



## The impact of hair coat color on physiological variables, reproductive performance and milk yield of Holstein cows in a hot environment

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### ABSTRACT

Vulnerable animals to heat stress have been described as ones with dark or black hides due to increasing absorption of solar radiation. The effect of coat color in pluriparous contemporary Holstein cows in a hot environment (mean annual temperature 24.6 °C), on body surface temperature (infrared thermography), physiological and hematological variables as well as milk yield and reproductive performance was assessed using 178 Holstein pluriparous cows (74 predominantly white and 104 predominantly black). Data were collected in the morning and afternoon in July (mean temperature-humidity index 82 units). Body condition score at mid-lactation (128 ± 32 days in milk at the start of the experiment) was higher ( $P < 0.01$ ) in predominantly white than in black cows (3.3 vs. 3.2). Respiration rate did not differ between groups (72 ± 23 vs. 73 ± 20 breaths/min for white and black cows, respectively, sampling time combined). In contrast, rectal temperature of black cows was 0.1 °C higher ( $P \leq 0.01$ ) than white cows, regardless of sampling time. The only significant hematologic change was a slight increase in mean corpuscular volume in black cows (54.7 fL,  $P < 0.01$ ) compared to white cows (53.8 fL), but it remained within the reference range. Differences due to coat color did not alter body surface temperatures at any time of the day. Conception rates, services per conception, calving intervals and fetal losses were not associated with hair coat color, but cows with predominantly white coat produced 394 kg more ( $P < 0.01$ ) fat-corrected milk in 305 days compared to cows with predominantly black coat. It was concluded that in this hot-arid environment with cows housed in facilities with extensive cooling, black hair coat moderately reduces 305-d milk yield without affecting milk composition, body surface temperature, and reproductive performance.

### 1. Introduction

Maximum ambient temperature > 30 °C in arid zones of northern Mexico extend for about 8 months. Thus, intense radiant energy is prolonged in this environment causing a chronic heat stress for dairy cows, with little relief from heat during the evening hours. Lactating Holstein cows create a large quantity of metabolic heat which make them particularly susceptible to heat stress due to the high metabolic load of milk synthesis and visceral metabolism associated with high feed intake needed to sustain lactation (Dunshea et al., 2013) and accumulate additional heat from radiant energy (West, 2003). Under these climatic conditions, cows produce and accumulate heat which increases heat load in the cow due to the compromised cooling capability of Holstein cows (Baumgard and Rhoads, 2013).

Temperatures higher than the cow's comfort zone have a negative effect on feed intake (Wheelock et al., 2010), postabsorptive metabolism (Rhoads et al., 2009), nutrient partitioning (Baumgard and Rhoads, 2013), reduced milk yield (West et al., 2003; Bohmanova et al., 2007), reduced milk components (Garner, 2017), reproduction (Mellado et al., 2013) and growth (López et al., 2017). Additionally, acute heat stress has a negative effect on the cow's well-being. These declines are associated with physiological changes in the stressed cows, including increased sweating, respiration and panting rates, core body temperature, metabolic and endocrine-system changes that are important to dairy cow health and productivity (Wheelock et al., 2010).

While much is known about the effects of high ambient temperature on production of dairy cows, there are some shortfalls in knowledge on this topic. For example, it is required a better understanding of the

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biology of heat stress in Holstein cows with predominantly white or black coat, as the amount of radiant heat absorbed by the animal's coat is partly determined by color (Stuart-Fox et al., 2017). It has been documented that dark coats absorb more solar radiation than light coats (Armitage, 2009), although penetration of fur by solar radiation is a function not only of the color but also of the structure of the coat (Stuart-Fox et al., 2017). In facilities without shade, lower milk yield has been reported for Holsteins cows with black hair coat compared to animals with white hair coat (3.3 kg. vs 1.5 kg; Hansen, 1990). Other studies in subtropical (Becerril et al., 1993) and tropical (Maia et al., 2005b) environments also have documented higher milk production in Holsteins cows with white hair coat compared to animals with black hair coat. However, other studies in subtropical areas have concluded that milk yield of Holstein cows was not related to or not influenced by hair coat color (Lee et al., 2016; Dikmen et al., 2017). Therefore, further studies are needed to examine whether hair coat color in Holstein cows may play an indirect role in milk yield and reproductive performance under conditions that induce heat stress during prolonged periods in temperate climates.

