Productivity of Holstein dairy cows without shade at two seasons of the year

Productividad de vacas lecheras Holstein sin sombra en dos épocas del año

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ABSTRACT

In order to evaluate the effect of season on the productivity of Holstein dairy cows in a commercial herd, 10 cows were assigned to one of two treatments, cows in winter (Inv) and cows in summer (Ver). The study lasted 70 days (d) divided into two periods of five weeks, respectively. The data were collected three times per week. The animals were under the same diet in both seasons, from an integral ration based on concentrate, alfalfa hay, and corn silage. The maximum temperature-humidity index was 70 and 75 units during the winter and summer, respectively. The cows in winter had lower (P<0.05) milk production, respiratory rate and rectal temperature than summer cows. The temperatures on the right flank and buttock area in winter cows were lower (P<0.05), with respect to summer cows. Drinking water, floor, and environment temperatures through the black bulb were consistently lower (P<0.05) during the winter season with respect to summer. Summer cows showed mild heat stress and increased 24 % plus milk yield than winter cows, but did not improve milk quality. The use of shades during the summer can improve the physiological status milk quality in lactating dairy cows.

Keywords: Dairy cows, without shade, mild heat stress, productivity.

RESUMEN

Con el propósito de evaluar el efecto de época sobre la productividad de vacas lecheras Holstein, 10 vacas fueron asignadas a uno de dos tratamientos, vacas en invierno (Inv) y vacas en verano (Ver). El estudio tuvo una duración de 70 días (d) divididos en dos periodos de cinco semanas, respectivamente. Los datos fueron colectados tres veces por semana. Los animales fueron alimentados bajo el mismo régimen alimenticio en ambas épocas, a partir de una ración integral a base de concentrado, heno de alfalfa y silo de maíz. El índice de temperatura-humedad máximo fue de 70 y 75 unidades durante el invierno y verano, respectivamente. Las vacas Inv tuvieron menor producción de leche (P<0.05), tasa respiratoria y temperatura rectal que vacas Ver. Las temperaturas de costado derecho y nalga en vacas Inv fueron menores (P<0.05), respecto a vacas Ver (P<0.05). Las temperaturas de agua de bebida, piso y ambiental a través del bulbo negro fueron consistentemente menores (P<0.05) durante la época de invierno con respecto al verano. Las vacas Ver presentaron estrés calórico ligero e incrementaron 24% más la producción de leche respecto a vacas Inv, pero no mejoraron la calidad en leche. El uso de sombras durante el verano, puede mejorar el estado fisiológico y calidad de la leche en vacas lecheras en lactación.

Palabras clave: Vacas lecheras, sin sombra, estrés calórico leve, productividad.

INTRODUCTION

The increase in environment temperature (TA) has intensified mainly in desert and semi-desert areas due to global warming, resulting in warmer summers (Avendaño *et al*., 2012). In addition to this, there are conditions such as heat stress (EC), which impact the livestock-agriculture relationship in four important aspects: 1) grain production for livestock consumption, as well as availability and price, 2) production and quality of pasture and forage crops, 3) livestock production, reproduction, growth and health, and 4) disease distribution (Francis and Vavrus, 2012).

During 2011, high temperatures in the United States of America caused producers to suffer losses in milk production, which exceeded one trillion dollars (NOAA, 2012). The EC is described as an interaction between the increase in body temperature and internal heat, which is generated from the metabolism of nutrients coupled with the inefficiency of animals to lose body heat, in combination with environmental factors, such as: Relative humidity (HR), TA, wind speed and solar radiation (McManus *et al*., 2011). The latter is the main factor that ensures that animals gain heat directly or indirectly from the environment (Krishnan *et al*., 2017).

The temperature-humidity index (ITH) is used to quantify the degree of EC in animals and this starts from 72 units (West, 2003). On the other hand, from the physiological point of view and in order to minimize the heat coefficient, the cows first experience an increase in the rate of sweating, due to a redistribution of the blood towards the surface of the skin (Hernández *et al*., 2011; Habeeb *et al*., 2018). Also, these same authors mention that secondarily, organs such as the udder and the uterus decrease their functionality, altering the hormonal levels that have to do with the production and reproduction. In fact, animals that have been exposed to conditions of intense heat, showed an increase in the concentration of cortisol, which is directly related to the level of stress. They also showed a decrease in insulin, thyroxine, triiodothyronine (T3) and plasma aldosterone (Habeeb *et al*., 2018).

