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# EFFECT OF TIME OF FEEDING ON BODY TEMPERATURE OF WAD BUCKS AND PREGNANT DOES IN TROPICAL ENVIRONMENT

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## ABSTRACT

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### Keywords

Body temperature  
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Tropics.

This study aims to assess the impact of time of feeding on the body temperature of West African dwarf (WAD) goats. Twenty-seven goats (15 buck and 12 pregnant does) were used in this experiment. The bucks and gravid does were fed same experimental diet once daily at either, 06:00h, 12:00h or 18:00h in the morning, afternoon or evening, respectively. Rectal temperature ( $P < 0.001$ ) of bucks fed at 18:00h was higher than 12:00h fed bucks which was higher than 06:00h fed bucks. In contrast, pregnant does fed in the evening had lowest ( $P = 0.009$ ) axillary and rectal temperature while afternoon-fed does had the highest. Time of feeding induced increase ( $P < 0.001$ ) in axillary and rectal temperature of the bucks and pregnant does. The excursion ranges of temperature of morning, afternoon and evening-fed bucks was 0.42-0.79, 1.11-1.25, 1.15-1.19°C, respectively, while the excursion range of temperature of morning, afternoon and evening fed bucks was 0.17-0.19, 0.55-0.72, 0.45-0.47°C respectively. This study shows that time of feeding can entrain body temperature and animal physiological state can affect the temperature rhythm of animals. In conclusion, feeding bucks or pregnant does in the morning or evening may be an effective strategy to manage heat stress in the tropics. Feeding livestock in the afternoon should be avoided. Feeding in the evening may be adopted in the future due to the changing climate that will be accomplished by increased ambient temperature.

**Contribution/Originality:** This study is one of the very few studies that has investigated the impact of time of feeding on the body temperature of livestock specie fed once daily. Feeding in the evening is a good management strategy to reduce body temperature in bucks and pregnant does.

## 1. INTRODUCTION

Many factors influence the body temperature including food availability and ambient temperature [1, 2]. Naturally, in diurnal animals, body temperature rises from dawn to dusk which coincide with the increase in ambient temperature. Yet, time of feeding has been shown to affect the rhythmicity of expression of body temperature in mammals [3-5]. The rhythm of core body temperature was entrained by feeding time where temperature was phase shifted and amplitude decreased by night feeding in the summer, indicating alteration of the central clock [6]. Similarly, Salfer and Harvatine [5] reported that night feeding also phase delayed the rhythm of core body temperature, while day-restricted feeding increased its amplitude. The above scenario suggest that time of feeding can be used to manage the time of body temperature peaks.

The climate is continually changing and there is little to nothing farmers can do to put a stop to it. This climate change will induce increases in ambient temperature and humidity, which may result in increased heat-stress in the tropics. Already, climatic conditions are one of the main factors limiting the development of animal production in tropical regions [7] with an ambient temperature as high as (22-32 °C or higher) [8]. This increase in global temperatures is an unsettling factor in livestock production, and elevations of 3-5°C are expected during this century [9]. Feeding cattle at night in hot weather reduced metabolic heat load during daytime when ambient temperature is high while more heat production will be shift to night when the ambient temperature is low [10]. Since farmers cannot stop the climate change-induced increases in temperature, it is plausible to find adaptive techniques to manage it. This study is meant to investigate the impact of time of feeding livestock on the body temperature because it can advance our knowledge of how diet influences thermogenesis in ruminant. Furthermore, it also aims to examine the best time to feed animals in order to reduce the coincidence of high temperature and metabolic heat.

## 2. MATERIAL AND METHODS

### 2.1. Experimental procedure

The experiment was carried out at the Goat unit, Teaching and Research farm of the Federal University of Technology, Akure. Twenty-seven goats were used in this study. Experiment 1 consist of fifteen bucks randomly distributed into three treatments of five replicates while in experiment 2, twelve pregnant does were randomly distributed into three treatments of four replicates. The experiment on bucks and pregnant does were carried out concurrently. The buck and gravid does were fed guinea grass (*Panicum maximum*) and concentrate Table 1 at ratio 50:50 dry matter and fed once daily at 06:00h, 12:00h and 18:00h in the morning, afternoon, and evening, respectively. Fresh water was offered *ad libitum*.

Table-1. Gross composition (g/100g) of the concentrate diet.

