



Effect of Friesian Dairy Cows' Coat Color on Their Productive Performance under Heat Stress Conditions

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Abstract | Dark-coated cattle absorb more solar radiation than lighter-coated ones, increasing heat stress and reducing productivity. The present study aimed to select the best percentage of white vs. black skin coat color of Friesian dairy cows and its effect on their productive performance under Delta Egyptian conditions during the hot months. The study included 20 mid-lactating dairy cows, aged 3–8 years and with 2–5 parities, housed loosely in the same yard with semi-open sheds throughout the experimental periods from 1st June to 30th August 2022. Animals were split up into two similar groups (10 each) by related percentage of white (WH) vs. black (BK) area on the skin coat. The first group (G1) is called dark-colored cows because it had 25% WH and 75% BK, and the second group (G2) is called light-colored cows because it had 50% WH and 50% BK. The current results showed that over different experimental months, all analyzed thermoregulatory responses such as skin and rectal temperatures, pulse and respiration rates were considerably ($P < 0.001$) higher in G1 than in G2. Thyroid hormones (T3 and T4) and cortisol levels were considerably ($P < 0.001$) reduced, although prolactin was considerably elevated, while thyroid stimulating hormone was not affected in G2 compared to G1 under heat stress conditions. Serum urea and sodium concentrations were significantly ($P < 0.001$) increased, but potassium was significantly ($P < 0.05$) decreased, while serum phosphorus was not affected in dark-colored cows compared to light-colored cows. Daily milk yield, and percentages of total solid, solid not-fat, milk protein, and milk fat were significantly ($P < 0.01$) increased by 12.16%, 3.64, 4.67, 10.20%, and 1.41% in light-colored cows compared to dark-colored cows throughout the experimental months. It was concluded that there is a negative relationship between black fur-colored cows and physiological status, milk yield, and composition under thermal-stress conditions. Cows with a larger black surface area may be more susceptible to the harmful impacts of thermal stress due to greater absorption of solar radiation as heat.

Keywords | Coat color, Friesian cows, Physiological status, Productive performance, Heat stress

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Cattle coats possess characteristics that help them adapt to various environments and regulate body temperature. These characteristics include color, thickness, quality, and sheen of the coat and skin color. In hot climates, the density of the short, soft lower hair decreases, which reduces the volume of air trapped in the coat, as well as the long, coarse hair of distinct color in several places of the coat, which facilitates the loss of excess heat. In addition, the thickness of the animal's skin is inversely related to heat gain from the surrounding environment, which makes cows with less skin thickness gain more heat than others. Cows in tropical regions are better adapted to hot climates. Cows with thicker skin have difficulty in circulating air and moisture, reducing water evaporation and increasing susceptibility to heat stress (HS). So, European cows also fail to adapt to hot regions due to the density of hair on their fur, which reduces the efficiency of regulating their body temperature, and thus reduces their production. The degree of sheen of the body coat has an important role in reducing the influence of thermal stress on cows. Moreover, coat of animals in hot regions is characterized by a higher degree of shine than others, reflecting the greatest amount of direct sunlight due to the large secretion of fatty substances from the sebaceous glands in the skin. The dark color of the cows' body cover is directly proportional to the ambient temperature (Ashmawy, 2014).

The productive performance of dairy cows is affected by coat color. Milking, which affects breeders' selection of their animals according to the color of the outer coat as an attempt to achieve the highest productivity and the lowest costs (Leite *et al.*, 2018), or dark cows produce lower milk without affecting the components of the milk (Ealy *et al.*, 1993; Anzuere-Olvera *et al.*, 2019), excess thermal energy is lost through the cow's external surroundings (Berman, 2005) to reach thermal balance between the external environment and the animal. Direct sunlight improved the ability of Holstein cows to regulate their internal temperature and more productive than their black counterparts (Hansen *et al.*, 1990; Dikmen *et al.*, 2009). In addition, some animals have a comfort zone and become stressed if it is exceeded in an attempt to maintain their thermal balance (Nardone *et al.*, 2006).

The current investigation sought to define the effect of color coat under the influence of Egyptian hot months on the productive performance of Friesian cows.

MATERIALS AND METHODS

EXPERIMENTAL DESIGN AND FEEDING SYSTEM

Twenty mid-lactating dairy cows aged 3–8 years and 2–5 parities housed loose in the same yard with semi-open sheds

throughout the experimental periods from 1st June to 30th August 2022. Every cow had good physiological and clinical health. Animals were split up into 2 similar groups (10 each) according to the related percentage of white (WH) vs. black (BK) area on the skin coat by photographic analysis. The first group (G1) is called dark-colored cows because it had 25% WH and 75% BK, and the second group (G2) is called light-colored cows because it had 50% WH and 50% BK. The total mixed ration provides 16.91 g/kg DM protein, 4.10 kg Total Digestible Nutrients (TDN), 14.40 Mcal/kg DM metabolizable energy, 20g calcium, and 16g phosphorus. Weekly feed levels were modified accordance with body weight and milk output. Cows were permitted to drink water at all times. All cows were milked two times daily by automatic milking. Milk components were identified by the Milko-Scan[®] analyzer (USA).

MEASUREMENT OF TEMPERATURE-HUMIDITY INDEX (THI)

Although the weather conditions were standardized for all experimental animals, Daily readings of the ambient temperature (AT, °C) and relative humidity (RH, %) were made throughout the experiment. The wet bulb thermometer and the dry bulb were posited inside the shadow area in yards 3 meters above the floor. THI value was determined using the AT and RH values by an equation of Mader *et al.* (2006) and Omran *et al.* (2019) as follows:

$$THI = (0.8 \times AT) + [(RH/100) \times (AT - 14.4)] + 46.4$$

THERMO-REGULATORY RESPONSES

Nine consecutive sunny days during hot months (from June to August 2022), the thermo-regulatory measurements were recorded for each cow at 7.00 a.m., 10.00 a.m., 1.00 a.m., and 5.00 p.m daily. Skin temperature (ST) was determined by the infrared digital thermometer (Instrutherm TI-550) using the groin, scapula, forehead, and shank temperatures. A digital clinical thermometer (TH-150 model G-Tech) was placed 5 cm into the rectum and left there for two minutes to measure the rectal temperature (RT). Respiratory rate (RR) was determined using the count-up timer by counting the motion numbers of the right flank at 15-second intervals and multiplying by four without annoying the cows. Pulse rate (PR) was determined using a stethoscope (Rappaport P.A Med.) by auscultating the heartbeats/min. between the 3rd and 5th intercostal space.

