grasa (grasa, %), proteína (Pro, %), lactosa (Lac, %), sólidos totales (Sol, %), entalpía (h, KJ kg-1), índice de temperatura y humedad del globo negro (GTHI), índice de temperatura y humedad (THI), carga térmica radiante (RTL, W m-2), temperatura rectal (RT, °C), frecuencia respiratoria (RR, mov min-1) y temperatura del pelaje (ST, °C) en el turno de mañana en ambas estaciones.)

[1]Var	[2]Tim	Summer					Winter				
		[3]m	[4]SD	[5]CV	[6]Min	[7]Max	m	SD	CV	Min	Max
Prod	0	10.84	0.63	5.80	9.91	11.30	11.69	0.73	6.26	10.84	12.62
	10	11.08	0.37	3.34	10.75	11.59	11.77	0.38	3.23	11.42	12.26
	20	11.36	0.16	1.41	11.21	11.58	11.77	0.96	8.18	11.07	13.18
	30	11.54	0.48	4.20	11.04	12.20	11.74	0.96	8.20	10.45	12.62
Fat	0	3.08	0.22	7.19	2.85	3.35	3.01	0.26	8.72	2.63	3.19
	10	2.64	0.23	8.77	2.39	2.86	3.00	0.40	13.24	2.62	3.55
	20	2.88	0.34	11.80	2.41	3.19	2.99	0.35	11.53	2.59	3.34
	30	2.74	0.31	11.36	2.37	3.02	3.10	0.25	8.04	2.73	3.27
Pro	0	2.71	0.14	5.13	2.52	2.84	2.75	0.09	3.17	2.63	2.83
	10	2.69	0.10	3.57	2.60	2.82	2.74	0.09	3.40	2.61	2.81
	20	2.71	0.05	1.83	2.64	2.76	2.76	0.06	2.20	2.67	2.80
	30	2.66	0.06	2.14	2.58	2.71	2.79	0.06	1.98	2.72	2.85
Lac	0	4.42	0.11	2.48	4.34	4.58	4.56	0.11	2.32	4.43	4.65
	10	4.50	0.15	3.28	4.36	4.70	4.61	0.06	1.40	4.54	4.67
	20	4.51	0.12	2.69	4.41	4.69	4.60	0.05	1.08	4.53	4.65
	30	4.52	0.12	2.58	4.39	4.67	4.61	0.11	2.43	4.50	4.76
Sol	0	11.11	0.19	1.68	10.91	11.27	11.25	0.14	1.28	11.06	11.39
	10	10.72	0.10	0.93	10.61	10.81	11.28	0.41	3.60	10.97	11.88
	20	10.96	0.32	2.93	10.56	11.32	11.28	0.34	3.03	10.83	11.64
	30	10.82	0.35	3.25	10.36	11.16	11.43	0.18	1.58	11.19	11.62
h	0	60.30	1.54	2.55	58.10	61.50	54.42	2.03	3.73	51.90	56.80
	10	58.33	1.16	1.98	57.10	59.70	50.55	6.58	13.02	41.10	55.20
	20	57.93	1.41	2.43	56.70	59.90	49.73	6.43	12.94	40.40	54.10
	30	57.45	1.02	1.78	56.20	58.70	52.33	1.54	2.94	50.20	53.60
GTHI	0	69.25	0.50	0.72	69.00	70.00	64.75	0.96	1.48	64.00	66.00
	10	68.00	0.00	0.00	68.00	68.00	64.00	0.82	1.28	63.00	65.00
	20	67.50	0.58	0.86	67.00	68.00	63.50	0.58	0.91	63.00	64.00
	30	67.50	0.58	0.86	67.00	68.00	63.50	0.58	0.91	63.00	64.00
THI	0	70.00	0.00	0.00	70.00	70.00	67.00	0.82	1.22	66.00	68.00
	10	69.00	0.00	0.00	69.00	69.00	66.00	1.41	2.14	64.00	67.00
	20	68.75	0.50	0.73	68.00	69.00	65.75	1.50	2.28	64.00	67.00
	30	68.00	0.00	0.00	68.00	68.00	65.75	0.50	0.76	65.00	66.00
RTL	0	420.35	6.16	1.47	411.80	426.50	381.32	11.26	2.95	367.70	392.30
	10	401.90	14.83	3.69	385.60	420.30	352.60	26.80	7.60	317.50	376.70
	20	396.60	23.50	5.94	364.60	419.40	359.80	30.20	8.39	319.50	387.80
	30	407.60	10.57	2.59	394.30	420.10	348.90	23.40	6.70	323.10	376.50
RT	0	38.18	0.13	0.33	38.00	38.30	38.03	0.22	0.58	37.80	38.30
	10	38.28	0.05	0.13	38.20	38.30	38.15	0.10	0.26	38.00	38.20
	20	38.15	0.17	0.45	38.00	38.30	38.13	0.19	0.50	38.00	38.40
	30	38.03	0.15	0.39	37.90	38.20	37.95	0.10	0.26	37.90	38.10
RR	0	36.00	4.76	13.22	33.00	43.00	28.00	1.41	5.05	26.00	29.00
	10	27.75	1.26	4.53	26.00	29.00	26.50	2.65	9.98	24.00	30.00
	20	28.00	2.71	9.67	26.00	32.00	26.75	2.22	8.29	24.00	29.00
	30	25.75	1.26	4.89	24.00	27.00	26.00	2.83	10.88	22.00	28.00
ST	0	30.08	0.94	3.12	29.20	31.30	26.70	1.51	5.65	25.10	28.60
	10	27.70	0.92	3.32	26.60	28.60	26.58	1.14	4.31	25.60	28.20
	20	26.68	0.85	3.17	25.60	27.40	25.70	0.08	0.32	25.60	25.80
	30	26.45	0.79	2.97	25.40	27.10	24.95	2.25	9.01	22.60	28.00

