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The Effects of Evaporative Cooling on Heat Stressed Dairy Holstein Cows Under a Semi-Arid Environment in Riyadh Area, Saudi Arabia

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Abstract: Heat stress has been identified as a major cause of lower productive and reproductive performance in animal farming. Methods for protecting livestock from heat stress were investigated during the summer months, where one six Holstein cows kept under shade only (group 1), and another six cows kept under shade with evaporative cooling (group 2). The results show that shade and water sprayers (evaporative cooling) significantly lowered ambient temperature and thus reduced the heat stress experienced by dairy cows in Saudi Arabia. Evaporative cooling plus shade, lowered ambient temperature (41.80 ± 0.74 vs. 47.40 ± 0.84°C), increased relative humidity (0.33 ± 0.01 vs. 0.24 ± 0.01) and decreased the temperature humidity index (80.24 ± 0.60 vs. 84.77 ± 0.68) when compared to shade alone. In addition, cows kept under evaporative cooling (38.4 ± 0.32°C) experienced lower rectal temperatures compared to cows under shade alone (39.53 ± 0.44°C). Cows under evaporative cooling had higher serum concentrations of triidothyronine (2.50 ± 0.90 vs. 0.75 ± 0.20 ng/ml) and thyroxine (11.94 ± 1.60 vs. 7.22 ± 1.88) than cows under shade alone. Thus, evaporative cooling can decrease the heat stress experienced by dairy cows in Saudi Arabia and limit its associated detrimental effects.

Keywords: Dairy Cows, Evaporative Cooling, Ambient Temperature, Rectal Temperature, Relative Humidity, Temperature Humidity Index, Triidothyronine, Thyroxine

1. Introduction

Desert environments have high daytime temperatures and solar radiation levels during the summer months [1]. More than half of Saudi Arabia is desert land, and the average summer temperature reaches 43°C, and can often hit a high of 54°C [2, 3].

The detrimental effects of heat stress on dairy cows during summer months are well documented [4, 5]. Heat stress induces changes in dairy cows' respiration rate, heart rate, sweating, blood chemistry, and hormone levels [5, 6]. In addition, heat stress increases the rectal and core body temperatures of dairy cows [7, 8].

Rectal temperature and core body temperature of dairy cows are positively correlated [8]. Increased body temperature reduces uterine blood flow [9, 10] leading to an increased uterine temperature, resulting in a decrease in fertility because of an unfavorable uterine environment for successful insemination. Environmental heat stress triggers blood flow changes that direct the flow of blood away from the uterus, thereby interfering with the nutrients and hormones supplied to the conceptus, thus damaging or killing the developing embryo [11]. Research has shown that cooled Holstein dairy cows have higher blood flow to the ovaries during estrus near ovulation than control group, which may contribute to improved fertility in dairy cows [12].

Even for a short period, the effects of heat stress on dairy cows in general, and especially in arid and semi-arid regions, include reduction in milk production and number of births [13, 14]. Heat stress compromises follicular development, steroidogenesis and oocyte quality [11], increases early embryonic death and days open, and prolongs days to first service, number of inseminations per pregnancy and calving interval [15, 16]. Stress responses to summer conditions are especially severe, and diurnal patterns of rectal temperature seldom return to the thermoneutral zone [7].

Dairy farms respond to heat stress by providing shade and evaporative cooling. Cooling should improve reproductive performance, provided that it adequately lowers body temperature. Dairy cows are known to suffer from heat stress at a temperature humidity index (THI) greater than 70–72 [17], which reduces milk production proportionally to rectal temperature [18].

The hypothalamus regulates the secretion of triidothyronine (T3) and thyroxine (T4), which in turn, inhibits the cow's appetite and energy metabolism [19]. Blood thyroid hormones' concentrations (T3 and T4) are also affected by heat stress. Blood concentrations of T3 and T4 are decreased in cows that are subjected to heat stress, since lowered thyroid hormone levels reduce heat production, which helps the body adapt to warmer environments [20].