BLOOD CONSTITUENTS

Blood was drawn biweekly from the jugular vein, as described by Pugh (2002), and serum was collected after centrifuging at $1.370 \times g$ for 15 minutes and kept in dry and clean tubes at -20 °C till used in double samples monthly / each animal. Thyroid stimulating hormone (TSH), triiodothyronine (T3) and thyroxine (T4) were measured in serum by using an ELISA kit (Immunospec Corporation,

USA, catalog No PekinElmer-10304, PekinElmer-10301, and PekinElmer-10302, respectively). The prolactin assay is based on a solid phase enzyme-linked immunosorbent assay with sensitivity 0.2 μ IU/ml, 0.25 ng/ml, and 0.5 μ g/dl, respectively. Cortisol was measured in serum by using ELISA kits (PekinElmer-10005; 00000; DBC, Canada; catalog No. CAN-C-270 and SinoGeneClon-SG-60105, with sensitivity 0.2 ng/ml; 0000; 0.4 μ g/dl and 0.5 ng/ml, respectively). Levels of total protein (TP), urea, creatinine, sodium (Na), and potassium (K) were determined by Tietz (1986) methods using commercial kits. Serum phosphorus (P) was measured by the method reported by Young *et al.* (1975).

STATISTICAL ANALYSIS

Data were analyzed using a factorial experimental design (2 treatments, 4 months) using the GLM approach defined by SAS (2003) software. Before analysis, all percentages were logarithmically transformed to equalize data distribution. Duncan (1955) test was employed to identify significant variations between experimental groups. Chi-square analyses were used to calculate the conception rate as a percentage. The following statistical model was used:

$$Y_{ijk} = \mu + T_i + M_j + TM_{ij} + e_{ijk}$$

Where, Y_{ij} is the dependent valuable; μ is the overall mean, T_i is the effect of treatment (i = control, and treatment), M_j is the effect month post-treatment (j = 1st, 2nd, 3rd, and 4th month post-treatment); TM_{ij} is the effect of interaction between treatment and month post-treatment, e_{ijk} is the residual experimental error.

RESULTS AND DISCUSSION

VARIATIONS IN CLIMATIC CONDITIONS

Data for AT, RH, and THI throughout the experimental period are presented in Table 1 and Figure 1. Table 1 shows that the high, low, and average values of AT were 38, 25 and 27 $^{\circ}$ C, respectively, and RH were 75, 40 and 48.8%, respectively. Also, the recorded THI values monthly were 74.1, 89.8, and 83.7, respectively during the experimental period. Figure 1 shows that June had the lowest values of AT, RH, and THI during their four weeks, followed by August, compared to July, which had the highest values.

THI was classified in dairy cattle as reported by Omran *et al.* (2019) according to the respiration rate of the animals (breath/min) in the North of Delta (Kafer El-Sheakh Governorate) as thermally neutral (≤ 67.12), mild HS (> 67.12 to 77.12), moderate HS (> 77.12 to 86.68), and severe HS (> 86.68 to 89.97). Accordingly, in the current study, June 2022 was in the mild HS zone (HS), July was within the severe HS zone, and August was within the moderate HS

zone (Table 1 and Figure 1). THI is considered one of the best indicators used to describe stress conditions in dairy cows, with different physiological effects (Dikmen *et al.*, 2009). The range of the thermal neutral zone for dairy cows is from 5 to 25 $^{\circ}$ C ($68/\text{THI} < 72$), in order to maintain the cows body temperature physiologically between 38.4–39.1 $^{\circ}$ C (Yousef, 1985) despite the increase in the air temperature surrounding the cow. Over 25–37 $^{\circ}$ C in a tropical zone or, 20–25 $^{\circ}$ C in a temperate zone, which increases heat gain above the rate of body heat loss and stimulates HS (Sunil *et al.*, 2011). Dairy cattle breeders use temperature and humidity index to determine the stress range (Dimov *et al.*, 2020) and it may rise up to 78% in reaction to the weather conditions (Gaughan *et al.*, 2002).

Table 1: Variation in ambient temperature (AT, $^{\circ}$ C), relative humidity (RH, %) and temperature-humidity index (THI) during the experimental period.

Month	AT ($^{\circ}$ C)			RH (%)			THI ²
	Min.	Max.	Avg. ¹	Min.	Max.	Avg. ¹	
June, 2022	25	29	27.0	40	55	48.8	74.1
July	35	38	36.0	60	75	67.5	89.8
August	30	35	32.8	55	70	60.8	83.7

¹ The average values of AT and RH were calculated using the month's thirty-day readings; ² $\text{THI} = 0.8 \times \text{AT} + [(\% \text{RH} / 100) \times (\text{AT} - 14.4)] + 46.4$.

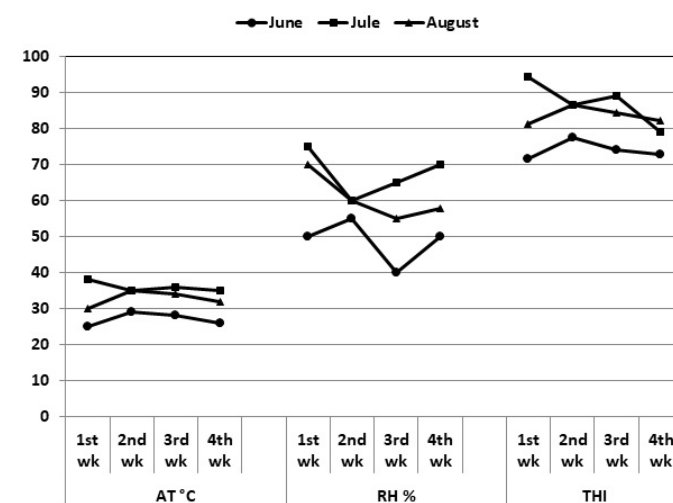


Figure 1: Variation in ambient temperature (AT, $^{\circ}$ C), relative humidity (RH, %) and temperature-humidity index (THI) during the experimental period.