Ingredient	Diet
Cassava peel	40.00
Palm kernel cake	26.00
Wheat offals	14.00
Brewer dried grains	15.00
Bone meal	2.0
Urea	1.0
Premix	1.0
Salt	1.00
Total	100
Calculated crude protein (%)	10.73
Calculated crude fibre (%)	9.82

### 2.2. Body Temperature Measurement

The axillary and rectal temperature of the bucks and pregnant does was carried out for 8 weeks between March and May 2020. The pregnant does were in mid-gestation stage. The temperature reading for all morning, afternoon and evening-fed goats were carried out three time daily between 06:00-07:00h, 12:00-13:00h and 18:00-19:00h and three times in a week. The readings were taken using a clinical digital thermometer (SKU:WA904SE1ICXF2NAFAMZ and Bio-check). For the rectum, the thermometer was inserted 2cm deep into the rectum and the reading were taken once the thermometer beeps. The skin temperature was taken through the axillary point. The ambient temperature and relative humidity records were taken between 06:00-06:15h, 12:00-12:15h, and 18:00-18:15h, respectively, using a digital hygro-thermometer (Thermopro TP50). The average of the recordings taken three times a week were used as weekly value. The temperature humidity index (THI) was calculated from the recorded daily relative humidity and ambient temperature according to Marai, et al. [11];

$$THI = db^{\circ}C - \{(0.31 - 0.31 RH) (db^{\circ}C - 14.4)\}$$

Where:

THI = Temperature – humidity index

db°C = Dry bulb temperature °C

RH = Relative humidity (RH %)/100

THI was rated as follows:

ahs = absence of heat stress (values < 22.2).

mhs = moderate heat stress (values between 22.2 to < 23.3).

shs = severe heat stress (values between 23.3 to < 25.6).

ehs = extreme heat stress (values from 25.6 and more).

### 2.3. Statistical Analysis

A factorial design with the following model:  $Y_{ijk} = \mu + a_i + b_k + ab_{ik} + e_{ijk}$  was used. Where  $Y_{ij}$ = any of the response variables;  $\mu$  = the overall mean;  $a_i$ = effect of the  $i$ th time of feeding,  $b_k$ = effect of time of measurement,  $ab_{ik}$ = interaction of time of feeding and time of measurement and  $e_{ij}$ = random error due to experimentation. All data collected were subjected to analysis of variance (ANOVA) using SPSS version 23.0 [12]. The differences between treatment means were examined by Duncan multiple range test of the same package.

## 3. RESULTS

### 3.1. Overall Axillary and Rectal Temperature of Bucks

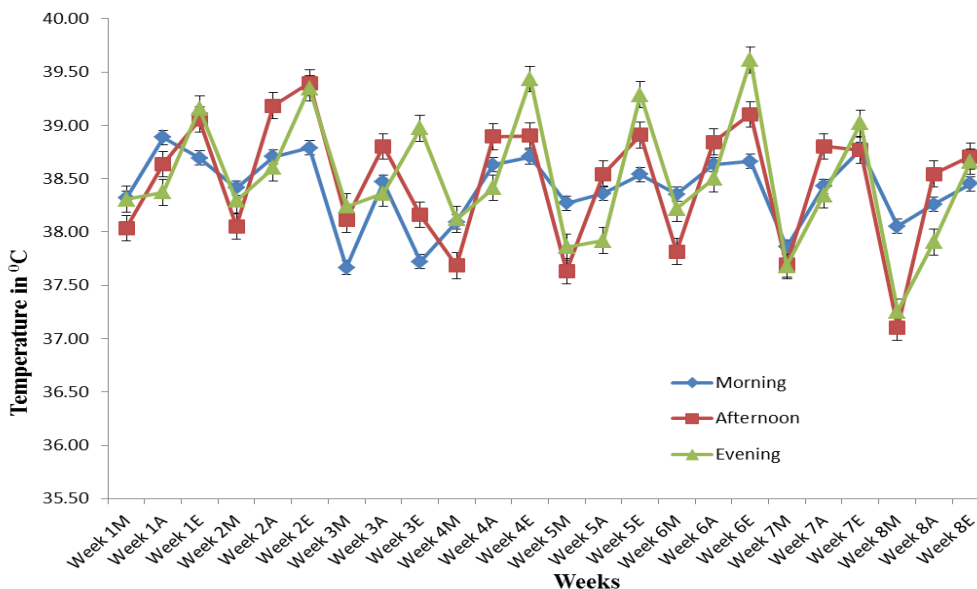
Trends of overall axillary and rectal temperature of bucks animal fed under different feeding regime and at different time are shown in Figure 1, Figure 2. Time of feeding had no impact ( $P>0.05$ ) on the axillary temperature of bucks fed in the morning, afternoon or evening Table 2. Rectal temperature of bucks fed in the evening was higher ( $P<0.001$ ) than those fed afternoon, while morning-fed bucks had the lowest rectal temperature. Regardless of feeding time, axillary and rectal temperature ( $P<0.001$ ) increased from dawn to dusk. Time of feeding and time of measurement interaction, showed that irrespective of feeding time, buck axillary and rectal temperature increased ( $P<0.001$ ) from dawn to dusk. Furthermore, for axillary temperature, at 06:00h, the temperature of bucks fed in the morning was similar to bucks fed in the evening but higher ( $P<0.001$ ) than those fed in the afternoon. At 12:00h, axillary temperature of bucks fed in the afternoon was higher ( $P<0.001$ ) than bucks fed in the morning while the evening-fed bucks had the lowest axillary temperature.