The aim of this study was to use evaporative cooling to reduce the high environmental temperature, and its detrimental effects on rectal temperature and thyroid hormones in dairy Holstein cows in the semi-arid environment of the Riyadh region in Saudi Arabia.

2. Materials and Methods

The Faculty Research Ethics Committee at King Saud University approved all procedures in this experiment. Twelve Holstein dairy cows in a dairy farm in the Riyadh region were used. Cows were randomly divided into two groups of six. All cows were cycling, milked twice daily and at least 45 days postpartum.

The experiment period was during the hottest months of the year in Saudi Arabia, July and August. Cows were kept for 2 weeks under open shade without evaporative cooling for acclimatization before the beginning of the experiment, which lasted for 22 days. One group was kept under shade without cooling (shade only group), and the other was kept under shade plus (spraying) evaporative cooling (evaporative cooling group). Evaporative cooling was applied throughout the day (8:00 to 20:00).

Environmental temperatures were measured daily using a data logger (Poket Logger, Pace Scientific Inc., North Carolina, USA), recording the highest and lowest temperatures. In addition, rectal temperatures were measured using a digital thermometer (Citizen Systems Japan Co, Ltd). THI was used to estimate the environmental severity, which was calculated using the following adapted equation: THI = Tdb (in °C) + 0.36 * Tdp (in °C) + 41.2 [21]. This formula uses dry bulb temperature (Tdb, °C) and relative humidity (RH). The RH is divided by 100 to express the percentage in decimals.

All cows were provided with water at libitum and fed according to the National Research Council [22] protocols for dairy cattle. Blood samples were collected daily from each cow via coccygeal venipuncture into vacutainer tubes (Becton, Dickinson and Company, New Jersey, USA). All samples were immediately placed on ice and transported to the laboratory. Serum was separated by centrifugation at 3,000 rpm for 30 min at 4°C, transferred into 1.5 ml Eppendorf tubes and stored at -20°C until being assayed for T3 and T4. Samples were analyzed in duplicate in the same assay using an ELISA kit (Kayman Pharm, Czech Republic).

Data were statistically analyzed using the general linear model (GLM) procedure of Statistical Analysis System (SAS, Inst. Inc., Cary, NC, USA) to determine the effects of evaporative cooling on environmental, rectal temperature, T3 and T4, and relative humidity and THI.

