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Evaluating the efficacy of lycopene on rectal temperature fluctuation in Red Sokoto Goats during the cold-dry (harmattan) season

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Abstract

The cold-dry (harmattan) season is characterised by relatively low ambient temperature (AT) in the early morning and evening hours of the day, and high in the afternoon. Lycopene is a potent antioxidant that has anti-stress properties. The study aimed to determine the rectal temperature (RT) fluctuations in Red Sokoto goats during the cold-dry (harmattan) season, and the effect of lycopene administration. A total of 20 goats were randomly divided into experimental and control groups (n = 10). The experimental group was administered lycopene (0.142 mg/kg) for two weeks and RT values were recorded on days 8, 11 and 14 of the study. Thermal environmental data of ambient temperature (AT) and relative humidity (RH) were recorded hourly at the experimental site from 07:00 to 18:00 h using a dry- and wet-bulb thermometer and temperature-humidity index for 3 days. The RT was measured hourly, from 7:00 to 18:00 h each day. RT variation was predominantly due to the hourly influence of thermal environmental parameters, rather than an individual feature of the animals. The DBT (Dry-bulb Temperature) fluctuated from 18:00 to 35:00 °C with a mean value of 28.44 ± 1.56 °C. The RH (relative humidity) recorded during the study period fluctuated between 13 and 46%, while the overall mean value of RH was 30.82 ± 2.58%. The THI (temperature-humidity-index) fluctuated between 76:00 ± 0.52 and 78.64 ± 0.04. In conclusion, lycopene modulated cold-dry induced stress in goats by increasing RT values of Red Sokoto goats, between 16:00-18:00 h during the cold-dry season.

Keywords: Ambient Temperature, Harmattan, Lycopene, Rectal temperature, Relative humidity

Introduction

The cold-dry (harmattan) season is one of the three seasons in Northern Nigeria (cold-dry, hot dry and rainy season). It is characterised by relatively low ambient temperature (AT) in the early morning and evening hours and high in the afternoon. The relative humidity (RH) is very low during the season. During the season, the wind is cold-dry (9°C) and dust-laden (Minka & Ayo, 2016). The harmattan season is the most thermally stressful season of all the three seasons in the Northern Guinea Savannah zone of Nigeria (Adenkola *et al*., 2011; Ayo *et al*., 2011; Minka & Ayo, 2014). Stress is the ability of the body to maintain a stable internal environment to challenges from widely variable environments, described by Claude Bernard in 1878 and later referred to as homeostasis (Goldstein, 1990). Hans Selye defines stress as a complex or general adaptation syndrome (GAS) of an organism in response to extraneous factors. The thermal stress induced by the cold-dry season exerts adverse effects on the animals; especially during the cold-dry season (Ayo *et al*., 2011; Habibu *et al*., 2022; Minka & Ayo, 2014). The rectal temperature (RT) is a reliable parameter measured to indicate the body temperature in animals. It reflects the extent of homeothermy (Minka & Ayo, 2014). Several agents exert antistress effects on goats, including antioxidants. Lycopene is a potent antioxidant, possessing powerful antistress activity. It is a major carotenoid in tissues and the most abundant in tomatoes (Palozza *et al*., 2012; Ayo *et al*., 2022). It scavenges singlet oxygen and other reactive oxygen species (ROS), and protects the cells from lipo-peroxidation (Sahin *et al*., 2016; Ayo *et al*., 2022). Administration of lycopene has been used in human patients to relieve stress (Bello *et al*., 2023). It was conceivable that lycopene may modulate body temperature and exert beneficial effects on adaptive responses to cold-stress conditions in goats.

The study aimed to determine RT fluctuations in Red Sokoto goats during the harmattan season in the Northern Guinea Savannah zone of Nigeria, and the effects of lycopene administration on the fluctuations.

Materials and Methods

Experimental site

The experiment was performed in January, at a small ruminant farm in Samaru-Zaria (11° 107N, 07° 30'E), located in the Northern Guinea Savannah zone of Nigeria during the cold-dry season. The cold-dry season in Nigeria occurs between November and February (Ileojo, 2004).

Animal management

Twenty, apparently, healthy young Red Sokoto goats, aged 1-3 years, comprising 12 males and eight females served as subjects. The live weights of the goats were 10 - 12 kg. They were purchased from the market. The goats were dewormed using albendazole at the dosage of 7 mg/kg as they had no previous medical history. They were acclimatized for seven days and reared under in a pen-intensive management system and had access to an enclosure with net wire. The floor of the animal pen was not cemented. The animal pen had no roof, but some trees served as shade. All the goats were allowed to walk freely within the animal pen and the enclosure. Feeding of the goats was performed using bean husk, dry groundnut leaves and maize offals. The goats were fed twice a day and given access to water *ad libitum*.