Conversely, it has been observed that animals under EC conditions, housed in shaded pens, have cortisol and plasma T3 in smaller and greater amounts respectively (Kamal *et al*., 2016[b]). Then the water consumption, rectal temperature (TR), pulse, respiratory rate (Three) and tachypnea are increased; finally, it decreases the consumption of nutrients and dry matter, rumination process and food passage rate (Kamal *et al*., 2016[b], Kamal *et al*., 2016[a]). Consequently, when the TA exceeds 29 °C, the productive efficiency of dairy cows in lactation is usually reduced, mainly in cows that have been exposed to high temperatures for at least 67 days (Ammer *et al*., 2018).

The absence of shadows and high room temperatures are severe conditions, which can cause the death of dairy cows under EC (Rhoads *et al*., 2013). Therefore, the simple use of shadows in the pen helps to reduce the impact caused by CD in animals (Berman and

Horovitz, 2012). In fact, it has been shown that animals that have been directly exposed to solar radiation can reduce the heat load in the shade from 30 to 45 % (Ulvshammar, 2014).

Finally, in dairy herds located in northern Mexico, there have been reports of moderate to severe EC with ITH of 84 units during the summer months (Correa-Calderón *et al*., 2014, Anzures-Olvera *et al*., 2015). In certain regions of central Mexico, where traditionally it was not necessary to place shadows in the corrals, producers have begun to identify high temperatures, especially in the summer season; however, this has not been evaluated objectively, and it is likely that there is a negative effect on the productivity of dairy cattle.

Therefore, the objective of this study was to evaluate the effect of time on the quality and production of milk, physiological and climatic responses in lactating Holstein dairy cows, housed in shaded pens during the winter and summer in a commercial ranch of "El Marqués", Querétaro, Mexico.

MATERIAL AND METHODS

Location. The study was conducted in a commercial herd located at 20° 44'00" North latitude, and 100° 17' 39" West longitude, in El Marqués municipality, Querétaro, Mexico; with an altitude of 1945 m a.s.l, average annual temperature of 18 °C and annual rainfall of 500 mm. The dominant wind is from Northeast to Southwest. The climate is predominantly semi-dry-temperate in 87 % of the municipality, the rest is temperate-sub-humid and sub-humid (INEGI, 2009).

Animals and treatments. The work was carried out during the winter and summer seasons, with a duration of 70 days divided into two periods of five weeks, respectively. The cows counted on a total area of 880 m^2 inside the corral without shade, including 24.5 m of feeder in front. Taking into account, the days in milk (30 to 130 d), number of births (2 to 5) and the production of milk prior to the beginning of the experiment and to give statistical normality to the data, 10 Holstein multiparous cows were assigned in a manner randomized to one of two treatments, (Inv); (n = 5): cows in winter season; (Ver); (n = 5): cows in summer time. The data were collected three times a week and the milking schedule was performed at 06:00 and 17:00 hours (h), with duration of three and two hours, respectively; at the end of the milking, the food was already served in the trough to the floor. In both seasons, an integral ration was provided based on concentrate (600 g/kg of consumption), alfalfa hay (300 g/kg of consumption), corn silage (100 g/kg of consumption) and it was formulated according to the recommendations of the NRC (2001), containing 958 g/kg MS, 172 g/kg PC, 40.8 g/kg of fat and 41.7 g/kg of FDN. Access to water was *ad libitum*.

All the procedures performed on the animals were approved by the Bioethics Committee of the Faculty of Natural Sciences of the Autonomous University of Querétaro.

Productive variables. Milk production was measured in kilograms per cow, during milking time; through the weighers of the WAIKATO brand (inter Ag, Hamilton, New Zealand). Immediately after the weigher, a milk sample was taken in plastic cups (50 ml) with cap; obtaining before closing the glass, the temperature of the milk (°C), with the help of a digital thermometer in the form of a gun and an integrated infrared system (Fluke® model 63). Finally, the milk was stored in a cooler for further analysis in the dairy laboratory of the Faculty of Engineering of the Autonomous University of Querétaro. To determine the quality of the milk, the components (protein, fat, non-fat solids, lactose and pH) were obtained with the LACTOSCAN Milk Collecting Center (MCC, Bulgaria, 6000 Stara Zaragoza, 167, Tsar Simeon Veliki, A, 25).

From the total milk production (PLT) and the percentages obtained from fat and protein in milk, the energy variable in milk (EL) was obtained by the following formula, *EL* = ({[(40.72 × *fat*, %) + (22.65 × *protein*,%) + 102.77] ÷ 1000} × 2,204) × *PTL* (Tyrrell and Reid, 1965). In addition, with the information of PLT and percentage of fat in milk, milk production corrected to 3.5 % fat was calculated (Parekh, 1986), using the formula: *LCG* = [((0.425 × PTL) + (16425 × ((*fat*,% ÷ 100) × PTL)))]. Where: LCG = Milk corrected to 3.5 % fat.