1Var: variables; 2Tim: adiabatic evaporative cooling time (0, 10, 20 and 30 min); 3m: medium; 4SD: standard deviation; 5CV: coefficient of variation; 6Min: minimum; 7Max: maximum.

Studies by Yilmaz *et al*. (2011) estimated the heritability of brown Swiss bovine milk production characteristics, through factor analysis obtained results of 82.8% of the explanation of the total variance of the studied variables, therefore, similar to the present study.

The thermal comfort indices and physiological variables showed a positive correlation for the morning shift in summer and winter, except for the rectal temperature (RT), which was neutral, that is, without the influence of comfort indices (**Table II**). This was due to the lower temperatures in the morning shift, which were in the comfort range of the animals.

The negative association between the levels of protein, fat and total solids with milk production (**Table II**), occurred due to greater dilution of protein, fat and total solids in milk, given the higher volume produced in the morning shift (**Table I**). Gabbi *et al*. (2018), also found the same negative relationship between protein, fat, and total solids. The relationship between fat and protein was already expected, as these variables have a

Table II. **Principal components of comfort indexes, physiological variables, behavioral parameters, production and composition of milk and dairy cows in the morning shift in summer and winter (**Componentes principales de los índices de confort, variables fisiológicas, parámetros de comportamiento, producción y composición de leche y vacas lecheras en el turno de mañana en verano e invierno**).**

Variable	Principal Summer Component		Principal Winter Component	
	*PC1	PC2	PC1	PC2
¹h	0.244	-0.017	0.165	-0.298
²GTHI	0.239	-0.077	0.242	-0.032
³THI	0.239	0.026	0.225	-0.112
⁴RTL	0.184	-0.259	0.234	-0.043
⁵RT	0.121	0.338	0.033	0.417
⁶RR	0.242	-0.041	0.240	0.013
⁷ST	0.239	-0.027	0.196	0.220
⁸Prod	-0.227	-0.111	-0.196	0.251
⁹Fat	0.192	-0.125	-0.118	-0.355
¹⁰Pro	0.191	0.208	-0.134	-0.342
¹¹Lac	-0.242	0.053	-0.234	0.094
¹²Sol	0.182	-0.125	-0.178	-0.281
Eigenvalue	16.732	5.590	16.732	5.590
Proportion	0.697	0.233	0.697	0.233
Accumulated	0.697	0.930	0.697	0.930