In the past, physiologists have investigated the effects of coat color of mammals and birds on solar heat gain; but this phenomenon has been little described for dairy cattle in zones of intense heat and solar radiation. Few studies have documented that dark-colored cattle are more sensitive to heat stress than light-colored cattle (Gaughan et al., 1998; Brown-Brandl et al., 2006), although other studies have not provided support for this view (Schütz et al., 2009).

Based on the limited information describing the responses of high-yielding dairy cattle with predominantly white or black hair coat subjected to a chronic heat stress conditions, the objective of the present research was to determine the milk yield, reproductive performance hematological variables and physiological responses of lactating Holstein cows. It was hypothesized that cows with predominantly white hair will present higher milk production, and will present lower values for physiological indicators of stress, compared with cows having predominantly black hair coat.

## 2. Materials and methods

### 2.1. Cows and design

The experimental procedures and animal care conditions were approved by the Ethics Committee of the Research Department of the Agrarian Autonomous University Antonio Narro. The experiment was conducted on a commercial dairy farm located in northeastern Mexico (26°27'N, 103°13' W, elevation 1125 m, mean annual temperature 24.6 °C, mean annual rainfall 221 mm) beginning in June 2016 and ending in July 2017. The total length of the experiment was the time between two consecutive parturition or 305 days of lactation for non-pregnant cows. During the study period, the maximum ambient temperature ranged from 28 °C to 41.1 °C; relative humidity from 11% to 83%.

The herd consisted of approximately 2600 lactating Holstein cows housed in open-dirt pens with fans and sprinklers for forced evaporative cooling during the warm weather. A total of 178 Holstein contemporary (lactations starting in winter) pluriparous cows (74 predominantly white and 104 predominantly black) which calved between January and February 2016, were included in the study. Cows were in mid-lactation (128 ± 32 days in milk; mean and SD) at the start of the experiment. None of these cows showed cases of clinical diseases or disorders around calving.

Cows were fed diets formulated to meet or exceed recommended total daily nutrients for 670-kg dairy cows producing 38 kg/day of 3.7% fat-corrected milk (FCM; National Research Council (2001)). Cows were fed total mixed diets contained soybean meal and ground shelled corn as the base ingredients of the concentrate mix (49% of diet); the forage portion of the diet was alfalfa hay and corn silage. Cows were fed and

milked three times per day. Animals had free access to water at all times. Cows that were included in the study had to meet the following criteria: a) minimum of two lactations, b) the body hair coat color had to be at least either 75% black or 75% white by visual evaluation, c) had complete 305-d lactation records, and d) free of diseases throughout lactation. Milk yield and reproductive variables were recorded and tracked using the AfiFarm software version 4.1.1 (AfiMilk Ltd., Kibbutz Afikim, Israel).

### 2.2. Physiological and body temperature measurements

At mid-lactation (summer), cows were scored by the herd veterinarian according to their body condition (BCS) using a 5 point scale (1 = thin to 5 = fat) in a modified quarter point system (Wildman et al., 1982). The physiological measurements were recorded twice a day at 0700 and 1500 h. Rectal temperature (RT) was measured by the insertion of a digital thermometer (DeltaTrak, Pleasanton, CA, USA) in the rectum wall of the cow at a depth of approximately 20 cm during 60 s. Respiration rate (RR; breaths per minute) was assessed by counting visible uninterrupted flank movements and using a stopwatch. Panting score (PS) was recorded using the 0–4.0 scale (Mader et al., 2006), where PS 0 describes a cow under no heat load, and PS 4.0 designates a severely heat-stressed cow). These recordings were made in summer and cows were held in a shaded holding pen.