To estimate the projection at 305 days in milk (DEL) of the groups of cows Inv and Ver the formula proposed by Häubi Segura and Gutiérrez Lozano (2015), *Proy305* = *MilkDEL* ÷ *CoefDEL* × 100, where: Proy305, is the estimate of the projection of milk per cow adjusted to 305 DEL; MilkDEL, is the production of milk on a specific day of the DEL; divided between CoefDEL, which is the coefficient corresponding to the same specific day of the LEDs, multiplied by 100. This coefficient was obtained from Wood's formula (1967) = *a* × *t* ^ *b* × *exp-c* × *t*, where: t = days in milk (DEL); a = 0.434285; b = 0.318412; c = 0.142361 (R^2 = 0.995). Once the 305 DEL projection of the Inv and Ver cow groups was obtained, the national average production (PMN) of milk for 2017 was requested from the Holstein Association of Mexico A.C. (AHM, 2018) and from these three data, the Winter, Summer and Control lactation curves were modeled, the latter created as a national reference for the Holstein breed.

The lactation curves were modeled by clearing the Proy305 formula, to obtain the kilos of milk corresponding to the LEDs of the *kgDEL = (Proy305 ÷ 100) × CoefDEL* curve. Finally, 0.1 was assigned to the first DEL, to reflect the milk production of the first hours after delivery, after the second DEL onwards; it is continued from 1 to 305, corresponding to the days of a complete lactation.

Physiological variables. The body condition (CC) was evaluated once a week on a scale of five points, where "1" corresponded to a too skinny cow and "5" to a too obese one (Wildman *et al.*, 1982). The temperature of the skin layer (TP) and Three were obtained at 1500 h inside the pens. The TR was obtained during the milking of the afternoon, for this a rod-
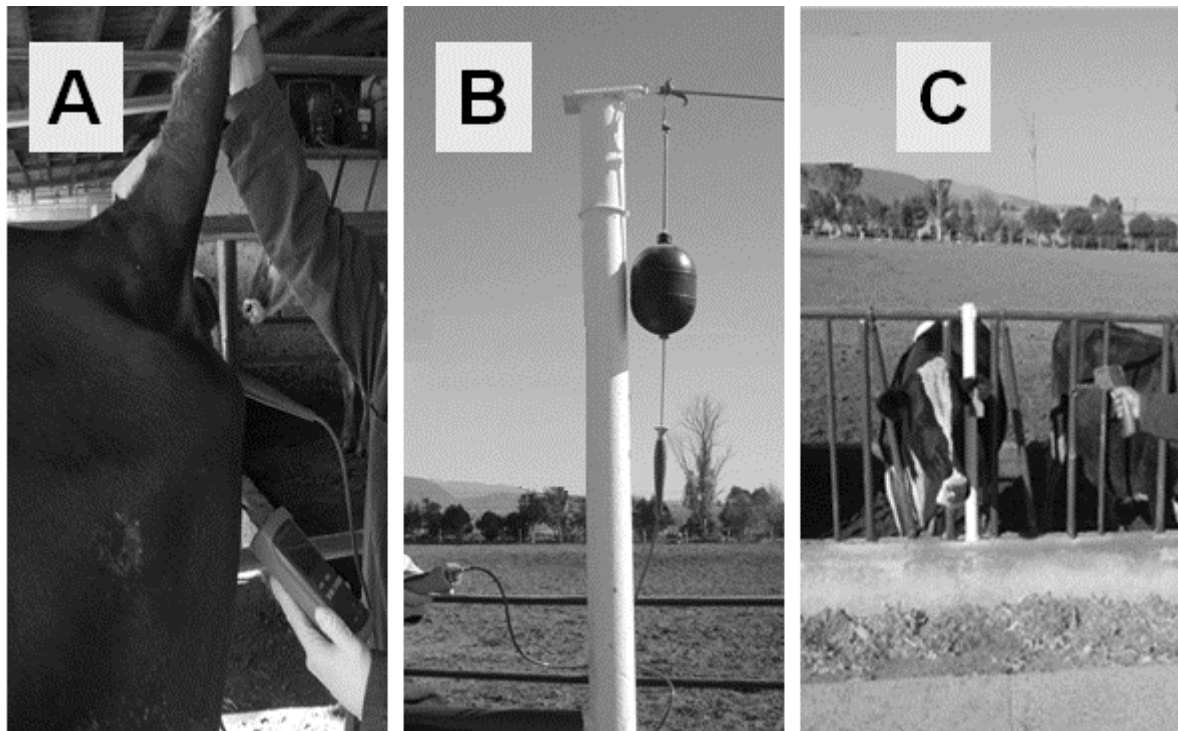
Figure 1. Rectal temperature readout (A); reading of the room temperature through the black bulb, the rod-shaped attachment and digital thermometer (B); Take the temperature reading of the skin layer at a distance with the digital thermometer in the form of a gun and integrated laser (C).

shaped attachment was used and it was connected to a digital thermometer (Fluke® models 80 PK-22 and 51-2, respectively, Figure 1-A).