Dairy cattle need more care to compensate for energy loss under the influence of HS (Johnson *et al.*, 1959), as the incidence of mastitis increases ($P < 0.01$) with a decrease in the productive performance of dairy cows (Jingar *et al.*, 2014), due to the existence of a positive relationship between Evaluate the AT and THI and mastitis or milk yield decreases with an increase in squamous cell carcinoma (Morse *et al.*, 1988). During the hot summer months

above 24 °C, both the number of cancer stem cells and the number of bacteria increase with a decrease in dry matter intake, which causes energy imbalance, sero-negative and decreased immunity (Olde *et al.*, 2007). High-producing dairy cows that produce more than ten liters of milk daily have more heat sensitivity to for than less-productive cows. Under HS conditions, *Bos indicus* cows are less tolerant than *Bos taurus* (Bajagai, 2011) and dry cows are more resistant than lactating cows, also cows in the middle of lactation are more affected by HS than cows in the early and late lactation stages. Multiparous cows are the most susceptible to HS. HS reactions have a detrimental impact on health, body temperature, and a variety of productive characteristics of dairy cows, such as increased RT, RR, decreased feed consumption, milk yield, milk composition, and reproduction (Atrian *et al.*, 2012). Furthermore, dairy cattle may die amid the sweltering summer, and the deaths number increases dramatically as the THI main a degree of stress (Ha and Kim, 2013).

Table 2: Effect of environmental condition on thermo-regulatory responses of Friesian dairy cows under heat stress conditions.

Factors	Thermal responses parameters			
	Skin temp (°C)	Rectal temp (°C)	Respiration rate (B/min)	Pulse rate (P/min)
Coat colour effect				
25% white	37.14 ^a	38.38 ^a	40.13 ^a	72.00 ^a
50% white	35.81 ^b	37.72 ^b	35.67 ^b	61.67 ^b
±SEM	0.09	0.05	0.37	0.85
Month effect				
June	36.11 ^b	37.89 ^b	34.20 ^c	63.50 ^c
July	36.96 ^a	38.26 ^a	41.50 ^a	70.00 ^a
August	36.36 ^b	38.01 ^b	38.00 ^b	67.00 ^b
±SEM	0.11	0.06	0.45	1.04
Interaction effect				
25% white June	36.67 ^b	38.17 ^b	35.50 ^c	68.00 ^{bc}
July	37.77 ^a	38.64 ^a	44.40 ^a	76.00 ^a
August	36.97 ^b	38.33 ^b	40.50 ^b	72.00 ^{ab}
50% white June	35.54 ^d	37.60 ^d	32.90 ^d	59.00 ^c
July	36.14 ^c	37.87 ^c	38.60 ^b	64.00 ^{cd}
August	35.74 ^{cd}	37.68 ^{cd}	35.50 ^c	62.00 ^{de}
±SEM	0.16	0.09	0.64	1.48
P value:				
Coat colour	<0.0001	<0.0001	<0.0001	<0.0001
Month	<0.0001	0.0005	<0.0001	0.0002
Interac-tion	<0.0001	0.0062	<0.0001	0.0015

Values with different superscripts within the same column are significantly different (P<0.05).

THERMOS-REGULATORY MEASUREMENTS

Table 2 shows that mean values of ST, RT, RR, and PR were significantly (P < 0.001) lower on light-colored cows (G2) than the dark-colored cows (G1) during the hot summer months. The color, length, and condition of the animal's hair all affect how much radiant heat the coat absorbs (Acharya *et al.*, 1995). Physiological responses like RT, RR and PR were more frequently regarded as markers of HS tolerance (Sanusi *et al.*, 2011; Al-Dawood, 2017). Dark-colored cows exhibited higher ST, RT, RR, and PR values compared to light-colored cows. These outcomes align with the findings of Okoruwa (2015) and Baenyi *et al.* (2020). This suggests that dark-colored cows' highest RT was caused by their dark pigmentation absorbing solar radiation (Okoruwa 2015), while light-colored cows affect radiant heat loss, which affects body weight and other productive adaptation aspects in cattle species (Peters *et al.*, 1982). According to Lefcourt *et al.* (1986), ST and RT are crucial signs of physiological status and a perfect way to determine stress in animals. McDowell (1976) reported that most cattle species' performance can be negatively impacted by a rectal temperature increase of less than 1°C.

The ST and RT data were significant (P< 0.001) increased between groups. The 1st group recorded the highest values (37.77, and 38.64 °C, respectively) in July compared to the 2nd group, which had the lowest values (35.54, and 37.60 °C, respectively) in June. The difference between RT of cows for all shades of color is 0.6 °C (Brody, 1948), as light cows absorb about 40–50% of the thermal radiation lower than dark cows. As well as Angus cows, they observed white individuals sweat more, with their body temperature being more stable than black ones (Gebremedhin *et al.*, 2008), and 70% have slightly lower body temperatures than those that are black. Light-colored cow's RT and ST were lower and RR as an indication of acclimatization and thermoregulation compared to dark-colored cows in tropical countries (Anzures *et al.*, 2019). The correlation coefficients between coat color, skin temperature, rectal temperature, and respiratory rate in British cattle are 0.580, 0.434, and 0.300, respectively (all P < 0.01), and were lower when mixing British cattle with zebu cattle (Schleger *et al.*, 1960). Dark coat color can also adapt to the tropical environment through body temperature, respiratory and pulse rates (Putra *et al.*, 2021).