Ethical clearance to conduct the study was sought and approved by the Ahmadu Bello University Committee on Animal Use Care (ABUCAUC/2019/27).

Experimental design

After one week of acclimatization, each goat was identified by a number using a permanent marker on the ear. The goats were assigned to experimental and control groups by simple randomization method. Each group consisted of 10 goats. Lycopene was dissolved in olive oil, three tablets per 20 ml of olive oil, and administered for 14 days at the dose rate of 0.142mg/kg (Sun *et al*., 2015). The RT was recorded for three days on days 8, 11 and 14 of the experiment.

Measurement of thermal environmental parameters

Thermal environmental data of ambient temperature (AT) and RH were recorded hourly at the experimental site from 07:00 to 18:00 h using a dry- and wet-bulb thermometer (Brannan, Made in England) for 3 days. Temperature-humidity index (THI) was calculated using the equation below (Ocheja *et al*., 2020).

$$THI = 0.72\,(W\,°C + D\,°C) + 40.6$$

Where W °C = wet-bulb temperature, and D °C = dry-bulb temperature.

Measurement of rectal temperature

The RT was measured using a Hartmann digital thermometer (Bush Beach Engineering Limited, England). The thermometer was inserted at a depth of 4 cm into the rectum and tilted at an angle of 30°. The thermometer was held at that position until an alarm sound was heard from the thermometer, indicating the end of the reading. The measurement was taken hourly for three days, from 7:00 to 18:00 h each day. Each day of the recording was, on days 8, 11 and 14 of the study period.

Data analysis

All data obtained were subjected to the use of repeated-measures ANOVA and Pearson's correlation analysis. Graph pad Prism version 5.03 data was the software used for the analysis. Data were expressed as mean ± standard error of the mean (Mean ± SD). Values of $P < 0.05$ were considered significant.

Results

The thermal environment conditions obtained in the present study are shown in Figure 1. The DBT fluctuated from 18:00 to 35:00 °C with the mean value of 28.44 ± 1.56 °C. The lowest DBT value of 18:00 °C was recorded at 7:00 h with the mean value of 18:00 ± 0.44 °C, while the highest value, 32.33 ± 2.59 °C, was obtained at 14:00 h. The lowest extreme minimum and mean DBT values were recorded at 7:00 h, respectively. The RH recorded during the study period fluctuated between 13 and 46%, while the overall mean value of RH was 30.82 ± 2.58%. The RH was particularly low from 13:00 h to 17:00 h, when mean values fluctuated from 21.00 - 25.5%. The extreme RH values were between 18 and 30%. The lowest THI of 61.84 was recorded at 07:00 h, while the highest of 80.92 was obtained at 18.00 h. The lowest mean THI was recorded at 07:00 h with a value of 63.04 ± 0.04, while the highest mean value of 78.64 ± 2.04 was obtained at noon and the value was sustained until 18:00 h. The THI fluctuated between 76:00 ± 0.52 and 78.64 ± 0.04 (Figure 3).

In experimental goats, the extreme minimum RT was 37.14 °C recorded at 7:00 h, while of the maximum value of 40.34 °C was obtained at 16:00 h with a range of 3.20 °C. The lowest mean value of RT was 37.80 ± 0.33 °C (7:00 h), while the highest mean value was 40.15 ± 0.10 °C (16:00 h). The RT values fluctuated between the extreme minimum of 37.30 °C recorded at 7:00 h, and the extreme maximum value of 40.17 °C recorded at 15:00 h, giving a range of 2.87 °C. The mean values of RT fluctuated between the lowest value of 37.45 ± 0.11 °C obtained at 7:00 h, and the highest values of 39.86 ± 0.14 °C and 39.86 ± 0.16°C were recorded at 14:00 h and 15:00 h, respectively. The overall mean value of RT recorded in the control group was 39.08 ± 0.26 °C. The value was not significantly different from that of 39.32 ± 0.28 °C, obtained in experimental goats (Figures 3 and 4).