The TA inside the pen was collected by using the black bulb, as suggested by Veissier *et al*. (2018), before each milking (Figure 1-B). For this, the same attachment and thermometer described in TR was used. On the other hand, with the digital thermometer in the form of a gun and integrated laser beam (Fluke® model 63), TP data were obtained in its different regions (Figure 1-C), such as: head, right side, buttock and udder of all animals *in situ*, therefore. It was necessary to do the evaluation at a distance of approximately three meters in relation to the cow, so as not to frighten them or provoke in them discomfort; the laser beam helped indicate the region and obtain accurate readings. Then, to obtain more information about the internal conditions of the corral, the temperatures of the drinking water and the ground floor were obtained, with the same thermometer described in TP, during the morning and afternoon, before starting the milking. Finally, the Three was determined from the number of breaths per minute (resp/min), observing the movement of the thorax of the cows.

Climatic variables. The meteorological status information was obtained daily from the experimental climatological station of the Faculty of Engineering of the Autonomous University of Querétaro, located 2 km from the study area. The climatic variables collected

every fifteen minutes were TA (°C) and HR (%). Then the ITH was calculated with the following formula proposed by Hahn (1999): ITH = 0.81 TA + HR (TA-14.4) + 46.4. Where: ITH = Temperature-Humidity Index, TA = Ambient Temperature and HR = Humidity. Subsequently, averages, maximums and minimums of each variable were obtained.

Statistical analysis. All the variables were analyzed under a completely randomized design with 2x5 factorial arrangements, with the Proc Mixed procedure of the SAS (2004). The general statistical model used for each variable was $Y_{ijk} = \mu + E_i + S_j + (E_i \times S_j) + \mathcal{E}_{ijk}$ where: Y_{ijk} is the dependent variable, μ is the general average, E_i is the fixed effect of time, S_j is the effect fixed week, $(E_i \times S_j)$ is the effect of interaction per week and $\mathcal{E}_{ijk}$ is the experimental error. The means and standard errors were recorded in each variable. To establish the differences between means, a least squares test was used and statistical significance was declared at a 5 % probability, considering a tendency to a probability of 10 %.

RESULTS AND DISCUSSION

The records of the climatic variables during winter and summer are shown in figure 2. During the winter, the maximum value of TA was 20 °C and 95 % RH; while the ITH was 70 units; the minimum values were 3 ° C, 7% and 33 units, respectively. In the summer the maximum values of TA, HR and ITH were 30 °C, 95 % and 75 units, respectively; and the minimum values 12 °C, 23 % and 55 units, respectively.

These results coincide with that reported by Dalcin *et al*. (2016), where they obtained a maximum ITH of 75 units during the morning in Holstein dairy cows. The maximum HIT reached during the summer was maintained for at least 10 h each day; this means that the animals were subjected to a light EC. The rest of the day, the minimum ITH did not reach 60 units, which, as they did not present any type of EC, the animals had the opportunity to alleviate the heat obtained during the sunny hours (Silanikove and Koluman, 2015). Figure 3 shows the effect of epoch*week interaction (P <0.01), with respect to the maximum and minimum values of ITH in the study time. During the summer, the minimum ITH remained constant at around 58 units in the five weeks of the study; while in the second week of winter the lowest point was recorded with 38 units. In the summer, the maximum ITH remained above 72 units for the first four weeks of study, reaching 75 units in the first week; however, less than 72 units were registered during the last week; on the other hand, in the winter the 70 units were not exceeded in any of the weeks.