Skin temperature of the head, ears, eye, nose, neck, shoulder, back, rear ribs, flank, abdomen, lateral udder (registered before milking), hock, switch and dew claw was measured in summer with an infrared thermography (IRT; a gun type, battery operated digital infra-red thermometer that gathers infrared energy without contact (Fluke Ti10, Everett, WA, USA). 640 × 480 pixels thermal images with a resolution of 0.1 °C were obtained (Fig. 1). During the period of recording of cow physiological variables and blood samples collection, the relative humidity (RH, %) and maximum ambient temperature were recorded. A temperature-humidity index was calculated according to the following formula (Thom, 1959):

$$\text{Temperature-humidity index (THI)} = (0.8 \times \text{maximum ambient temperature}) + [ \% \text{ relative humidity} / 100 \times (\text{mean ambient temperature} - 14.4) ] + 46.4.$$

### 2.3. Milk measurements and sampling

All cows included in this study were in their second to fourth lactation. Cows were milked three times daily (0700, 1500 and 2300 h), and individual milk production was daily recorded electronically. Cows completed their experimental tenure when they completed 305 days in milk. For lactations exceeding 305 days, milk production up to 305 days was computed.

Samples for milk-composition analyses were taken from six milkings (0700, 1500 and 2300 h; two consecutive days) at mid-lactation, composited and analyzed for total solids, solids-not-fat, fat, protein and lactose content using a near-infrared milk analyzer (MikoScope analyzer; Scope Electric Ltd, Germany). All lactations were adjusted to energy-corrected milk (ECM) which was calculated using the equation of Tyrrell and Reid (1965):

$$\text{ECM kg/cow/day} = \text{milk yield (kg)} \times (376 \times \text{fat}\% + 209 \times \text{protein}\% + 948) / 3138$$

### 2.4. Blood collection and analyses

Blood samples (5 ml) were taken in summer by coccygeal venipuncture at 1600 h into two evacuated tubes containing sodium EDTA (Vacutainer; Becton Dickinson, Franklin Lakes, NJ). Blood samples were placed immediately on ice and taken to the laboratory. A fully automated blood analyzer (BC-3000 plus, Mindray Bio-Medical