3. Results

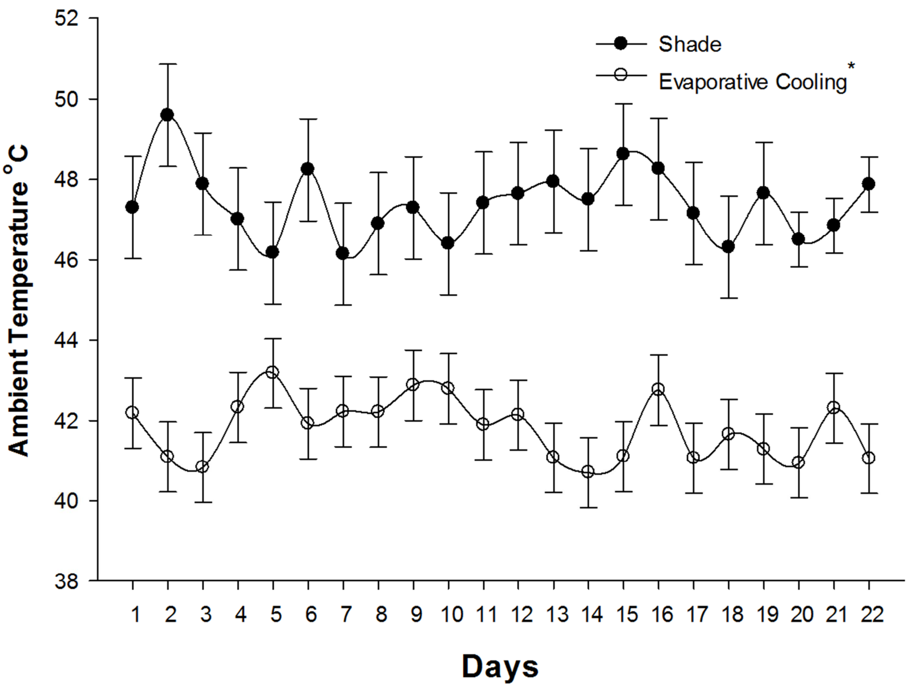

Figure 1. *Ambient temperature (°C) under shaded only and evaporative cooling conditions (means ± SE). * indicates significant difference at P<0.05.*

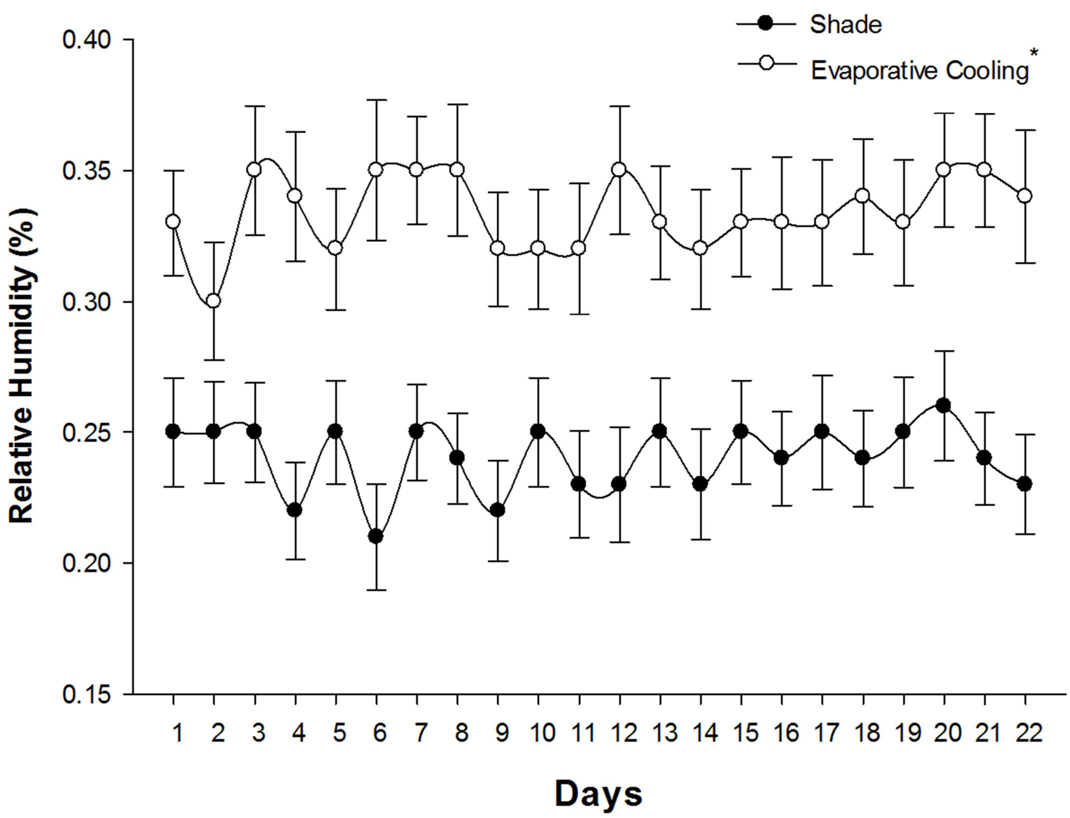

Figure 2. *Relative humidity under shade only and evaporative cooling conditions (means ± SE). * indicates significant difference at P<0.05.*