ITH values less than 72 units, indicates that the animals are stress-free, that is, comfortable; from 72 to 78 units there is a slight stress; of 79-88 units is moderate, and greater than 89 units is considered severe stress, in danger of death (Akyuz *et al*., 2010). Eigenberg *et al*. (2010) evaluated the effect of different types of shadows on dairy cows and discovered a lower EC load in them, when compared with animals housed in shaded pens, especially
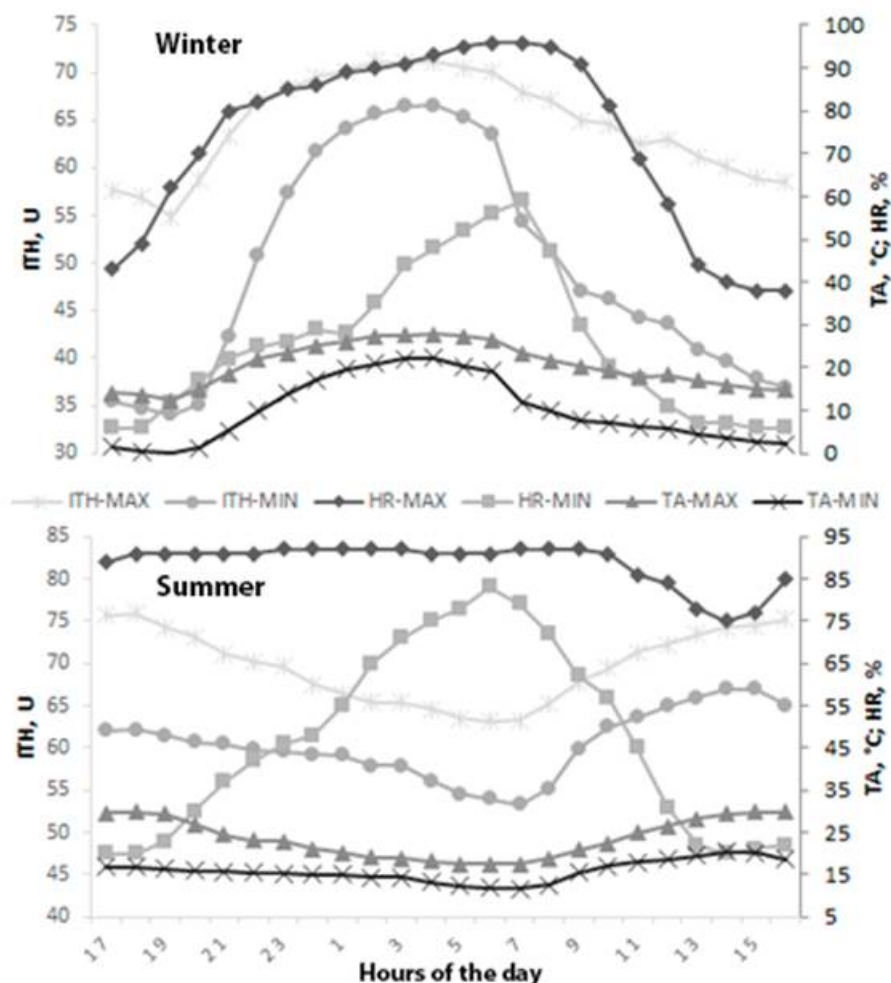
Figure 2. Hourly records of the temperature-humidity index (ITH), room temperature (TA) and relative humidity (HR) maximum and minimum during the winter and summer seasons

during daytime hours when high temperatures were recorded. Veissier *et al*. (2018) on the other hand, they estimated the percentage of time used by the cows under shade in the pen. These authors reported that the use of shade increased when the heat load in animals increased exponentially (P <0.01).

The effect of epoch*weeks interaction had no effect (P> 0.05) on the productive, physiological responses and temperatures of drinking water, floor and black bulb. The results of the physiological variables are shown in Table 1. The body condition of the cows was similar (P> 0.05) in both seasons; this indicates that the conditions of nutritional management were similar between the Inv and Ver animals. The Inv cows had lower (P <0.05) Three and TR (45 rpm and 38.3 °C, respectively) than the Ver cows (56 rpm and 38.6 °C), respectively).