RR values increased clearly in the dark Friesian cows over light Friesian but throughout the trial term, coinciding with the THI values ranged from 74.1 to 89.8 as an indication of the adaptation of Friesian cows to the high temperature during the hot months in the region. The Nile Delta, in which the environmental temperature exceeds the ideal temperature for dairy cows, becoming from 25 to 38 degrees, where direct environmental stimulation on the sensory receptors in the lid is transmitted to nerve signals

in the hypothalamic temperature center because a slow, linear rise in RR due to increase breathing. To get rid of carbon dioxide gas, which causes a rise blood's alkaline reserve and subsequently more perspiration, the temperature of the cows rises. The animal loses about 60% of the total excess heat when exposed to an environmental temperature higher than 37 degrees. When the temperature of the surrounding environment is greater than or equal to the body temperature, the animal resorts to increasing its breathing rate and then increasing its sweating rate through the evaporative cooling system to get rid of the largest amount of burden. RR is a convenient indicator of heat load in dairy cows (Gaughan *et al.*, 2000) because it is closely related to AT (Campos Maia *et al.*, 2005). It rises in the afternoon to raise the tissues' need for oxygen, so the energy lost rises with the rise in AT during that period (Garner *et al.*, 2016). The respiratory rate in non-stressed Holstein cows reaches about 60 breaths/minute at THI = 68 (Kendall *et al.*, 2007), but it increases to 83 breaths per minute during that period in arid and hot places (Da Silva *et al.*, 2012), and RR higher than 100 breaths/min have also been recorded under the shade for Holstein cows under hot climates (Anzuere-Olivera *et al.*, 2015). To regulate heat, the volume of plasma and extracellular fluid increases (Kadzere *et al.*, 2002).

It is known that the PR indicates the stability of blood circulation at its normal level for metabolic processes. With an increase in ambient environmental temperatures, blood flow to the surface of the body increases to get rid of excess heat without a change in PR. The pulse rate values were significantly ($P < 0.05$) higher in the 1st group (72 P/min) than in the 2nd group (61.67 P/min). This may be due to the increased ability of Friesian cows with light colors to dark, as they recorded the lowest values (59, 64, and 62 P/min) compared to dark-colored cows that recorded the highest values (86, 76, and 72 P/min) in June, July, and August, respectively. Okoruwa (2015) also noted that the PR according to the animal's coat characteristics was increased in sheep with black coat color (87.49 beats/min) compared to light-brown sheep (79 beats/min). This rise in PR could be attributed to vasodilatation of the skin capillaries, which would enhance blood flow to body surface places to aid the amelioration of HS (Wojtas *et al.*, 2014). The higher PR noted in dark-colored cows is likely due to the higher RT related to black coats, which may exceed the comfort zone, leading to blood redistribution to peripheral tissues throughout heat exposure (Al-Haidary *et al.*, 2012).

The findings are in agreement with Sofi *et al.* (2019). As Ellison *et al.* (2017) showed the local Ngoni black cows in South Africa are particularly vulnerable to the negative consequences of HS by absorbing a greater amount of environmental heat, which makes them more mobile to get rid of the heat burden (Campos Maia *et al.*, 2005) while reducing their intake (Mader *et al.*, 2002). Furthermore, I

suggest, Purwanto *et al.* (1990) found that the color of the lid affects the amount of food eaten to control the excess heat produced. Black Holstein cows are less able to cope with HS compared to white cows, and the average difference in AT between black and white were about 0.1 °C (Dalcin *et al.*, 2016).

Table 3: Changes in serum TSH, T4, T3, cortisol and prolactin hormones concentration of Friesian dairy cows under heat stress conditions.

Factors	Hormonal profile				
	TSH (μIU/ml)	T3 (ng/ml)	T4 (μg/dl)	Cortisol (μg/dl)	Prolactin (ng/ml)
Coat colour effect					
25% white	0.83	2.47 ^a	9.12 ^a	15.21 ^a	203.83 ^b
50% white	0.82	1.66 ^b	5.85 ^b	12.90 ^b	351.00 ^a
±SEM	0.02	0.05	0.34	0.23	19.06
Month effect					
June	0.89 ^b	2.71 ^a	8.63 ^a	10.92 ^c	357.50 ^a
July	0.75 ^a	1.57 ^c	5.95 ^b	12.74 ^b	299.75 ^b
August	0.84 ^b	1.92 ^b	7.88 ^b	18.63 ^a	245.00 ^b
±SEM	0.02	0.06	0.41	0.28	23.35
Interaction effect					
25% white June	0.84 ^{ab}	3.22 ^a	10.20 ^a	12.25 ^d	334.00 ^a
July	0.78 ^{bc}	1.84 ^c	7.10 ^b	13.43 ^c	152.00 ^b
August	0.87 ^{ab}	2.34 ^b	10.05 ^a	19.95 ^a	125.50 ^b
50% white June	0.93 ^a	2.20 ^b	7.05 ^b	9.59 ^e	381.00 ^a
July	0.72 ^c	1.30 ^d	4.80 ^c	12.05 ^d	307.50 ^a
August	0.81 ^{bc}	1.49 ^d	5.70 ^{bc}	17.30 ^b	364.50 ^a
±SEM	0.03	0.08	0.58	0.40	33.02
P value:					
Coat colour	0.7642	<0.0001	<0.0001	<0.0001	<0.0001
Month	0.0015	<0.0001	0.0016	<0.0001	0.0007
Interaction	0.0011	0.0009	0.0014	<0.0001	<0.0001

Values with different superscripts within the same column are significantly different ($P < 0.05$); TSH: Thyroid stimulating hormone; T3: Triiodothyronine; T4: Thyroxine.

HORMONAL PROFILES

THYROID FUNCTION: T3 and T4 are recognized as having a major role in the control of metabolic and physiological mechanisms associated with heat resistance (Campos *et al.*, 2004). TSH, T3, and T4 hormones are presented in Table 3. There were significant ($P < 0.001$) decreases in thyroid hormones (T3 and T4) in light-colored cows compared to black-colored cows. However, the TSH hormone did not significantly ($P > 0.05$) differ. These hormones achieved the highest values in July compared to June, and August had the lowest values. The results showed that light-colored cows