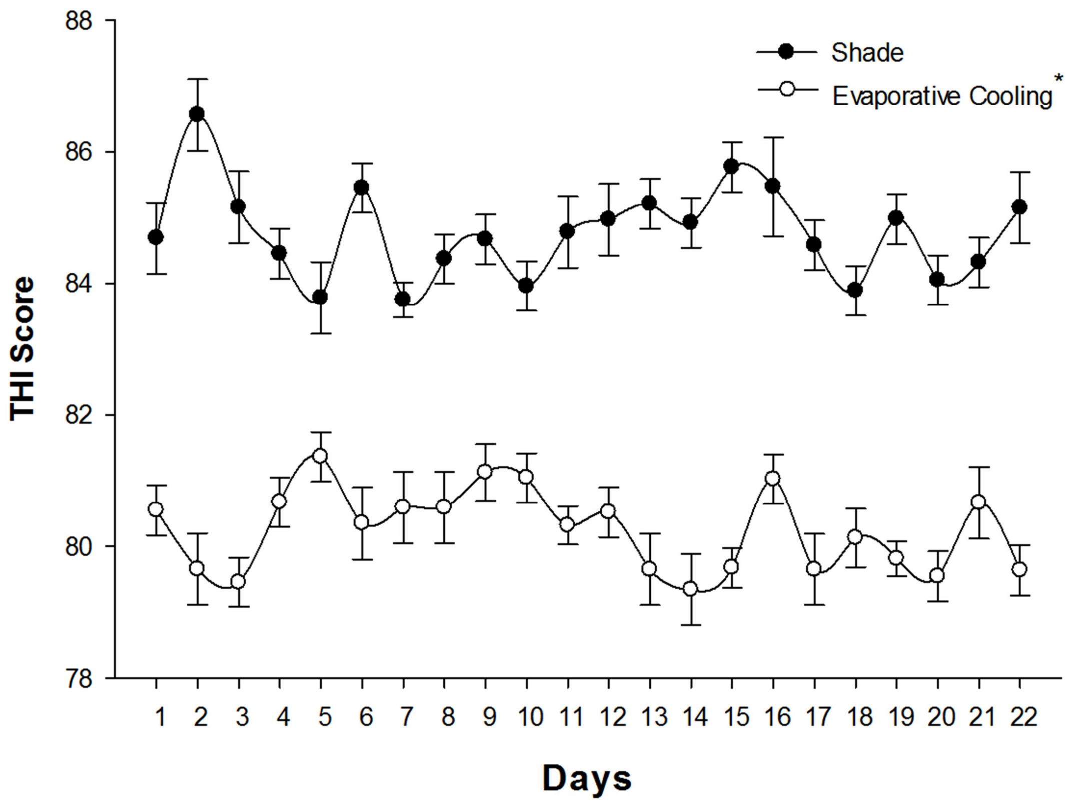

Figure 3. *Temperature Humidity Index (THI) under shade only and evaporative cooling conditions (means ± SE). * indicates significant difference at P<0.05.*

Figure 4 shows the average rectal temperature in cows during the experimental period. Rectal temperature was lower for the evaporative cooling group (38.4 ± 0.32°C) than the shade only cows (39.53 ± 0.44°C, $p<0.05$).