**Table-2.** Body Temperature (°C) of WAD bucks under different feeding regimes.

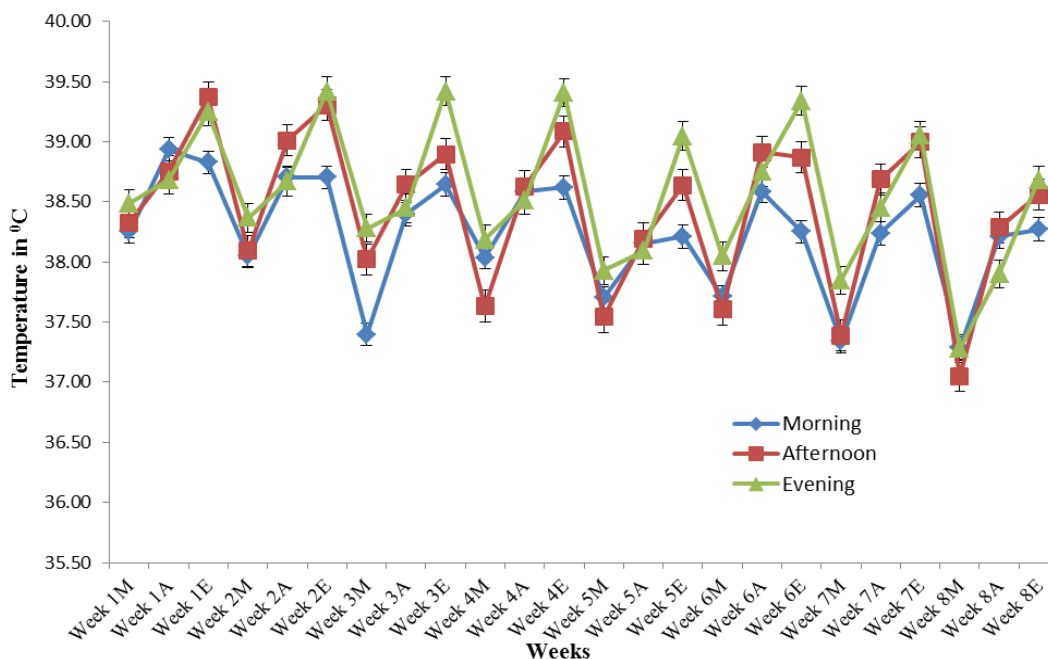
ToF	Axillary	Rectal	ToM	Axillary	Rectal	THI	AT (°C)	RH (%)
Morning	38.41	38.24 <sup>c</sup>	6:00	37.96 <sup>c</sup>	38.05 <sup>c</sup>	24.72 <sup>c</sup>	24.99 <sup>c</sup>	91.63 <sup>a</sup>
Afternoon	38.47	38.44 <sup>b</sup>	12:00	38.54 <sup>b</sup>	38.44 <sup>b</sup>	30.02 <sup>a</sup>	31.93 <sup>a</sup>	65.83 <sup>b</sup>
Evening	38.50	38.56 <sup>a</sup>	18:00	38.87 <sup>a</sup>	39.20 <sup>a</sup>	28.88 <sup>b</sup>	30.60 <sup>b</sup>	66.25 <sup>b</sup>
SEM	0.040	0.041	SEM	0.040	0.041	0.319	0.415	1.649
P-Value	0.243	<0.001	P-Value	<0.001	<0.001	<0.001	<0.001	<0.001
ToF x ToM		6:00	12:00	18:00	SEM	P-value	Excursion	
Axillary	Morning	38.13 <sup>aB</sup>	38.55 <sup>bA</sup>	38.54 <sup>cA</sup>	0.047	<0.001	0.42	
	Afternoon	37.77 <sup>bB</sup>	38.78 <sup>aA</sup>	38.88 <sup>bA</sup>	0.079		1.11	
	Evening	38.00 <sup>aC</sup>	38.30 <sup>cB</sup>	39.19 <sup>aA</sup>	0.076		1.19	
Rectal	Morning	37.72 <sup>bB</sup>	38.48 <sup>bA</sup>	38.51 <sup>cA</sup>	0.062	<0.001	0.79	
	Afternoon	37.71 <sup>bC</sup>	38.64 <sup>aB</sup>	38.96 <sup>bA</sup>	0.078		1.25	
	Evening	38.05 <sup>aC</sup>	38.44 <sup>bB</sup>	39.20 <sup>aA</sup>	0.070		1.15	