were significantly ($P < 0.001$) better adapted to HS than black-colored cows. The current findings are in agreement with those of Zia-Ur-Rehman *et al.* (1982), who reported that dairy cows try to adapt to hot climate conditions by reducing the amount of heat produced by reducing dry matter intake in an attempt to reduce metabolism and heat production, which results in a decrease in the productive performance of dairy cows. According to Magdub *et al.* (1982), studying thyroid function may help explain how animals adapt to HS. Some studies have associated thyroid hormones with various nutrition and management situations (Valle, 2002). Thyroid gland hypofunction results from heat-stressed cows reducing their feed intake and slowing down their basal metabolism to avoid producing more metabolic heat (McManus *et al.*, 2009). According to Magdub *et al.* (1982), studying thyroid function may help explain how animals adapt to HS. Some studies have associated thyroid hormones with various nutrition and management situations (Valle, 2002). Thyroid gland hypofunction results from heat-stressed cows reducing their feed intake and slowing down their basal metabolism to avoid producing more metabolic heat (McManus *et al.*, 2009). In the present investigation, there were significant variations in serum T3 and T4 concentrations between both experimental groups, probably suggesting the effect of solar radiation on light-coated cows was lower than on dark-coated cows. Bovines that were adapted or introduced into tropical environments (Velásquez *et al.*, 1999) had lower serum T3 levels than bovines from temperate regions. This could be a sign that the hot environment causes the thyroid to secrete fewer thyroid hormones as a way to reduce body heat. The regulation of body temperature is significantly influenced by thyroid hormones. Animal basal metabolism rises in colder climates in order to produce more heat through the rise in T3 secretion. The opposite happens at high temperatures (Guyton, 1989).

CORTISOL AND PROLACTIN HORMONES CONCENTRATIONS:

It is clear in Table 3 that the data of dark-colored cows (G1) were affected by HS to a significant ($P < 0.001$) degree more than the light-colored cows (G2). Cortisol hormone concentration increased significantly ($P < 0.001$) in the G1 group with high temperatures in the summer, which indicates their HS because it is one of the most important physiological indicators for determining the state of HS (Abilay *et al.*, 1975). This is to participate in various functions of the body, such as the immune response and metabolism of fats, carbohydrates, and proteins (Podder *et al.*, 2022). According to a prior investigation on Holstein cows and heifers, coat color can substantially impact HS levels. For example, black-coated cows had higher hair cortisol levels than white-coated cows (Peric *et al.*, 2013). In high-heat environments, stressed cows tended to have lower serum cortisol levels, which could be due to a reduction of rate of metabolism and heat output

to prevent tissue injury (Lu *et al.*, 2021). These results are in agreement with those of Ghassemi, Nejad *et al.* (2017), who found that white dairy Holstein cows have a lower concentration of cortisol than black cows, making them more susceptible to HS under direct sunlight. Under long periods of HS, cortisol synthesis is affected as a result of changing the activity of the peripheral hypothalamic pituitary adrenal (HPA) axis (Bennett *et al.*, 2010). Cortisol is produced by the hair follicle from the hair shaft. Black cows have hair follicles that produce cortisol with higher differences than white cows (Ghassemi, Nejad *et al.*, 2017). Abnormal animal behavior like anxiousness and sensitivity has been demonstrated to be closely associated with elevated blood cortisol levels (Möstl and Palme, 2002; Bristow and Holmes, 2007). One way to gauge stress levels is by looking at decreased animal productivity (Cooke *et al.*, 2012; Bova *et al.*, 2014). Moreover, elevated peripheral hypertension has been linked to a higher heart rate (Reule and Drawz, 2012).

On the contrary, prolactin concentration decreased significantly ($P < 0.001$) in dark-colored cows compared to light-colored cows, especially in July, which achieved the highest THI degree. HS is considered to harm productive and physiological reproduction performance, as it raises the body temperature, which causes the animal to reduce its daily feed intake to reduce the heat produced by metabolism, but in consequence, it reduces dairy production and reproduction performance by reducing fertility rates and general health by lowering immunity, which makes it vulnerable to diseases such as mastitis. The color of cows' outer coats is considered an important factor in the susceptibility of dairy cows to HS, as black absorbs solar radiation to a greater extent than white (Rhoads *et al.*, 2009). The endocrine alterations are essential to the metabolic reaction to HS during both glandular and neuronal hormone release for dairy cattle, like concentrations of prolactin increasing (Alvarez *et al.*, 1973). One of prolactin's actions is inhibiting hair development (Littlejohn *et al.*, 2014; Davis, 2019; Sosa *et al.*, 2022). Therefore, the slick phenotype seems to improve this prolactin signaling feature. Cattle with one or two copies of the PRLR SLICK1 mutation have short hair, which is due to prolactin's increased ability to suppress hair development (Littlejohn *et al.*, 2014). A possible effect is that during HS, animals with the mutation's slick phenotype are better at controlling their body temperature (Landaeta-Hernández *et al.*, 2011; Dikmen *et al.*, 2014; Landaeta-Hernández *et al.*, 2021). Moreover, Davis (2019) reported that higher body weights and lower hair coat grades (slicker hair covers) have been associated with elevated prolactin levels. Animals in the "low prolactin" category showed a higher degree of hairiness throughout. The cows classified as having low prolactin consequently weighed less than those in the moderate and greater prolactin categories.

There is enough evidence to show how higher AT and RH affect dairy cattle’s hormonal responses to HS, particularly alterations in cortisol and prolactin levels, indicating the likely impact on the immune system (Gupta *et al.*, 2022). Additionally, cows exposed to HS have endocrine changes, particularly in cortisol and prolactin levels. The necessity to enhance heat loss is accommodated by this increase (Collier *et al.*, 2008a). It is recognized that both hormones have an impact on the immune system. Cortisol (Vijayan *et al.*, 2003), and prolactin (Stocco *et al.*, 2001) have an impact on genes involved in immunological responses, particularly the heat shock proteins (HSPs), molecular chaperons that shield cells from the harm resulted from elevated temperatures. Also, everyone agrees that heat stress leads to excessive prolactin release, and it has been shown that higher heat stress gradients are positively correlated with increased prolactin release. (Ronchi *et al.*, 2001; Scharf *et al.*, 2011). For instance, when the ambient temperature rose from 21 °C to 32 °C, prolactin levels raised fourfold, according to Tucker and Wetteman (1976). When comparing heat-stressed dry dairy cows to non-stressed cows, Do Amaral *et al.* (2011) discovered that the former had noticeably higher prolactin levels. According to other research, heat-stressed cows through the dry season have higher levels of prolactin and lower levels of estrogen (E2) than cows kept in cool or thermoneutral environments (Collier *et al.*, 1982a; Do Amaral *et al.*, 2010). In contrast to thermoneutral settings, Ouellet *et al.* (2021) reported that HS through the dry season modifies the prolactin expression and E2 receptors in cows’ udders. This suggests that HS through the dry season modulates the mammary cells’ responsiveness to prolactin and E2. It is unclear exactly why HS alters E2 and prolactin. High prolactin levels have been suggested to aid in the synthesis of HSPs and encourage perspiration and hair molting, all of which work together to enhance heat abatement (Baumgard *et al.*, 2013). However, Djelailia *et al.* (2021) found a positive correlation between rectal temperature and both prolactin and cortisol.