The overall RT obtained in individual experimental animals was 39.27 ± 0.17°C,

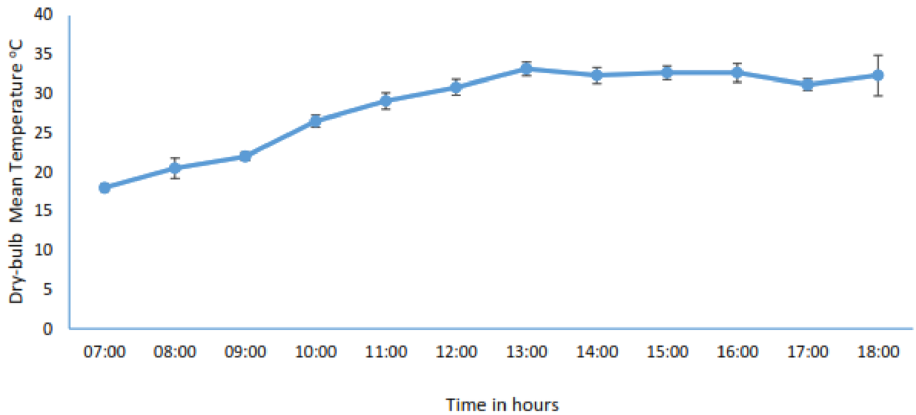

Figure 1: Hourly variations of dry-bulb temperature during the period of the experiment

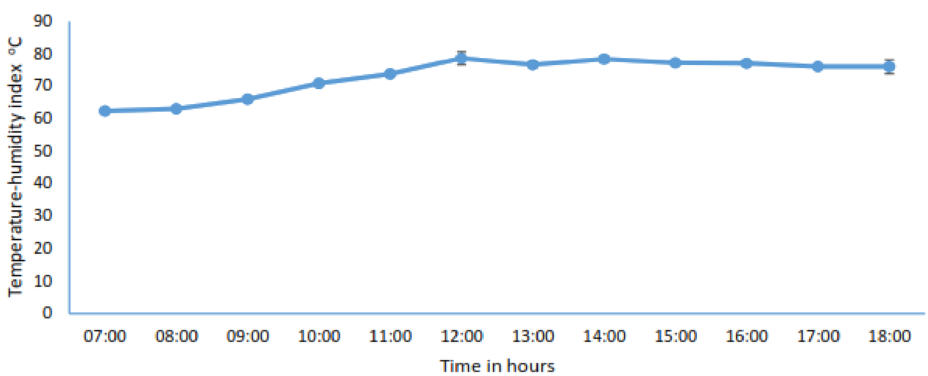

Figure 2: Diurnal variations in temperature-humidity index during the study period

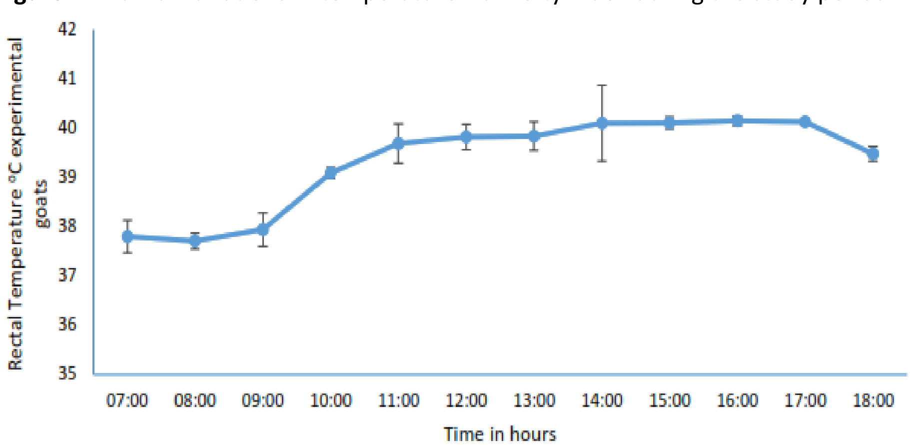

Figure 3: Hourly Rectal Temperature Fluctuations in Experimental Goats (n = 10)

and this value was not significantly different from 39.08 ± 0.17 °C, recorded in control goats. Similarly, the main values of extreme maximum and extreme minimum RT as well as the range values of RT in both the experimental and control goats were not significantly different. However, wider standard error values were recorded in hourly RT fluctuations than those of individual fluctuations in RT. This fact demonstrated that the RT variation was predominantly due to the hourly influence of thermal environmental parameters, rather than individual features of the animals (Table 1 and 2). The relationship between the hour of the day and the RT was significant ($P < 0.01$) and positive in control and experimental goats (r = 0.879 and 0.816, respectively). The thermal micro-environmental (AT) and RT parameters were significantly and positively correlated. The relationships between the THI, DBT and RT as well as range RT were negatively correlated. The RH was also negatively correlated and significant with RT parameters. An exception was the RT range and RH, which were positive and insignificant in the control (r = 0.135), but positive and significant in experimental goats (r = 0.561); $P < 0.05$. On the overall, the relationship was stronger between RT and thermal environment parameters of the controlled goats, compared to that of experimental goats.