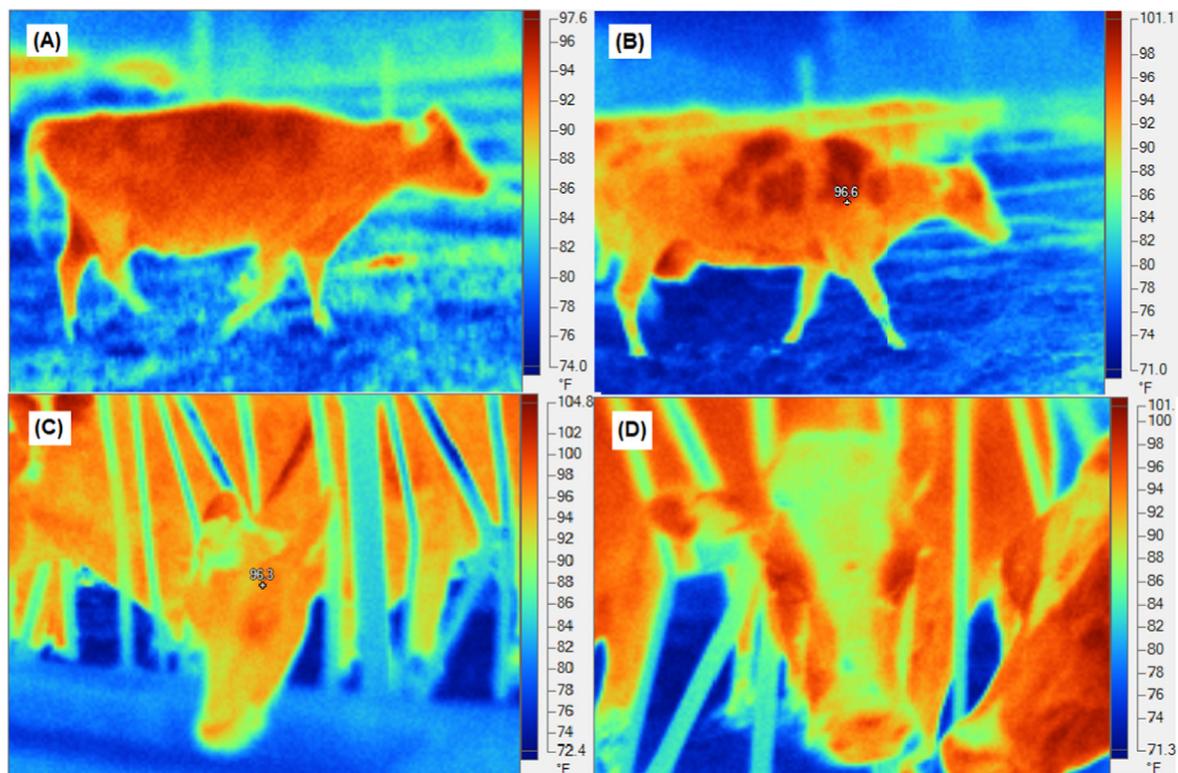


Fig. 1. Images measured with infrared thermography in different regions of Holstein cows with predominantly black (A and C) or white (B and D) coat color.

Electronics Co., Ltd, Guangdong Sheng, China) was used to determine erythrocytes, hematocrit, hemoglobin, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular volume concentration, leucocytes, lymphocyte absolute count, lymphocyte percentage, basophil granulocytes, mid-range absolute count, platelets, and mean platelet volume.

### 2.5. Reproductive management

All cows were routinely vaccinated against diseases that impair reproduction functions, such as infectious bovine rhinotracheitis, bovine viral diarrhea, bovine respiratory syncytial virus, para-influenza and leptospirosis (5-varieties; CattleMaster®GOLD FP® 5 L5, Zoetis Inc. Kalamazoo, MI, USA). Herd veterinarians examined fresh cows routinely to identify and treat cows with postpartum reproductive disorders such as retained placenta and metritis. Cows became eligible for artificial insemination (AI) after 67 days in milk (DIM).

Cows that returned to estrus prior to pregnancy diagnosis were re-inseminated upon estrus detection and considered to be non-pregnant from previous AI. Cows not pregnant around 90 DIM and with more than two services with clear estrus signs and no clinically detectable reproductive disorders, were implanted with a CIDR (CIDR®, Zoetis Inc. Kalamazoo, MI, USA). At the time of insertion, 25 mg of PGF<sub>2α</sub> (Lutalyse, Pfizer, New York, NY) was also applied; cows were inseminated after estrus detection. Cows not pregnant after repeated services or that showed estrus after an abortion and with more than 300 DIM were not inseminated.

Pregnancy was detected by palpation of the uterus per rectum about 43 days post-AI. All pregnancy examinations were performed by the same veterinarian throughout the study period. For each cow, the following data were collected: calving interval, all-services conception rate, number of breedings per conception and fetal losses. All-service conception rate was defined as the number of cows that conceived out of the ones that were inseminated  $\leq 8$  services over the period of the study.

### 2.6. Statistical analyses

Rectal and body surface temperature and RR were analyzed using the GLM procedure in the Statistical Analysis System (SAS Institute, Inc., Cary, NC). The dependent variables were coat color groups and sampling time. The following model was used:  $Y_{ijkl} = \mu + C_i + H_j + CH_{ij} + Cov_k + E_{ijkl}$ , where:  $Y_{ijkl}$  = dependent variable for cow having the coat color  $i$  in the sampling time  $j$ ;  $\mu$  = overall mean;  $C_i$  = the fixed effect of coat color;  $H_j$  = the fixed effect of sampling time;  $CH_{ij}$  = the fixed effect of the interaction coat color  $\times$  sampling time;  $Cov_k$  = is the covariate adjustment for lactation number of each cow;  $E_{ijkl}$  = residual error.

Fat-corrected 305-d milk yield, milk composition, body condition score and calving interval were analyzed using the GLM procedure of SAS. The effect of coat color on the number of services per pregnancy and panting score was evaluated by the bivariate Wilcoxon rank sum test (proc npar1way; SAS) without adjustment for confounders. The GENMOD procedure of SAS was implemented to assess the effect of hair coat color on conception rate and fetal losses. It was assumed that the errors were independent and distributed according to the normal distribution with 0 mean and  $s^2$  variance. Significance was declared at  $P < 0.05$ .