*PC: principal component; 1h: enthalpy (h; KJ kg-1); 2GTHI: globe temperature and humidity index; 3THI: temperature and humidity index; 4RTL: radiant thermal load (W m-2); 5RT: rectal temperature (ºC); 6RR: respiratory rate (mov min-1); 7ST: skin temperature (ºC); 8Prod: milk production (liters); 9Fat: fat (%); 10Pro: protein (%); 11Lac: lactose (%); 12Sol: soluble solids (%).

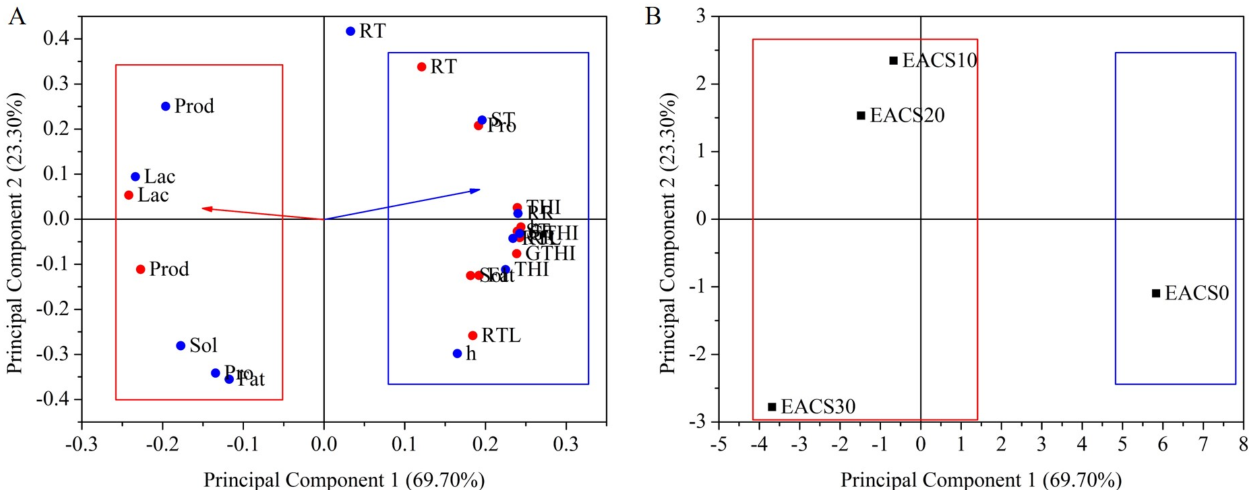


Figure 2. Principal components of the physiological variables, animal comfort indices, production and composition of milk of cows in the morning shift in summer and winter (A); Principal components of the operating time of the evaporative adiabatic cooling system in the morning (B) (Principales componentes de las variables fisiológicas, índices de confort animal, producción y composición de la leche de vacas en el turno de mañana en verano e invierno (A); Componentes principales del tiempo de funcionamiento del sistema de enfriamiento adiabático evaporativo por la mañana (B).

positive relationship with each other (Macciotta *et al*. 2012 and Mele *et al*. 2016).

Figure 2 presents the principal components of the physiological variables, animal comfort indexes, production and composition of milk of cows submitted to EACS (0, 10, 20 and 30 min) in the morning shift (summer/winter).

The highest milk production (Prod) in the summer season was for animals exposed to EACS for 30 min of cooling in pre-milking (**Table I**). The longer exposure time to EACS provided better comfort, with a consequent reduction in thermal comfort indexes and physiological variables (**Table I**). It is noted in **Figure 2A** that the time of 30 min is opposite to comfort indexes and physiological variables. Silva and Passini (2018) evaluated different cooling system in the waiting room for crossbred cows (⅞ Holstein x ⅛ Dairy Gir), using environmental variables, milk production, and economic indexes in the summer in a tropical climate region and observed similar results to the present study, in which the evaporative adiabatic cooling time for 30 minutes, provided the best comfort conditions for the animals.