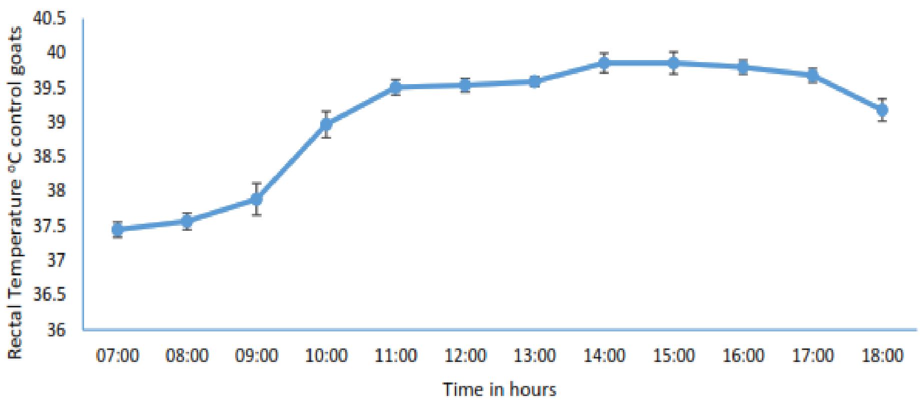

Figure 4: Hourly rectal temperature fluctuations in control goats (n = 10)

Discussion

The values of thermal micro-environmental parameters obtained during the present study were predominantly outside the established

Table 1: Individual variation in rectal temperature (^{0}C) of experimental goats during the study period

No of Animals	Mean ± SD	Maximum	Minimum	Range
1	40.02 ± 2.24	40.52	39.52	1.00
2	39.08 ± 1.48	39.42	38.76	0.66
3	38.94 ± 0.76	39.10	38.76	0.34
4	39.24 ± 0.76	39.40	39.06	0.34
5	38.96 ± 3.22	39.48	38.14	1.34
6	40.02 ± 1.25	40.34	39.81	0.53
7	38.83 ± 1.43	39.03	38.46	0.57
8	39.10 ± 2.50	39.70	38.60	1.10
9	39.48 ± 1.65	39.89	39.17	0.72
Overall Mean ± SD	39.27 ± 0.76	39.62 ± 0.85	38.92 ± 0.80	0.62 ± 0.40

Table 2: Individual fluctuations in rectal temperature (^{O}C) of control goats during the study period

No of Animal	Mean ± SD	Maximum	Minimum	Range
1	38.56 ± 0.36	38.68	38.41	0.27
2	39.20 ± 0.36	39.20	39.04	0.16
3	39.74 ± 0.72	39.91	39.41	0.50
4	39.46 ± 1.57	40.15	39.05	1.10
5	39.41 ± 1.48	40.05	38.95	1.10
6	39.66 ± 1.57	40.05	38.95	1.10
7	39.01 ± 1.07	39.44	38.62	0.82
8	38.97 ± 2.68	40.00	37.91	2.09
9	38.41 ± 1.12	38.90	38.07	0.83
10	38.37 ± 0.67	38.63	38.10	0.53
Overall Mean ± SD	39.08 ± 0.71	39.50 ± 0.85	38.71 ± 0.76	0.86 ± 0.85

thermoneutral zone (21.67 ± 2.03 ^{o}C) (Minka & Ayo, 2011) for goats in the tropical region. They showed that the goats were subjected to low ambient temperature during the early morning hours of the day and high ambient temperature during the afternoon hours of the day. At 7:00 h to 10:00 h, the goats were observed to shiver. To result shivering is an important mechanism of thermogenesis in animals. This physical thermogenesis is responsible for increasing the body temperature of the animals subjected to low ambient temperature, aimed at maintaining homeothermy (thermal equilibrium). The finding of the present study is similar to the result obtained by Minka & Ayo (2016), who demonstrated that the cold-dry (harmattan) season, prevailing in the Northern Guinea Savannah zone of Nigeria were thermally stressful and that measures aimed at alleviating the thermal stress may enhance performance of animals during the season. Based on THI, the result of the present study further demonstrates that the season was predominantly stressful for the goats. The normal thermoneutral zone in goats is 12^{o} C-24 (Yadav *et al*., 2024). According to Silanikove (2000), values of THI of 75-78 are stressful, while those above 78 induce extreme distress in animals and impair thermoregulatory mechanisms. The THI obtained starting from 12:00 h up to 19:00 h showed that the animals were subjected to heat stress. Therefore, measures aimed at enhancing thermoregulatory mechanisms during the afternoon hours of the day may alleviate the risk of adverse effects of heat stress in goats during the cold-dry season. The result of RH obtained during the study period showed that the cold-dry season was characterised by very low RH, especially during the afternoon hours of the day (Relatively high values of RH were recorded during morning hours of the day and evening at 18:00 h). The RH values were relatively high during the morning and evening hours, but low during the afternoon hours of the day. This result is in agreement with the established findings by Minka & Ayo (2016) and Ayo *et al.* (2007) that RH is low during the harmattan season in the Northern Guinea Savannah zone of Nigeria and that the season is characterized by dry and dust-laden wind. This makes the season impose a high thermal load on the goats.