RENAL FUNCTION

In the current investigation, there were increments (P< 0.001) in serum urea in dark-colored cows (Table 4), and these increases were higher in dark-colored cows than in light-colored cows. In general, the highest values of kidney enzyme concentrations were observed in the dark group, especially in July, compared to the light group in the remaining experimental months. For dairy cows in HS, many investigations (Wheelock *et al.*, 2010; Obitsu *et al.*, 2011; Zhang *et al.*, 2014) have also reported elevated blood urea-N levels. On the contrary, Cows cooled throughout the dry months had blood urea-N levels identical to uncooled ones (Do Amaral *et al.*, 2009; 2011). According to Bernabucci *et al.* (2010), heat-stressed cows and heifers also had higher blood urea-N concentrations than unheat-stressed cows. Various reasons cause elevated blood

urea levels, such as increased hepatic urea synthesis and decreased renal clearance due to impaired renal blood flow. Impaired kidney perfusion under chronic HS is caused by abrupt temperature-induced vasodilation in the peripheral body surfaces and increased evaporative water loss, which decreases blood pressure (Silanikove *et al.*, 1994) and thus increases water retention (Silanikove *et al.*, 1992).

Table 4: Renal function of Friesian dairy cows under heat stress conditions.

Factors	Renal function	
	Creatinine (mg/dl)	Urea (mg/dl)
Coat colour effect		
25% white	1.08	21.98 ^a
50% white	1.11	19.19 ^b
±SEM	0.02	0.52
Month effect		
June	1.02 ^b	20.05 ^b
July	1.07 ^b	22.19 ^a
August	1.19 ^a	19.53 ^b
±SEM	0.02	0.64
Interaction effect		
25% white	June	0.94 ^c
	July	1.09 ^b
	August	1.20 ^a
50% white	June	1.09 ^b
	July	1.05 ^b
	August	1.18 ^a
±SEM	0.03	0.91
P value		
Coat colour	0.2083	0.0004
Month	<0.0001	0.0115
Interaction	0.0101	0.0005

Values with different superscripts within the same column are significantly different (P<0.05).

Creatinine (CRT) concentrations did not differ significantly (P> 0.05) by different colored of experimental cows. They were not significantly associated with color-coated cows and there were not any notable distinctions between dark- and light- colored cows. The difference was insignificant in eliminating the heat burden due to the convergence of the concentrations of metabolic products in their blood. These outcomes could be explained by a reduction in rumen ammonia-N, offset by a rise in urea-N absorption in the rumen, which lowers blood urea and raises nitrogen excretion in the urine. These findings are in accordance with those of Fike *et al.*, (2005). Elevated serum creatinine may be another indicator of skeletal muscle breakdown and may be primarily due to decreased renal clearance and only partially due to a rise in severe muscle catabolism (Windisch *et al.*, 1995), which may be due to HS (Abeni *et al.*, 2007).

The serum CRT and urea concentrations in July was greater compared to June and August (Table 4). The impact of HS may be explained by compensation of reduced energy expenditure in hyperthermic firms by muscle protein degradation helping to raise the CRT for energy supply (Lamp *et al.*, 2015), but independent of diet (Asai *et al.*, 2005). In addition, HS increases peripheral vasodilation to increase heat loss and decreases blood flow to interior organs (Srikandakumar *et al.*, 2003), and the rate of CRT excretion is impacted by kidney perfusion and the rate of glomerular filtration. The blood flow of the kidney was reduced through HS, which may increase the plasma CRT concentration. The results in this study were consistent with those of Gaafar *et al.*, (2021). The heat load of dairy cows experiencing adequate supply of carbohydrate precursors via tissue protein catabolism is reflected in a CRT concentration response coinciding with adipose tissue fusion to lipolytic signals (Lamp *et al.*, 2015). In the same line, Ronchi *et al.* (1999) reported that HS resulted in a decline in blood glucose ($P < 0.001$), as well as an increase in CRT ($P < 0.001$) as a result of muscle catabolism for energy supply.

During the period of HS, the level of creatinine in plasma increases as a result of the mobilization of proteins in the muscles to produce creatinine (Abeni *et al.*, 2007) and similarly the level of glucocorticoids increases (Collier *et al.*, 1982a), as the binding of glucocorticoids within the blood circulation and the activity of proteins in the digestive system leads to an increase in the secretion of nitrogen and creatinine. Gaafar *et al.* (2021) indicated a noticeable decrease in total protein in the blood of cows under the influence of high temperatures surrounding the animal. explained by changes in the availability of metabolized proteins and reduced blood flow, which limits the absorption of amino acids (Scharf *et al.*, 2010) and reduces the contribution of amino acids to blood sugar synthesis (Ronchi *et al.*, 1999) because ruminants It prefers to catabolize proteins to provide less heat-producing energy for their vital functions in the body, under the influence of cortisol (Sejian *et al.*, 2015). The HSPs synthesis leads to a decrease in the availability of total protein concentrations (Gao *et al.*, 2017). The concentration of CRT increases may be due to the increase in metabolic activity in the liver and muscles (Temizel *et al.*, 2009), which reduces feed intake as a result of protein metabolism and decreases thyroid hormones (Table 3), which reduces created blood proteins and increases the end products of catabolism of proteins as blood Urea-N and creatinine (Habeeb *et al.*, 1992). Serum CRT is an indicator of muscle mass, and through HS, the change in CRT may be associated with muscle protein mobilization (Bell, 1995).