According to this, it is evident that the Inv animals supported more the conditions of EC, with respect to the Ver cows. The Three, of Ver cows was above that reported by Dalcin *et al*. (2016) in Holstein x Gir animals housed without shade. The authors point out that these animals were more tolerant to EC, with respect to Holstein cows of the same study, which
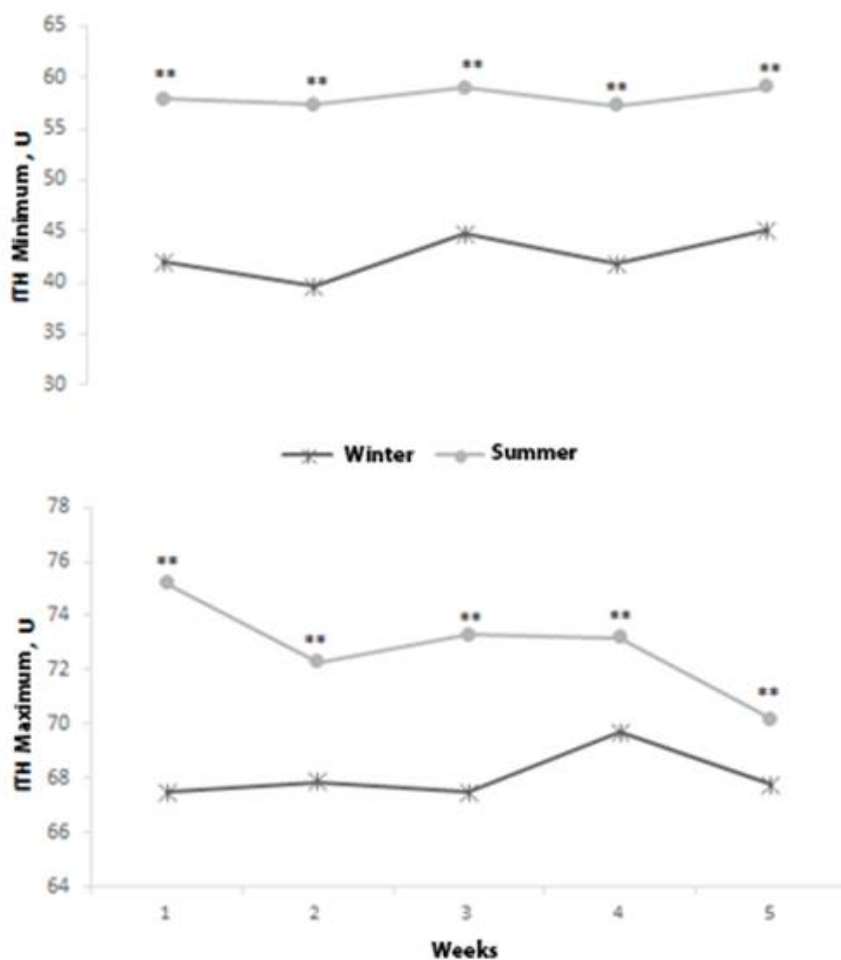
Figure 3. Weekly record of the maximum and minimum temperature-humidity index (ITH) of the group of winter and summer cows (differences between each point is shown with ** P <0.01).

Table 1. Effect of the winter-summer season on physiological responses in Holstein cows.

	Winter	Summer	E.E.[1]	P-Value
Body condition, 1-5[2]	3	3	0.0273	0.7710
Respiratory rate[3]	45	56	1.6186	<0.0001
Rectal temperature[4]	38.3	38.6	0.0434	<0.0001
Skin layer temperatures				
Head	34.8	35.6	0.8791	0.3517
Right side	34.2	36.1	0.7119	0.0105
Buttock	33.4	36.3	0.6584	<0.0001
Udder	34.6	34.6	0.4088	0.9912

[1] Standard error; [2] units; [3] breaths per minute; [4] Celsius degrees.

presented 46 rpm more than the cows of the Ver group. The normal Three in cattle is 20 rpm (Thomas and Pearson, 1986) ; that is to say, that both groups of Inv and Ver cows increased by 125 and 180 % plus the Three, respectively.

Collier et al. (2017), mention that the increase of three and TR are important signs of EC in dairy cattle. Arias *et al*. (2018) indicate that when the TA exceeds 27 °C, the Three increases above 56 rpm. This situation was similar for the cows of the Ver group, with respect to those same variables. Fabris *et al*. (2017) reported that cows increase Three and TR from 77 units of ITH. This increase is in response to the fact that the hypothalamus detects EC conditions in animals through thermo receptors of the central and peripheral nervous system (Veissier et al., 2018). Likewise, Igono et al. (1992) indicated that the average TR in dairy cows is 38.5 ° C, under normal conditions. Tao and Dahl (2013) observed a positive correlation between the TR recorded in the afternoon and milk production. On the other hand, the TR was increased enough to detect a difference (P <0.05) among the animals of the Ver group, with respect to the cows of the Inv group. This situation was similar to that reported by Veissier *et al*. (2018), when they observed that TR increased while EC increased in animals without shade. TPs such as the right and buttock sides of Inv cows (34.2 and 33.4 °C, respectively) were lower (P <0.05) than cows in the Ver group (36.1 and 36.3 °C, respectively).

Recently one study showed that animals under EC conditions but cooled in short periods of time, presented TP in leg and shoulder equivalent to those reported in the group of Inv cows (Tresoldi *et al*., 2018). On the other hand, in that same study, animals with shade and without cooling were similar to what was reported in cows of the Ver group. No differences (P> 0.05) were observed between the groups of Inv and Ver cows, with respect to the temperature of the head and udder.

The results of at least two TPs recorded in this study show a consistently higher increase in Ver cows than in Inv ones. This increase coincides with the results obtained in this study of Three and TR, during the same summer season. In addition, despite the fact that the Ver cows presented light EC, the animals did not compromise their eating and drinking activities inside the pen, as happened in a study carried out by Hernández *et al*. (2011). These same authors also reported that the increase in TP is associated with a higher rate of sweating and loss of body heat; in fact, in the need to stay cool, animals under EC conditions look for high places, preferably with shade, wind or constant air flow within the pen (Schütz *et al*., 2014; Van Laer *et al*., 2015; Kamal *et al*., 2018).