### 3. Results

BCS of predominantly white cows was greater ( $P < 0.05$ ) than black cows at mid-lactation ( $3.30 \pm 0.32$  vs.  $3.22 \pm 0.28$ ; mean  $\pm$  SD). The influence of coat color on RT was evident ( $P < 0.01$ ) for both recordings, AM and PM (Fig. 2). There was a coat color  $\times$  time of recording interaction ( $P < 0.05$ ) for this trait. The influence of coat color did not affect PS, but the PS was greater (mean 1.3;  $P < 0.01$ ) in the afternoon compared to the morning recording (mean 0.7). There was no color coat  $\times$  hour interaction for this trait. There were no statistically significant differences in average RR associated with coat color, but cows in the afternoon presented 21 more ( $P < 0.01$ )

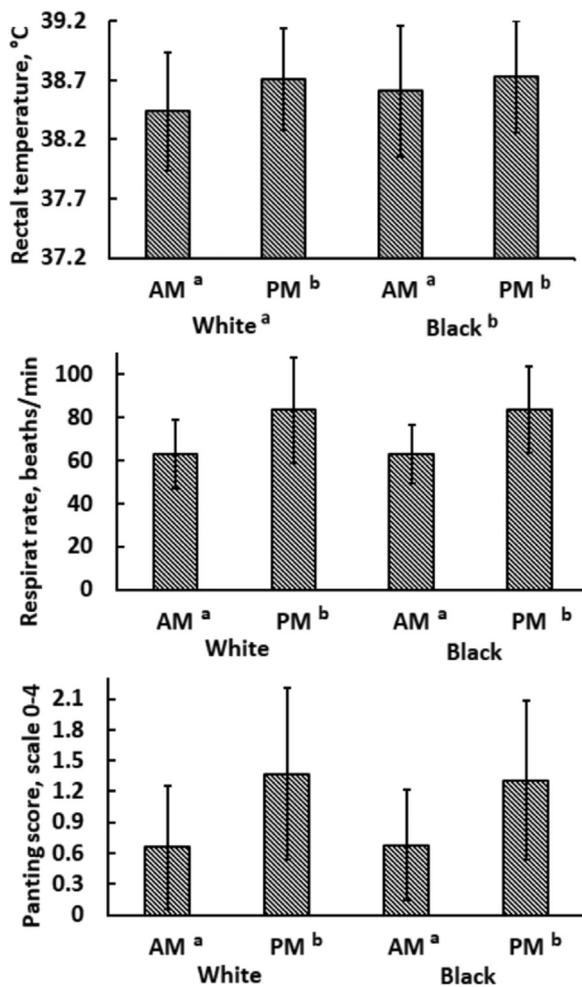


Fig. 2. Means and standard deviations (bars in columns) for physiological variables registered in the morning and afternoon in high-yielding Holstein cows in mid-lactation, with predominantly white or black coat in a hot environment. Within physiological variables, means bearing different superscript letters differ ( $P < 0.01$ ). For rectal temperature, there was a coat color x hour interaction ( $P < 0.05$ ).

respirations per min than those registered in the morning.

As for body surface temperatures, regardless of time of recording the body regions with the highest temperature were the udder and cow's eyes (Table 1), whereas the surface temperature of distal part of the legs was comparatively lower. White and black cows had similar surface temperatures in all body parts studied. Except for rear ribs, body surface temperatures were higher ( $P < 0.01$ ) in the afternoon than the morning hours. No effect of interaction ( $P > 0.05$ ) was found for any analyzed anatomical parts between hair coat color groups and recording time of body surface temperature.

Table 2 shows blood variables in white and black cows in summer. For most of the blood variables, there was no significant difference among groups of cows. Only mean corpuscular volume and mean corpuscular volume concentration differed between white and black cows. Milk composition did not differ among white and black cows (Table 3), but white cows produced 394 kg more ( $P < 0.01$ ) energy-corrected milk than black cows.