In the winter season, in the morning shift, the time of 10 min of exposure of the animals to the EACS was sufficient for thermal conditioning, with a positive effect on milk production (**Figure 2A** and **Figure 2B**).

PC1 was the one that best-explained milk production due to the other variables (**Figure 2A**). Крамаренко *et al*. (2017) evaluated the total yield of lactating cows through Principal Component Analysis (PCA) and observed that PC1 was sufficient to determine the potential level of productivity of dairy cows.

The times of exposure of the animals to the EACS provided changes in the composition of the milk, according to the averages shown in **Table I**. In contrast, Almeida *et al*. (2013) concluded that through analysis of variance and the Tukey test, that the use of different cooling times in the waiting pen in the summer season, did not show changes in the chemical composition of milk in the morning shift.

The same can be observed for the winter season (**Figure 2A** and **Figure 2B**) in which the EACS, influenced the composition of milk (**Table I**). However, Almeida Neto *et al*. (2014) using classical statistics, found that different times of evaporative adiabatic cooling in winter, in a semiarid region, did not show changes in milk composition.

Garner *et al*. (2017) observed that the temperature and humidity index - THI > 72 implied less milk production for Holstein cows. The results found by the authors corroborate that of the present study, in **Figure 2A** and **Figure 2B**, therefore, it is observed that in two seasons, milk production was inversely proportional to THI. However, it is noteworthy that in winter the THI values, even for the EACS 0 min (control) were less than 68.00, for the summer season the THI did not exceed 70.00 units, therefore, with little influence on milk production (**Table I**).

AFTERNOON SHIFT

The coefficient of variation (CV) was low for all variables studied, except for milk fat (Fat) of the animals submitted to EACS for 30 min, for the respiratory rate (RR) of the animals at all cooling times and, for the skin temperature (ST) for the control animals in the summer season, which presented average CV (12% < CV < 24%). In the winter season, the CV was average for Fat among animals exposed to EACS for 30 min and ST at 0 and 10 min (**Table III**).

The components PC1 and PC2 presented eigenvalues greater than 1 (16.616 and 4.806) respectively. The principal components used in the discussion of variables show a total variance of around 89.30% for PC2 (**Table IV**). Gabbi *et al*. (2018) related levels of total digestible nutrients and experimental period in milk production, composition, and quality, with Jersey, Jersey × Holstein, and Holstein cows, through the analysis of principal components and obtained results of the total variance of 87.24%, therefore, similar to the present study.

The relationship of protein with milk production and composition, as well as its association with comfort indexes and physiological variables, did not influence the percentage of protein in the afternoon shift for the summer season, according to PC1 (**Table IV**). Studies by Lambertz, Sanker and Gauly (2014) showed that the percentage of milk protein decreased under conditions of heat stress. These data contradict the findings of the present study for the summer season in the afternoon shift, in which the highest values of protein were observed when production was lower (**Table III**).

Wildridge *et al*. (2018) reported the existence of a delay in the animal's response from one to two days due to external weather conditions, identified by the temperature and humidity index. Thus, the non-influence on milk protein by comfort indexes and physiological variables probably occurred in response to the best comfort conditions that the animals received in the morning shift during pre-milking.

In **Figure 3**, the principal components of the physiological variables, animal comfort indexes, milk production, and composition of animals submitted to EACS in the afternoon (summer/winter) are presented.

Unlike the morning shift, in which the highest milk production in the summer was observed for animals exposed to EACS for 30 min, in the afternoon shift it was observed that animals exposed to EACS for 10 min, had positive responses in milk production (**Figure 2A** and **Figure 2B** and **Figure 3A** and **Figure 3B**). In the winter season in the afternoon, the use of the evaporative adiabatic cooling system did not influence milk production.

Observing the temperature and humidity index in both seasons (summer and winter), their values were higher in the afternoon shift, exceeding the threshold of 72 (**Table III**).