Table 2 shows the temperature results of the drinking water, floor and black bulb. The average temperatures of drink water, floor and black bulb were consistently higher (P <0.05) in the group of Ver cows (24.8, 27 and 25.1 °C, respectively), than in the group of Inv cows (18.8, 20.0 and 21.9 °C, respectively); however, the temperature of the black bulb during the morning showed no difference (P> 0.05) in both groups of animals.

On the other hand, during the summer evenings the temperatures of drink water, floor and black bulb were considerably higher (P<0.05) than in the winter evenings; which mean that these conditions improved the welfare of the group of Inv cows despite the absence of

Table 2. Drinking water, floor and black bulb temperatures in the lodging pen during the winter-summer season

Temperatures [2]	Winter	Summer	E.E.[1]	P-Value
Drinking water, AM[3]	15.0	23.0	0.4669	<0.0001
Drinking water, PM[4]	22.6	26.8	0.3430	<0.0001
Average	18.8	24.8	0.2856	<0.0001
Floor, AM[3]	15.5	18.8	0.5905	<0.0001
Floor, PM[4]	24.5	35.2	1.5372	<0.0001
Average	20.0	27.0	0.8521	<0.0001
Black bulb, AM[3]	17.0	18.4	0.7578	0.0624
Black bulb, PM[4]	26.8	31.8	0.6112	<0.0001
Average	21.9	25.1	0.4634	<0.0001

[1]Standard error; [2]degrees Celsius; [3]morning reading; [4]evening reading.

shadows. Then, as the dairy herd did not have facilities that would help mitigate the effects of solar radiation during the afternoon hours, it created a stressful environment that did not benefit the group of Ver cows; in fact, when the room temperature is higher than the TP, the animal gains heat from the surrounding environment, entering a state of discomfort (Avendaño-Reyes, 2012).

The results of the productive responses are shown in table 3. The temperature in milk during the morning was lower (P <0.05) in Inv cows than in the group of Ver cows, without presenting changes (P> 0.05) among the group of animals during the afternoon according to the results obtained in the climatic variables of this study.

The production of milk, LCG and energy in milk were higher (P<0.05) in Ver cows, with respect to Inv cows. Milk production was greater by just over 5.5 kg between the two groups of animals; this is due to the fact that the Ver cows, when presenting a light EC, mainly during the hours of the day with higher intensity of heat, had the need to mitigate this stress through the increase in water consumption. Ammer *et al*. (2018) reported that Holstein dairy cows under EC conditions, increase water consumption by about 1 L, per each unit of ITH increase.

In the case of Inv cows, as they did not present any kind of stress, they did not need to increase their water consumption; these assertions, although not recorded, are based on observations made during the development of the experiment. On the other hand, Polsky and von Keyserlingk (2017) mention that dairy cows in cases of dehydration due to EC, increase their activity, walking towards the feeders, drinking troughs and / or milking parlor; either individually or collectively. These same authors report that the routes of water loss in the body are through sweat on the skin, evaporation through panting, feces, urine and milk. Therefore, an increase in water consumption in animals under EC increases the amount of water in milk to release body heat; but it does not elevate the quality of it through its

Table 3. Effect of time on productive responses of Holstein cows

	Winter	Summer	E.E.[1]	P-Value
Milk[2]	23.06	28.71	0.9053	<0.0001
LCG[3] al 3.5%	24.50	30.62	1.2609	<0.0001
Energy in milk[4]	16.22	20.14	0.7052	<0.0001
Milk temperature[5], average	31.41	32.50	0.2431	<0.0001
AM[6]	31.19	33.11	0.4320	<0.0001
PM[7]	31.64	31.95	0.2308	0.1840
Fat[8], average	3.71	3.72	0.09602	0.8734
AM[6]	3.20	2.89	0.09334	0.0014
PM[7]	4.20	4.56	0.1446	0.0127
Protein[8], average	2.85	2.79	0.02609	0.0429
AM[6]	2.78	2.80	0.02972	0.6567
PM[7]	2.91	2.75	0.04785	0.0015
Lactose[8], average	4.03	3.97	0.03564	0.0778
AM[6]	4.02	3.96	0.03520	0.0896
PM[7]	4.03	3.97	0.05665	0.3292
SNG[9], average	7.65	7.43	0.06629	0.0011
AM[6]	7.72	7.46	0.1050	0.0141
PM[7]	7.58	7.37	0.07053	0.0028

[1]Standard error; [2]kg/day; [3]milk corrected in fat at 3.5 %, kg; [4]MCal/d; [5]Celsius degrees; [6]morning reading; [7]evening reading; [8]percent; [9]non-fatty solids, percentage.

components. The non-fat solids were consistently higher (P <0.05) in cows of the Inv group, when compared to cows See. Likewise, the percentage of fat during the morning was higher (P <0.05) in cows Inv, compared to cows See; but during the afternoon the opposite happened, being higher (P <0.05) in cows See that in cows Inv.