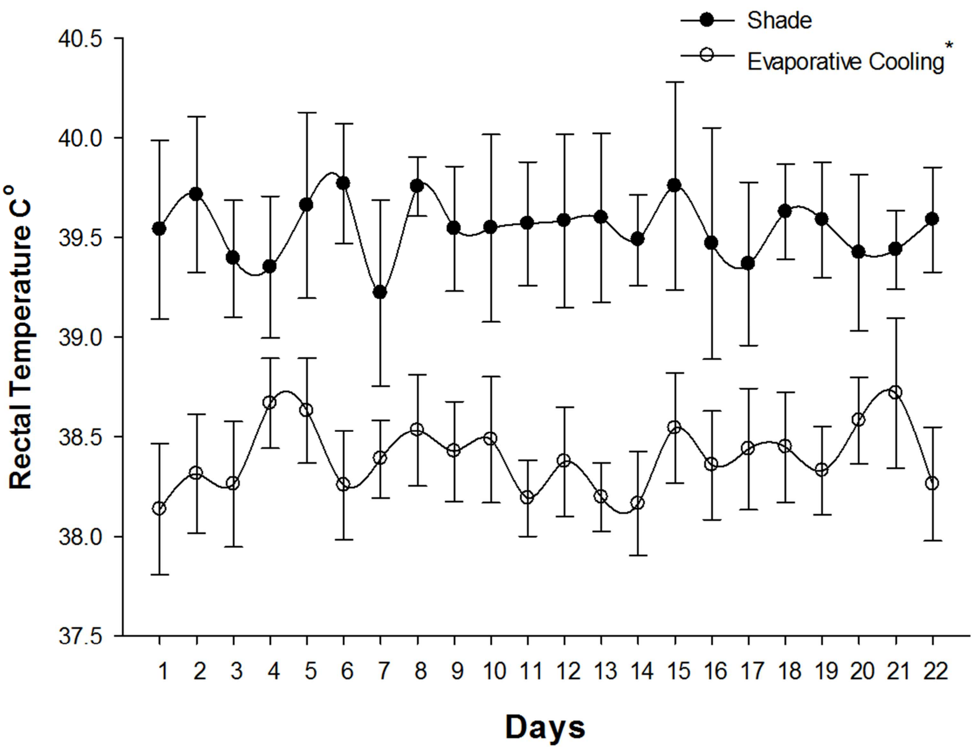

Figure 4. *Rectal temperature of cows under shade only and under evaporative cooling conditions (means ± SE). * indicates significant difference at P<0.05.*

Daily environmental parameters (AT, RH and THI) throughout the experiment period are shown in figures 1, 2 and 3. In both groups (evaporative cooling and shade only), the environmental temperatures were high. Ambient temperature (AT) was lower in the evaporative cooling group than in the shade only group (41.80 ± 0.74 vs. 47.40 ± 0.84°C, $p<0.05$). RH was greater and THI was lower in the evaporative cooling than in the shade only group (0.33 ± 0.01 vs 0.24 ± 0.01 and 80.24 ± 0.60 vs. 84.77 ± 0.68, respectively, both $p<0.05$).

Figure 5 shows that T3 serum concentrations were lower ($p<0.05$) in the shade group when compared to the evaporative cooling group (0.75 ± 0.20 ng/ml vs. 2.50 ± 0.90). Figure 6 shows that T4 serum concentrations were lower ($p<0.05$) in the shade group, compared to evaporative cooling cows (7.22 ± 1.88 vs.11.94 ± 1.60).