Because of the findings by Wildridge *et al*. (2018), it is safe to say that the response to the effect of climatization in the morning in both seasons, may be related to improvements in milk production and composition in the afternoon shift. Thus, the effect of the climatization carried out in the afternoon shift contributes to improvements in milk production and composition in the morning of the following day. As for the effects of

Table II. Descriptive statistics of milk production (Prod, liters), fat (Fat, %), protein (Pro, %), lactose (Lac, %), total solids (Sol, %), enthalpy (h, KJ kg-1), black globe temperature and humidity index (GTHI), temperature and humidity index (THI), radiant thermal load (RTL, W m-2), rectal temperature (RT, °C), respiratory rate (RR, mov min-1) and skin temperature (ST, °C) in the afternoon shift in both seasons.

[1]Var	[2]Tim	Summer					Winter				
		[3]m	[4]SD	[5]CV	[6]Min	[7]Max	m	SD	CV	Min	Max
Prod	0	6.67	0.29	4.40	6.35	6.98	7.67	0.62	8.06	6.83	8.21
	10	6.89	0.26	3.72	6.67	7.20	7.61	0.37	4.81	7.20	7.98
	20	6.75	0.29	4.30	6.39	7.04	7.61	0.35	4.63	7.20	7.94
	30	6.87	0.19	2.78	6.63	7.09	7.70	0.54	7.07	7.08	8.18
Fat	0	4.15	0.42	10.21	3.55	4.49	4.34	0.27	6.10	4.14	4.71
	10	4.69	0.55	11.66	4.11	5.32	4.31	0.44	10.30	3.74	4.74
	20	4.14	0.31	7.51	3.79	4.53	4.46	0.15	3.33	4.29	4.59
	30	4.40	0.61	13.95	3.72	5.11	4.44	0.59	13.26	4.03	5.29
Pro	0	2.71	0.17	6.32	2.45	2.82	2.79	0.08	2.91	2.67	2.84
	10	2.67	0.13	4.77	2.55	2.85	2.79	0.09	3.14	2.66	2.87
	20	2.72	0.07	2.44	2.64	2.80	2.79	0.04	1.34	2.74	2.82
	30	2.68	0.10	3.60	2.55	2.77	2.82	0.09	3.06	2.70	2.88
Lac	0	4.41	0.12	2.79	4.33	4.59	4.47	0.03	0.76	4.43	4.51
	10	4.42	0.13	2.87	4.28	4.59	4.53	0.03	0.77	4.49	4.57
	20	4.44	0.06	1.42	4.38	4.53	4.52	0.05	1.01	4.47	4.56
	30	4.43	0.14	3.09	4.30	4.60	4.51	0.07	1.65	4.46	4.62
Sól	0	12.19	0.40	3.26	11.61	12.50	12.54	0.33	2.65	12.23	13.01