It has been reported that animals exposed to direct radiation from the sun, change the composition of fat in milk, with a concomitant reduction in levels of fatty acids and an increase in saturated fatty acids (SEVI *et al*., 2002). The percentage of lactose during the morning and afternoon were similar (P> 0.05) between the groups of Inv and Ver cows. The percentage of protein during the afternoon was higher (P <0.05) in the group of Inv cows compared to the Ver cows. During the morning the percentage of protein was similar (P> 0.05) between both groups of cows. Interestingly, the pattern of protein percentage in milk is usually affected by high temperatures. The epithelial cells of the mammary gland in EC conditions produce heat shock proteins, which reduce the protein synthesis in milk, directly causing a residual effect in lactation curves; and indirectly, it causes other effects on the pregnancy and the metabolic state of the cow (Collier *et al*., 2017).

The milk PMN for Holstein cows was 9853 ± 1708 kg (AHM, 2018); the projection at 305 DEL for cows of the Inv and Ver group was 6037 ± 1550 and 7690 ± 881 kg, respectively.
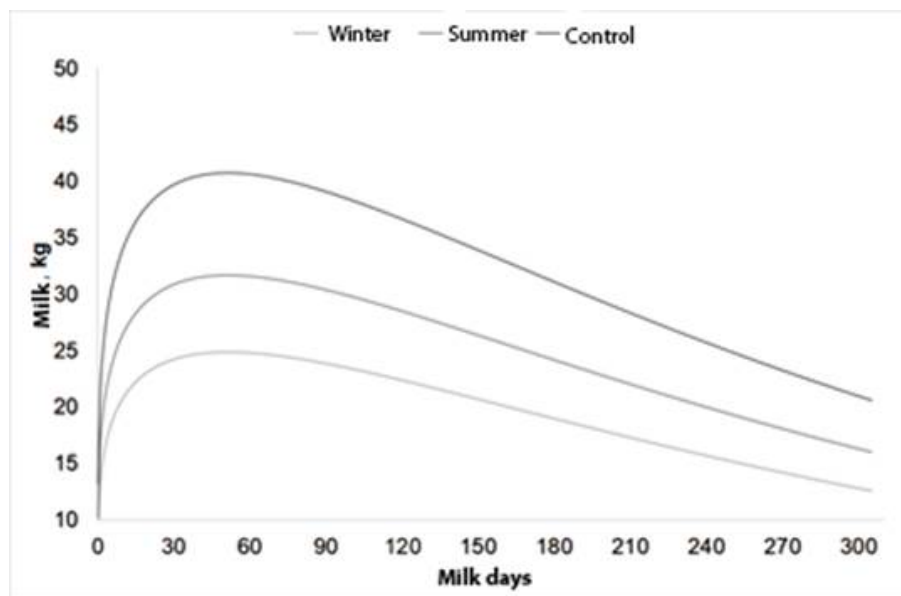
Figure 4. Production and projection curves at 305 days in milk of the group of cows Winter, Summer and Control.

Figure 4 shows the lactation curves at 305 DEL for the group of Inv, Ver and Control cows. The mathematical modeling of the curves indicated that the control group during the lactation peak exceeded the milk production by 15 and 10 kg, with respect to Inv and Ver cows, respectively. In agreement with what was reported by Collier *et al.* (2017) these curves showed a clear decrease with respect to the control group, since both groups of Inv and Ver cows, did not manage to express from the genetic or environmental point of view the potential that the Witness group showed regarding the PMN of milk.

The components of milk quality in general showed, in most cases, to be lower (P <0.05) in animals. Regarding Inv animals, which means that despite being greater the amount of fluid milk, it was lower the quantity of its components, which reinforces the argument of the presence of water in milk. Additionally, in some other cases, for example, the percentage of fat in milk showed similarities (P> 0.05) between the groups of Inv and Ver animals; which proportionally speaking turns out to be higher in the group of Inv cows than Ver ones. West (2003), reports that cows in the absence of shadows reduce the consumption of food and net blood flow to the digestive tract, resulting in a lower flow of nutrients to the mammary gland and lower milk quality.

CONCLUSIONS

The changes occurred in the physiological variables were more pronounced in the group of cows in summer, which presented light heat stress. During the study time, the cows of the group in winter did not show evidence of any type of heat stress. On the other hand, although the cows in summer produced 24 % more milk than the cows in winter, they did not manage to improve the percentage of non-fatty solids. Finally, the use of shadows during the summer

months can improve the physiological status and milk quality of lactating cows in "El Marqués", Querétaro, Mexico.

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