SERUM ELECTROLYTE CONTENTS

Table 5 revealed that the concentrations of the sodium (Na) element increased significantly ($P < 0.001$), while the

potassium (K) concentrations decreased significantly ($P < 0.05$) in serum dark cows compared to light cows. However, phosphorus (P) levels did not change significantly ($P > 0.05$). These findings may be due to the increasing frequent sweat production during hot weather and decreasing mineral intake (Collier *et al.*, 1982a). The increase in respiration will cause excessive water loss due to reduced mineral concentrations (Nayyar and Jindal, 2010). The mechanism of removing excess heat from the body leads to getting rid of the thermal burden on the animal, but it causes the loss of a lot of body electrolytes such as potassium, etc., thus causing an imbalance in the acid-base balance in the body.

Table 5: Serum electrolytic concentrations of Friesian dairy cows under heat stress conditions.

Factors	Serum electrolytic		
	Sodium (Na; mEq/l)	Potassium (K; mEq/l)	Phosphorus (P; mg/dl)
Coat colour effect			
25% white	108.93 ^a	3.79 ^b	5.68
50% white	93.46 ^b	4.10 ^a	5.65
±SEM	1.52	0.09	0.16
Month effect			
June	87.54 ^c	3.63 ^b	6.35 ^a
July	117.53 ^a	4.21 ^a	5.41 ^b
August	98.52 ^b	4.01 ^a	5.25 ^b
±SEM	1.86	0.11	0.20
Interaction effect			
25% white June	90.72 ^{cd}	3.51 ^c	6.37 ^a
July	133.83 ^a	4.03 ^{ab}	5.51 ^b
August	102.25 ^b	3.84 ^{bc}	5.16 ^b
50% white June	84.36 ^d	3.75 ^{bc}	6.32 ^a
July	101.22 ^b	4.38 ^a	5.30 ^b
August	94.79 ^{bc}	4.18 ^{ab}	5.33 ^b
±SEM	2.63	0.15	0.28
P value:			
Coat colour	<0.0001	0.0146	0.8945
Month	0.0006	0.0012	0.0003
Interaction	0.0043	0.0029	0.0050

Values with different superscripts within the same column are significantly different ($P < 0.05$).

The sweating mechanism was also increased by eliminating water, sodium, potassium, and chlorine through sweat (El-Nouty *et al.*, 1980) by secreting antidiuretic hormone (ADH) to preserve body water during periods of HS through transpiration and evaporative cooling, which activate hypothalamic baroreceptors and osmotic receptors to prevent dehydration by causing the release of ADH (La Salles *et al.*, 2017). Furthermore, Dehydration through-

out HS causes hypovolemia, which also stimulates the renin-angiotensin-aldosterone system, closely correlated to electrolyte balance maintenance. Decreased blood supply to the kidneys causes renin to be secreted, which raises the synthesis and secretion of angiotensin and, consequently, aldosterone (Balamurugan *et al.*, 2017). To maintain fluid balance, Schneider (1990) found that dehydration throughout HS causes water to be redistributed to tissues, which lowers plasma volume by raising the release of cortisol and aldosterone (ALD). To prevent electrolyte loss, high ALD levels help the kidneys reabsorb water and ions, particularly Na (Kim *et al.*, 2022).

The prolactin level could be involved in the turnover of K and Na during HS. It has been observed that high concentrations of prolactin cause Na and K balance during hot AT (Collier *et al.*, 1982b). As the AT rises, the amount of water consumed rises significantly along with the volume of urine, and heavy water drinking leads to heavy urination. Significant electrolyte loss: at high AT, the main mechanism for heat loss is evaporative heat loss from perspiration and panting.

Cattle lose a lot of K through perspiration, and the more they sweat, the more they lose (Jenkinson *et al.*, 1973). Heat-stressed cows' higher sweating rate can raise their K needs by up to 12% since cow sweat contains more K and less Na (Collier *et al.*, 2006). Minerals are thought to have a role in preserving animals' regular physiological processes, especially dairy cows (Min *et al.*, 2019). In animals, Na is a major extracellular cation that is essential for maintaining acid balance, osmotic pressure, and bodily fluid balance. Additionally, it is essential for the active passage of glucose across plasma membranes, a significant molecule associated with energy metabolism (Garcia *et al.*, 2015). A lack of Na has been correlated to decreased milk production and appetite (Thiangtum *et al.*, 2011). Dairy cows are more prone to various metabolic disorders to reduce cations. Increasing water intake due to loss of electrolytes as loss of potassium from the skin increased by 500% and increased urinary excretion rates of sodium (Habeeb, 2020). Aldosterone stimulates K⁺ excretion and Na⁺ retention by the kidney (Verlander *et al.*, 2020), however, heat-stressed cows, secreting K⁺ in sweat, have reduced aldosterone levels (El-Nouty *et al.*, 1980). Milk reduction, HSPs, cortisol, and K⁺ content are the most commonly utilized markers as indicators for monitoring heat tolerance (Mandal *et al.*, 2021).

MILK YIELD

It was shown that light-colored Friesian cows produced 12.16% more milk daily than dark-colored cows, with a significant difference ($P < 0.001$) during all experimental months. Generally, June had the highest values of milk yield/day, followed by August compared to July, which had the lowest values.

Regarding milk composition, there were significant ($P < 0.05$) increased in the percentages of total solids, solids not-fat total, total protein, and fat of light-colored cows compared to dark-colored cows, while lactose didn't differ significantly ($P > 0.05$). Ash% in milk increased significantly ($P < 0.001$) as a result of HS in dark cows than light cows as an indication of the higher nutritional value of milk from light than dark cows. Light Friesian cows increased milk total solids, solids not-fat, protein, and fat by 3.64, 4.67, 10.20, and 1.41% vs. dark cows, and the concentration of milk lactose did not significantly differ, but the ash was affected significantly by 7.46% to higher THI values than dark to light cows.

The superiority of G2 compared to G1 might be due to that level of TDN intake as reported by Abdou (2011), found a tendency for milk yield to rise with energy levels. Additionally, Bar-Peled *et al.* (1997) revealed that the TDMI of dairy cows was positively correlated with their milk production. Moreover, the thyroid hormones' galactopoietic action (Table 3) results from their direct and indirect effects on the metabolism of the mammary glands, which alter the rate of mammary production, nutritional partitioning, and breast blood flow (Davis *et al.*, 1988). Additionally, Bar-Peled *et al.* (1995) found that increased prolactin was correlated to high milk yield. According to the current investigation, higher milk output (Table 6) was related to higher prolactin levels (Table 3). Holstein light cows exposed to mostly direct solar radiation performed better at controlling body temperature and sustaining milk production than black cows exposed to mostly radiation (Hansen *et al.*, 1990; Laible *et al.*, 2021). The coat color lightening could help lessen these effects and give dairy animals a head start on becoming more acclimated. Consequently, dairy cows are no longer adequately suited to the anticipated realities of longer and more frequent hotter summer temperatures (Seneviratne *et al.*, 2014). Bouraoui *et al.* (2002) found that THI exceeding 69 resulted in a 0.41 kg/cow drop in daily milk production. The maximum essential temperature for the Holstein breed during hot months is between 25 and 26 degrees.