	10	12.70	0.59	4.63	11.97	13.39	12.57	0.52	4.14	11.90	13.10
	20	12.22	0.38	3.12	11.81	12.68	12.72	0.23	1.80	12.44	12.97
	30	12.45	0.59	4.73	11.68	12.98	12.71	0.68	5.36	12.15	13.69
h	0	70.65	2.23	3.16	68.40	72.90	65.93	1.73	2.63	63.50	67.60
	10	69.03	1.04	1.51	68.10	70.20	64.78	2.38	3.67	61.60	66.70
	20	67.63	0.96	1.42	66.80	69.00	62.72	2.50	3.99	60.40	65.80
	30	66.38	1.20	1.81	64.70	67.30	64.00	2.34	3.65	60.70	65.80
GTHI	0	82.25	2.50	3.04	79.00	85.00	75.75	1.89	2.50	73.00	77.00
	10	72.25	0.50	0.69	72.00	73.00	69.50	1.92	2.76	67.00	71.00
	20	71.50	0.58	0.81	71.00	72.00	69.00	1.41	2.05	67.00	70.00
	30	71.25	0.50	0.70	71.00	72.00	68.75	1.26	1.83	67.00	70.00
THI	0	77.75	1.26	1.62	76.00	79.00	74.50	0.58	0.77	74.00	75.00
	10	75.25	0.96	1.27	74.00	76.00	73.00	1.16	1.58	72.00	74.00
	20	73.50	1.00	1.36	72.00	74.00	72.25	0.96	1.33	71.00	73.00
	30	73.00	0.82	1.12	72.00	74.00	72.00	0.82	1.13	71.00	73.00
RTL	0	534.40	31.00	5.80	503.20	573.20	482.60	28.80	5.98	443.40	508.20
	10	388.32	8.85	2.28	379.30	399.30	353.70	40.10	11.34	313.80	396.70
	20	390.32	7.15	1.83	380.10	395.30	348.10	33.30	9.55	315.20	391.30
	30	397.45	5.48	1.38	390.40	403.10	347.40	32.50	9.36	317.10	389.30
RT	0	39.05	0.24	0.61	38.80	39.30	38.95	0.24	0.61	38.70	39.20
	10	38.93	0.21	0.53	38.70	39.10	38.73	0.21	0.53	38.50	39.00
	20	38.90	0.28	0.73	38.70	39.30	38.75	0.30	0.77	38.60	39.20
	30	38.73	0.15	0.39	38.50	38.80	38.63	0.17	0.44	38.40	38.80
RR	0	61.50	12.12	19.71	51.00	79.00	51.75	9.74	18.83	41.00	60.00
	10	38.75	7.41	19.12	32.00	47.00	38.75	7.14	18.41	30.00	47.00
	20	39.75	9.18	23.09	29.00	50.00	33.75	3.10	9.17	31.00	38.00
	30	35.25	7.14	20.24	27.00	44.00	31.50	3.11	9.87	28.00	35.00
ST	0	38.50	5.09	13.22	33.20	45.30	34.23	2.18	6.38	31.70	36.80
	10	31.93	1.27	3.98	30.10	33.00	30.15	0.70	2.31	29.50	31.10
	20	29.83	1.90	6.38	27.60	32.10	28.43	0.64	2.25	27.60	29.10
	30	30.78	2.07	6.73	27.80	32.60	29.48	0.91	3.08	28.60	30.60