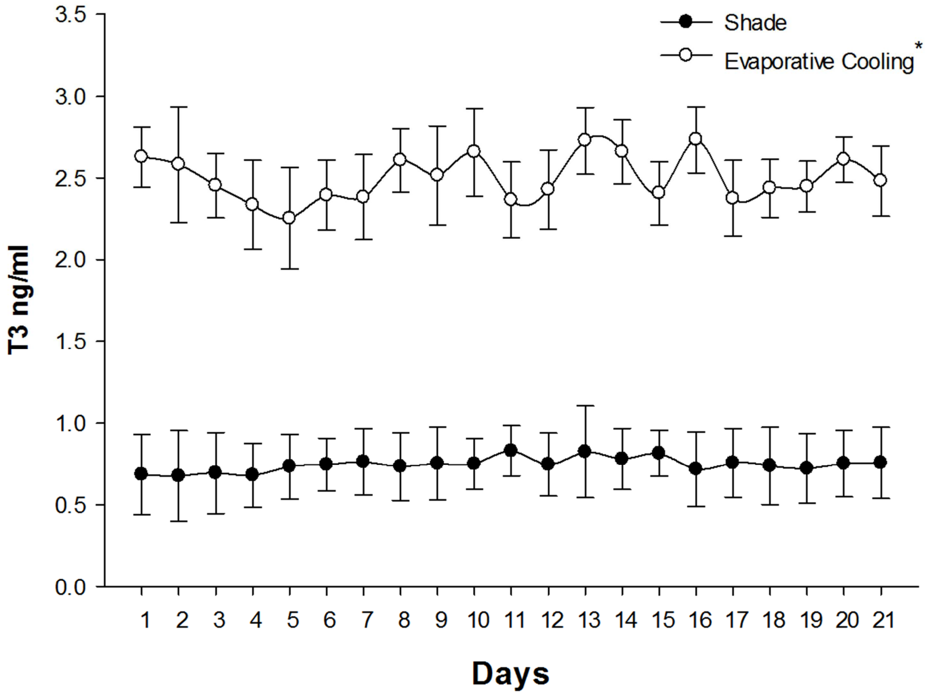

Figure 5. *Serum T3 concentrations (ng/ml) of cows under shade only and under evaporative cooling conditions (means ± SE). * indicates significant difference at P<0.05.*

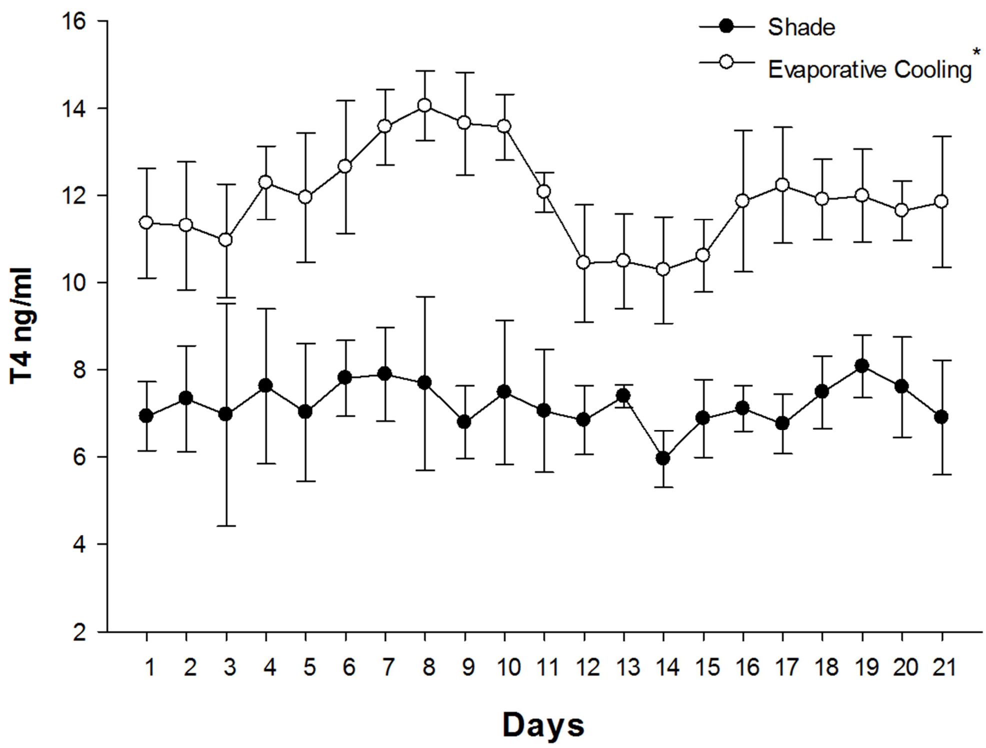

Figure 6. *Serum T4 concentrations (ng/ml) of cows under shade only and under evaporative cooling conditions (means ± SE). * indicates significant difference at P<0.05.*