The result of the present study on RT fluctuations demonstrated that the variation in body temperature was predominantly due to diurnal variations rather than individual fluctuations. The result shows that values of thermal micro-environmental parameters fluctuated with hours of the day, and that they exerted considerable influence on the RT of the Red Sokoto goats during the cold-dry season. Thus, the goats had lower RT values during morning hours of the day, from 7:00 h to 8:00 h. At 14:00 h to 16:00 h in the control animals, the peak values were recorded with an average of about 39.8 °C. This finding further confirms the result obtained by Minka & Ayo (2016) and Habibu *et al*. (2022) that the cold-dry season is thermally stressful to goats.

Furthermore, the higher values of RT, ranging from 39.8°C to 40°C, were recorded in experimental goats from 12:00 h to 17:00 h. The fact that higher extreme maximum value of RT was recorded at 16:00 h in the experimental goats demonstrated the tendency of lycopene to induce an increase in heat production in goats, subjected to the concomitant effect of cold stress in the morning, and heat stress in the afternoon hours of the day. This finding has suggested that lycopene was involved in thermoregulation in the goats during the cold-dry season by potentiating thermogenesis. This, apparently, resulted in increased body temperature in experimental goats compared to their control counterparts. The result of the study is in agreement with the finding of Ayo *et al.* (2007), who demonstrated that vitamin C as an antioxidant induce a dual response in goats, depending on the ambient temperature. When the ambient temperature is low, antioxidants enhance heat production in the body, resulting in the elevation of body temperature but maintained within the normal physiological range; while in high ambient temperature conditions, vitamin C lowers the body temperature, but still maintains homeothermy. Therefore, the increase in body temperature recorded in the present study agrees with the previous findings and shows that the values obtained are within the normal physiological range of 38.5°C to 40°C, established for goats (Ayo *et al*., 1999) effect of lycopene on the RT fluctuations demonstrated that the antioxidant exerted a thermogenic effect. The effect as evidenced by an increase in RT values of the goats; starting from 12:00 h with a peak value of 40.15 ± 0.10°C, recorded at 16:00 h. However, in control goats, a lower value of RT was obtained with a peak value of 39.86 ± 0.14 °C. In experimental goats, relatively high RT was sustained up to about 40°C at 17:00 h, and the overall RT value of the experimental goats was 39.48 ± 0.15 °C. This value was significantly higher than that of 39.08 ± 0.26 °C recorded in control goats. It appears, therefore, that lycopene possesses the ability to raise the body temperature in goats subjected to low ambient temperature compared to the control goats. The antioxidant may, therefore, enhance metabolic processes in the body during the cold-dry season and, consequently, be beneficial in goat production. This finding agrees with the result obtained by Kumar *et al*. (2012) that lycopene enhances metabolic rate. Further studies are required to investigate the optimum dose of lycopene in goats, especially its pharmacokinetics.

The relationships between the thermal micro-environment and RT parameters show that the relationships were predominantly stronger in control than experimental goats. The finding demonstrates that lycopene reduced the impact of fluctuations of thermal micro-environmental parameters on the body temperature responses of goats administered with lycopene. The result is in agreement with the findings of Ayo *et al*. (2011) and Minka & Ayo (2014), who reported that antioxidants ameliorated risk of adverse effects of thermal micro-environmental parameters during the hot-dry season. The results of the study indicate that lycopene, due to its antioxidant properties (Long *et al*., 2024), was effective in mitigating the negative effects of thermal stress on goats during the cold-dry season in the Northern Guinea Savannah zone of Nigeria. However, further research is needed to clarify the mechanisms underlying the modulatory role of lycopene on body temperature regulation in goats.

In conclusion, the afternoon hours of the day, starting from 12:00 -16:00 h, were thermally stressful to Red Sokoto goats during the cold-dry season. Lycopene increased the RT values of Red Sokoto goats, especially at 16:00-18:00 h, during the cold-dry season. The relationships between thermal micro-environmental and rectal temperature parameters were predominantly strong in both experimental and control goats.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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