1Var: variables; 2Tim: adiabatic evaporative cooling time (0, 10, 20 and 30 min); 3m: medium; 4SD: standard deviation; 5CV: coefficient of variation; 6Min: minimum; 7Max: maximum.

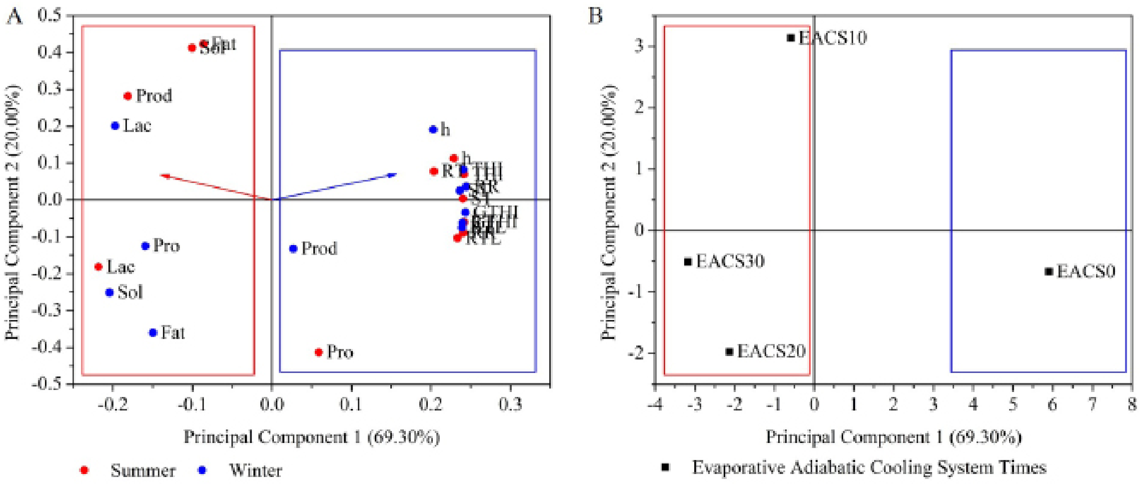


Figure 3. Principal components of the physiological variables, animal comfort indices, production and composition of milk of cows in the afternoon shift in summer and winter (A); Principal components of the operating time of the evaporative adiabatic cooling system in the afternoon (B) (Principales componentes de las variables fisiológicas, índices de confort animal, producción y composición de leche de vacas en turno vespertino en verano e invierno (A); Componentes principales del tiempo de funcionamiento del sistema de enfriamiento adiabático evaporativo por la tarde (B).
h: enthalpy (h; KJ kg-1); GTHI: globe temperature and humidity index; THI: temperature and humidity index; RTL: radiant thermal load (W m-2); RT: rectal temperature (ºC); RR: respiratory rate (mov min-1); ST: skin temperature (ºC); Prod: milk production (liters); Fat: fat (%); Pro: protein (%); Lac: lactose (%); Solid: soluble solids (%); EACS: adiabatic evaporative cooling system 0, 10, 20 and 30 minutes.

animal comfort indices and physiological variables, the effect of EACS is immediate.

As for the composition of the milk, the cooling times provided better results, with reductions in comfort indexes and physiological variables (**Figure 3**). Broucek *et al*. (2018) evaluated the effect of high temperatures on milk production of lactating Holstein cows in southern Slovakia and observed that the use of the evaporative adiabatic cooling system in dairy cows increased the amount of milk fat and protein.

CONCLUSIONS

The principal component analysis allowed us to identify the positive influence of evaporative cooling

Table IV. Principal components of comfort indexes, physiological variables, behavioral parameters, milk production, and composition of dairy cows in the afternoon shift in the summer and winter seasons (Principales componentes de los índices de confort, variables fisiológicas, parámetros de comportamiento, producción de leche y composición de las vacas lecheras en el turno de tarde en las temporadas de verano e invierno**).**

Variable	Principal Summer Component		Principal Winter Component	
	*PC1	PC2	PC1	*PC1
^{1}h	0.229	0.113	0.203	0.191
^{2}GTHI	0.242	-0.060	0.243	-0.034
^{3}THI	0.241	0.070	0.241	0.083
^{4}RTL	0.233	-0.103	0.239	-0.075
^{5}RT	0.204	0.078	0.240	-0.061
^{6}RR	0.241	-0.089	0.244	0.036
^{7}ST	0.240	0.004	0.236	0.025
^{8}Prod	-0.181	0.282	0.027	-0.132
^{9}Fat	-0.086	0.423	-0.150	-0.360
^{10}Pro	0.059	-0.413	-0.160	-0.125
^{11}Lac	-0.218	-0.181	-0.197	0.201
^{12}Sol	-0.101	0.413	-0.204	-0.251
Eigenvalue	16.616	4.806	16.616	4.806
Proportion	0.692	0.200	0.692	0.200
Accumulated	0.692	0.893	0.692	0.893

*PC: principal component; 1h: enthalpy (h; KJ kg-1); 2GTHI: globe temperature and humidity index; 3THI: temperature and humidity index; 4RTL: radiant thermal load (W m-2); 5RT: rectal temperature (ºC); 6RR: respiratory rate (mov min-1); 7ST: skin temperature (ºC); 8Prod: milk production (liters); 9Fat: fat (%); 10Pro: protein (%); 11Lac: lactose (%); 12Sol: soluble solids (%).

on thermal comfort, physiological responses, production, and composition of milk of lactating cows.

Among the seasons studied, the winter season provided the best comfort conditions, in the summer season, the evaporative cooling time for 30 minutes in the morning shift increased milk production in the afternoon and, from the exposure time by 10 minutes of evaporative cooling in the afternoon shift, improved the productive performance of the animals in the morning milking of the following day.

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