Conception rates for all service of cows were not influenced by hair coat color (Table 4). Services per conception were very high for both groups of cows but there was no difference between white (median = 9) and black (median = 7) groups. Fetal losses between 45 and 260 days post-insemination did not differ between white and black cows. The overall mean for fetal losses was 24%. Calving interval did not differ

**Table 1**  
Means of temperatures of different body surface regions measured with infrared thermography in high-yielding Holstein cows with predominantly white or black coat, in a hot environment.

Body regions	White coat		Black coat		SEM	Hour effect
	AM	PM	AM	PM		
Head	32.94	36.00	33.06	36.06	1.4	**
Ears	32.88	36.12	32.94	36.10	1.5	**
Eye	33.57	36.51	33.78	36.46	1.4	**
Nose	32.88	35.80	32.99	36.01	1.6	**
Neck	33.22	36.14	35.09	36.11	1.5	**
Shoulder	33.37	36.15	33.45	36.15	1.3	**
Back	33.19	36.01	33.03	36.10	1.8	**
Rear ribs	33.53	36.17	33.53	36.19	1.5	**
Flank	33.52	36.12	33.45	36.19	1.7	**
Abdomen	32.12	35.19	32.28	35.42	1.6	**
Lateral udder	33.71	36.38	33.70	36.37	1.6	**
Hock	33.25	36.13	33.12	36.07	1.7	**
Switch	32.36	35.35	32.30	35.38	1.8	**
Dew claw	30.60	33.92	30.50	33.87	2.1	**

No coat color effect; no coat color x hour interaction effect.

\*\* Significantly different at  $P < 0.01$ .

**Table 2**  
Selected hematologic variables in high-yielding Holstein cows in early lactation with predominant white or black coat in a hot environment.

Blood variables	White coat	Black coat	SEM
Erythrocytes ( $10^6/\mu\text{l}$ )	5.35	5.33	0.52
Hematocrit (%)	28.6	28.9	2.7
Hemoglobin (g/dL)	9.87	9.87	0.89
Mean corpuscular volume (MCV; fl)	53.8	54.7**	3.9
Mean corpuscular hemoglobin (pg)	18.4	18.5	1.2
MCV concentration (g/dL)	34.5	34.1**	1.5
Leucocytes ( $10^3/\mu\text{l}$ )	7.64	7.63	2.8
Lymphocyte absolute count ( $10^3/\mu\text{l}$ )	4.8	5.0	2.4
Lymphocyte (%)	29.9	29.7	8.8
Basophil granulocytes ( $10^3/\mu\text{l}$ )	2.45	2.47	1.7
Basophil granulocytes (%)	51.9	52.4	16.3
Mid-range absolute count ( $10^3/\mu\text{l}$ )	0.72	0.77	0.67
Platelets ( $10^3/\mu\text{l}$ )	401	387	133
Mean platelet volume (fl)	6.8	6.9	0.78

\*\* Significantly different at  $P < 0.01$ ; SEM = Standard error of the mean.

**Table 3**  
Milk yield and composition of pluriparous Holstein cows with coat color predominantly white or black in a hot environment.

Milk variables	White coat (n = 74)	Black coat (n = 104)	SEM
305-d energy-corrected milk yield (kg)	11583	11189**	1074
Milk fat (%)	3.6	3.6	0.31
Milk protein (%)	3.3	3.2	0.12
Milk lactose (%)	4.9	4.9	0.30
Solids-not-fat (%)	8.9	8.8	0.58
Total solids (%)	12.5	12.4	0.63

\*\*  $P < 0.01$ ; SEM = Standard error of the mean.

**Table 4**  
Reproductive performance of pluriparous Holstein cows with coat color predominantly white or black in a hot environment.

Reproductive variables	White coat	Black coat	SEM
Conception rate (%)	74.7 (65/87)	78.4 (76/97)	–
Services per conception	6.3	5.9	3.9
Calving interval (days)	416	406	51
Fetal losses (%)	23.1 (15/65)	23.7 (18/76)	–

SEM = Standard error of the mean.

between white and black cows; the median number of days between parturition was 390 for white cows and 385 for black cows.