Several authors have reported that Holstein white cows outperform mostly black Holsteins in terms of productivity in warm areas (Hansen *et al.*, 1990; Becerril *et al.*, 1993). The regression of milk yield on percentage white was 1.91 kg ($P < 0.01$), and the regression of days open on percentage white tended to be favorable for cows being rebred during the warm season (Becerril *et al.*, 1993). There is a negative correlation between the degree of darkness coat color and milk yield. Hair density had a positive impact on milk yield. Lower-density dairy cattle had increased milk production compared to higher-density cattle (Schleger *et al.*, 1960). Gaughan *et al.* (2000) reported that White cows produced 394 kg more milk in 305 days than black cows,

Table 6: Milk yield and its composition of Friesian dairy cows under heat stress conditions.

Factors		Milk yield (kg/d)	Milk composition (%)					
			TS	SNF	Protein	Fat	Lactose	Ash
Coat colour effect								
25% white		15.13 ^b	11.26 ^b	7.71 ^b	3.43 ^b	3.55 ^b	3.62	0.67 ^a
50% white		16.97 ^a	11.67 ^a	8.07 ^a	3.78 ^a	3.60 ^a	3.67	0.62 ^b
±SEM		0.30	0.09	0.09	0.07	0.02	0.04	0.01
Month effect								
June		17.87 ^a	11.62 ^a	8.06 ^a	3.76 ^a	3.56	3.66	0.64 ^b
July		14.87 ^b	11.28 ^b	7.69 ^b	3.45 ^b	3.59	3.58	0.67 ^a
August		15.41 ^b	11.49 ^{ab}	7.92 ^{ab}	3.60 ^{ab}	3.58	3.69	0.63 ^b
±SEM		0.37	0.11	0.11	0.09	0.02	0.05	0.01
Interaction effect								
25% white	June	16.22 ^{bc}	11.30 ^{bc}	7.75 ^b	3.41 ^b	3.55	3.68	0.65 ^b
	July	14.68 ^{cd}	11.27 ^{bc}	7.70 ^b	3.40 ^b	3.57	3.58	0.72 ^a
	August	14.48 ^d	11.23 ^c	7.69 ^b	3.47 ^b	3.54	3.59	0.63 ^b
50% white	June	19.52 ^a	11.95 ^a	8.37 ^a	4.11 ^a	3.58	3.64	0.62 ^b
	July	15.06 ^{bcd}	11.29 ^{bc}	7.68 ^b	3.49 ^b	3.61	3.57	0.62 ^b
	August	16.33 ^b	11.76 ^{ab}	8.14 ^{ab}	3.74 ^b	3.62	3.78	0.63 ^b
±SEM		0.52	0.16	0.15	0.13	0.03	0.08	0.01
P value:								
Coat colour		<0.0001	0.0031	0.0062	0.0015	0.0285	0.4480	<0.0001
Month		<0.0001	0.0147	0.0495	0.0485	0.6601	0.3082	0.0002
Interaction		0.0081	0.0054	0.0052	0.0014	0.5392	0.2760	<0.0001

Values with different superscripts within the same column are significantly different ($P < 0.05$); TS: Total solid; SNF: Solid not-fat.

even though dark cattle are more susceptible to HS than light cattle. Lee *et al.* (2016) reported that the rise in milk output is comparable to the 414 kg higher in 305-day lactations in Hawaii, despite the difference being negligible.

CONCLUSIONS AND RECOMMENDATIONS

It can be concluded that the dark-colored cows were more affected by the rise of heat and relative humidity index. Thus, they were more stressed than the light-colored cows, which quickly got rid of the heat burden on them. Light-colored cows were more efficient in adapting to HS conditions compared to dark-colored cows. They can modulate thermoregulatory responses, increasing thyroid hormones, prolactin, and milk production, and decreasing stress hormones such as cortisol. According to the findings, coat color can be used as a criterion to choose animals that are durable and adaptable to hot temperatures, and it can also enhance the knowledge of breeders to have the best performance under HS conditions.

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NOVELTY STATEMENT

Selection of the best ratio of white to black skin color for Friesian dairy cows in the absence of comfortable housing factors for the animal to maintain its productive performance under the conditions of the Egyptian Delta during the hot months.

AUTHOR'S CONTRIBUTIONS

Ashraf Ali Mehany came up with the concept, conducted the trials, gathered, and processed the data. The theory

was created by Wael Mohamed Wafa, who also prepared the manuscript and updated the design of the experiment. Mahmoud Sayed Sayah and A.F.A. El-Hawary edited the manuscript, paraphrased, and oversaw the experimental procedures. Nearly all of the technical specifics and numerical calculations for the proposed experiment were worked out by Reda Abdel-Samee Ahmed Rezk and Al-Moataz Bellah Mahfouz Shaarawy. The experimental techniques were carried out by Adel Bakr. Shima M. Ali developed, revised, and published the manuscript after curing and statistically analyzing the data. Each author contributed to the final article, reviewed the findings, offered insightful criticism, and helped mold the study.

ETHICS STATEMENT

This study was achieved the EU standards (2010/63/EU; Official Journal of the European Union, 2010) using for the protection of animals used for scientific purposes and feed legislation at Gemmezah Animal Production Experimental Station, Animal Production Research Institute (APRI), Agricultural Research Center, Egypt. The experimental work of the present study achieved the Institutional Animal Care and Use Committee (IACUC) protocol Number (ARC/APRI/107/24) for the protection of animals used for scientific purposes and feed legislation.

CONFLICT OF INTEREST

All authors declare that there is no conflict of interest in this study.

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