4. Discussion

The summer months in the Riyadh region, Saudi Arabia, are characterized by high temperatures and low humidity. Lactating dairy cows prefer ATs of between 10 and 25°C, known as the thermoneutral zone [23]). Whenever AT is beyond these limits, cows are considered to be under heat stress, thus, milk production declines [24]. In addition, THI values of 70–72 units or less are considered acceptable [17], while a THI greater than 72 units causes a reduction in dry matter intake and milk production and composition manifested by having reduced fat, protein and casein contents in dairy cows [14, 25]. In addition, a THI index of up to 84 was associated with reduction in triacylglycerol and polar lipid profiles [26]. Furthermore, an increased THI resulted in increased incidence of mastitis in cows [27]. Evaporative cooling significantly lowered AT (41°C vs 47°C) and THI (80 vs 84 units), and increased RH, compared to the shaded only group. Although AT and THI were lower in the evaporative cooling group, these values remain above the comfort zone for dairy animals.

Desert environments are characterized by fluctuations in temperature between day and night [2]. The high daytime temperatures in desert environments raise animal body temperatures due to inadequate evaporative heat loss, which leads to increased heat production by the animal [28]. When the evaporative heat loss ability (through sweating and panting) is less than the thermal load of the animal, fluid loss reaches a critical level, body temperature rises, and the animal may die from hyperthermia [29]. These effects account for the lower milk production and fertility of dairy farms during the summer season, even with the use of advanced environmental modifications to alleviate heat stress [4].

Animals can cope with environmental temperature changes by stabilizing their body temperature within certain limits. Body temperature is susceptible to increased environmental temperatures and can be used to estimate heat stress [24]. In addition, there are significant relationships between rectal temperature, skin temperature, respiratory rate and milk production [30]. Normal rectal temperature in dairy cows ranges from 38 to 39.3°C during the whole year [31]. When rectal temperature reaches 39°C, high producing cows in early lactation show a sharp decline in milk production, since these cows are more susceptible to heat stress than low producing cows [32]. Our results indicate that, although cows under evaporative cooling have decreased rectal temperature compared to cows under shade only, evaporative cooling was unable to completely ameliorate heat stress. In fact, rectal temperature was higher than the optimal, even in cows under evaporative cooling. These high rectal temperatures, even under evaporative cooling, could be due to the low efficiency of the evaporative cooling system practiced in the farm during the trial period, since no barn side shades were installed at the time.

Dairy cows are known to have low T3 and T4 in their blood during the summer, or when under heat stress, and high T3 and T4 concentrations during the winter [32]. Thus, changes in climatic situations (e.g., shade and cooling) are expected to affect the animal’s thyroid activity [33]. Cows under heat stress lower their metabolic activities, and thus their heat production [34]. In our experiment, all cows were kept for two weeks under shade without evaporative cooling for acclimatization, since the response of T3 and T4 to heat stress is slow [35]. Our T3 and T4 data for shaded only and evaporative cooling cows are in line with previous studies; T3 and T4 are lower in more heat stressed cows. However, in this study, all cows, including those under evaporative cooling, were under some degree of heat stress.

This study sheds light on the effects of evaporative cooling on dairy cows during the summer under a semi-arid environment, where AT is extremely high. Cows that produce little milk or do not become pregnant are usually culled, and heat stress is known to negatively affect reproductive performance of dairy cows. Our data show that, in arid and semi-arid regions (e.g., central Saudi Arabia), while heat stress cannot be eliminated, its detrimental effects on productive and reproductive performance can be lowered. Evaporative cooling lowered the AT around the animals, which reduced rectal temperature and affected T3 and T4 serum concentrations.

5. Conclusion

The results of this study showed that evaporative cooling, even without fans, lowers ambient and rectal temperatures. In addition, evaporative cooling increased serum concentrations of T3 and T4, which are used as a heat stress indicators. Evaporative cooling has a positive effect on dairy cows performance as a whole, and this study for the first time shows the effect of evaporative cooling during the estrous cycle under semi-arid environment in Riyadh, Saudi Arabia.

Conflict of Interest

The authors declare that they have no competing interests.

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