#### 4. Discussion

Body condition score was higher in white as compared to black cows at around mid-lactation, which is in line with results of [Katiyatiya and Muchenje \(2017\)](#) with Nguni cows in South Africa. This response may reflect the antagonistic effects of greater heat load and consequently discomfort in black cows, as these animals are more susceptible to detrimental effects of heat stress because more solar radiation is absorbed as heat in animals with dark colored coats ([da Silva et al., 2003](#); [Maia et al., 2005a](#)). This possibly led to lower body energy reserves, presumably derived from a decreased feed intake. This conjecture may find support in a study of [Mader et al. \(2002\)](#) who observed that restriction of feed intake markedly lower body temperature. Also, [Purwanto et al. \(1990\)](#) suggested that total heat production is partially dependent on feed intake.

Coat color showed a significant influence on RT of cows. Alterations in RT are basic physiological parameters for assessing the animal comfort and the adaptability to adverse environments ([Ferreira et al., 2009](#)). The slightly higher RT in black cows suggests that, in the present environment, black cows have an inferior ability to cope with heat stress relative to cows with white colored coats. However, the mean difference in RT between white and black cows was only 0.1 °C and the average values both in the morning and afternoon were constantly under 39 °C. These results are not in line with observations in hot environments where RT of Holstein cows have been > 39.6 °C ([Srikandakumar and Johnson, 2004](#); [Dalcin et al., 2016](#)). The ability of both white and black cows to maintain RT near 39 °C with a high THI (mean 82 units the month of sampling) denotes a high expression of adaptation mechanism to thermal stress ([Hammond et al., 1996](#)). This implies that both black and white cows in this particular environment are capable to maintain RT within reference values.

The RR recorded in July was similar between cows with white and black hair coat but this response to a high ambient temperature differed ( $P < 0.01$ ) between morning and afternoon hours. RR is a suitable indicator of the cow thermal load ([Gaughan et al., 2000](#)) because RR is highly associated with ambient air temperature ([Maia et al., 2005c](#)). The higher RR observed in the afternoon indicated an increase in the demand for oxygen in tissues, as energy expenditure increases with high ambient temperatures ([Garner et al., 2017](#)). The basal RR in Holstein cows under no stress (THI = 68) is approximately 60 breaths per minute ([Kendall et al., 2007](#)). Therefore, the 83 breaths per minute observed in the afternoon in the cows of the present study are considered as tachypnea, a characteristic of heat-stressed Holstein cows in hot-arid environments ([da Silva et al., 2012](#)). Much higher RR (> 100 breaths per minute under shade) has been observed in Holstein cattle in hot environments ([Anzuers-Olvera et al., 2015](#)). Black cows had higher rectal temperatures but showed the same respiratory rate than white cows, which means that the increase in RT did not have major consequences as no increase in water evaporation released through respiration was needed. However, heat stress influences energy and water metabolism ([Silanikove, 2000](#)) and it may induce increases in plasma and extracellular fluid volume in proportion to the thermoregulatory requirements ([Kadzere et al., 2002](#)).

In general, blood variables did not differ between white and black cows and these fell within the accepted standard values for cows ([Jain, 1993](#)). This means that coat color was not implicated in any physiological instability or poor health status of cows. Some authors have observed that hematological variables increased during heat stress ([Silva et al., 2006](#); [Ferreira et al., 2009](#)), particularly changes in erythropoiesis as one of the adjustments of the body to heat stress. In the present study mean corpuscular volume was the only variable affected by coat color. The higher mean corpuscular volume in black cows could be due to lower thyroid hormones production in these cows as hypothyroidism

increase MCV ([Dorgalaleh et al., 2013](#)), and  $T_4$  concentrations increases in heat-stressed cows ([Collier et al., 1982](#)). Also, the increase in MCV could be due to the release of immature red blood cells (reticulocytes) into circulation by the bone marrow to increase hemoglobin mass and protect body tissue from hypoxia ([Roland et al., 2014](#)). The small difference in MCV between white and black cows impedes the use of this blood variable as a biologic marker of heat stress.

Surface temperatures were not influenced by hair coat color showing that physiological factors and skin vascularization level affected animal groups in similar ways. Similar to findings of other researchers, the body regions with the highest temperature were the udder and cow's eyes ([Poikalainen et al., 2012](#); [Cardoso et al., 2015](#)). Eye temperature is the best observation point by means of thermographic images due to the high level of vascularization of the posterior eyelid border and fluctuations in blood flow by means of the sympathetic system ([Stewart et al., 2007](#)). In this study, udder surface temperature consistently exceeded 35 °C, which is similar to observations of [Gebremedhin and Wu \(2016\)](#). This suggests that high temperature in udder surface could be considered as a heat sink under heat stress. On the other hand, surface temperature of distal part of the legs was comparatively low and more influenced by surrounding environment temperature. Other studies have found that body extremities are the main locations regulating heat loss or storage ([Kotrba et al., 2007](#); [D'Alterio et al., 2011](#)).

In the present study white cows produced 394 more kg of milk in 305 d over black cows. This increment in milk yield is close to the 414 kg increase found by [Lee et al. \(2016\)](#) in 305-d lactations in Hawaii, although they did not detect statistically significant difference, and therefore their observation does not support the current findings. [Dikmen et al. \(2017\)](#) in Arizona and [Lemus-Flores \(2002\)](#) in Mexico did not find an effect of coat color on milk production either.

Similar to what was observed in the present study, [Becerril et al. \(1993\)](#) reported an increase of 1.91 kg in milk for each 1% increase in white color in Holstein cows in Florida. Also, [Maia et al. \(2005b\)](#) reported an increase of 465 kg of milk per lactation in Holstein cows in Brazil. Likewise, lower milk production was reported for Holsteins cows with black hair coat vs white hair coat (3.3 kg. vs 1.5 kg.) exposed to no shade ([Hansen, 1990](#)). Although a pool of evidence in the literature indicates that white cows are more likely to produce more milk/lactation than black cows under thermal stress, this matter does not seem to be totally resolved as comparison between studies is problematic because of the variation in climatic condition across geographical areas, production systems, equipment for fighting heat stress, types of dairy facilities and cow handling, among many other factors.

The results of the present study suggest that fertility was not related to or not influenced by hair coat color. Other studies concerning the effect of cow's color on fertility show varying results. A study from Arizona showed that white Holstein cows freshening in summer required fewer services per conception and had fewer open days than black cows ([King et al., 1988](#)). On the contrary, for high-yielding Holstein cows in a tropical zone of Brazil, cows with coat  $\geq 70\%$  black had the same number of inseminations/conception than cows predominantly white ([Bertipaglia et al., 2005](#)), but [Lemus-Flores et al. \(2002\)](#) reported lower services per conception in cows predominantly white. The lack of effect of hair coat color on reproductive variables in the present study is in line with [Becerril et al. \(1993\)](#) and [Godfrey and Hansen \(1996\)](#) who did not observe of clear advantage of hair coat color in subtropical and tropical environments on reproductive traits of Holstein cows. The lack of association between coat color and reproductive performance may have resulted from the fact that cows in the present study were managed in facilities with extensive cooling; therefore, factors not related to coat color could have played a more important role in the reproductive performance.

The reproductive performance of cows in the present study regardless of coat color is that of subfertile cows without any anatomic or infectious abnormality that does not become pregnant on average until

the fifth or subsequent breeding or remained unpregnant after ten services. The decreased fertility associated with heat stress in the present study is a multifactorial problem in which hyperthermia affects cellular function in various tissues of the female reproductive tract (Wolfenson et al., 2000; Hansen et al., 2001).

## 5. Conclusions

Although few subtle changes were noticed between cows with predominantly black or white hair coat, both body condition score at around mid-lactation and rectal temperature were important variables in assessing the physiological response when white or black Holstein cows are exposed to thermal stress for the most part of the year. In the present ambient conditions both respiration rate and panting score were not related to hair coat color. Likewise, hematological variables and body surface temperatures do not seem to play a role in physiological adjustments to thermal stress between cows with predominantly black or white hair coat.

Overall, white coat color confers no advantage in terms of reproductive performance when cattle are housed in open, dirt-based pens with some cooling facilities, but when comparing 305-d fat-corrected milk between cows with predominantly black and white coat color the later produced 3.5% more milk.

## Conflict of interest

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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