Note: abc= Means within the same column but with different superscripts are statistically ( $P<0.05$ ) significant. ABC= Means along the same row but with different superscripts are statistically ( $P<0.05$ ) significant; ToF: Time of feeding; ToM: Time of temperature measurement; THI: Temperature humidity Index; AT: Ambient Temperature; RH: Relative humidity.

At 18:00h, evening-fed bucks ( $P<0.001$ ) had the highest body temperature, followed by afternoon-fed bucks while morning-fed bucks had the lowest. At 06:00h, rectal temperature of evening-fed bucks was higher than morning and afternoon-fed bucks which were similar. At 12:00h, rectal temperature of evening-fed bucks was the higher than morning and evening-fed bucks which were similar. Furthermore, rectal temperature ( $P<0.001$ ) in evening-fed bucks at 18:00h was higher than afternoon-fed bucks while the rectal temperature of morning-fed bucks was the lowest. Ambient temperature and THI at 12:00h, was higher ( $P<0.001$ ) than 18:00 and 06:00h, while RH was higher at 06:00h than at 12:00h and 18:00h Table 2.



**Figure-1.** Overall axillary temperature for bucks under different feeding regimes. The M depicts 06:00h measuring time, the A depicts 12:00h measuring time while the E represents 18:00h measuring time. This shows the rhythm of axillary temperature at each measuring time for the three times measurement per week. It shows that the time bucks were fed actually entrained the pattern of distribution of their temperature. The axillary temperature of morning fed bucks was controlled in a tight excursion range resulting in less fluctuation compared to other feeding time.



**Figure-2.** Overall rectal temperature for bucks under different feeding regimes. The M depicts 06:00h measuring time, the A depicts 12:00h measuring time while the E represents 18:00h measuring time. This shows the rhythm of rectal temperature at each measuring time for the three times measurement per week. It shows that the time bucks were fed actually entrained the pattern of distribution of their temperature.

3.2. Overall Axillary and Rectal Temperature of Gravid WAD Does

Figure 3, Figure 4 shows the overall axillary and rectal temperature of pregnant does fed at different times of the day. Axillary and rectal temperature of gravid does fed in the morning and afternoon were similar but higher ( $P=0.009$ ) than does fed in evening Table 3. Axillary ( $P<0.001$ ) and rectal ( $P<0.002$ ) temperature at each time of measurement simultaneously increased from dawn to dusk Table 3. Interaction between the period of feeding and Time of measurement of axillary and rectal temperature of gravid does in all feeding regimes increased from dawn to dusk. At 06:00h, axillary temperature ( $P<0.001$ ) in morning-fed does was higher than evening-fed does while axillary temperature in afternoon-fed does was the lowest. At 12:00h, axillary temperature ( $P<0.001$ ) of afternoon-fed gravid does was higher than temperature of morning-fed does while evening-fed does have the lowest temperature. Axillary temperature of afternoon and evening-fed gravid does were similar but higher than in morning-fed does at 18:00h. Rectal temperature ( $P<0.001$ ) of morning-fed does increased compared to afternoon and evening-fed does at 06:00h. At 12:00h, rectal temperature ( $P<0.001$ ) of does fed in the afternoon increased compared to morning and evening-fed does which were similar. At 18:00h, rectal temperature ( $P<0.001$ ) of afternoon-fed does was higher than morning-fed does while the temperature of evening-fed does was.

Table-3. Body Temperature of gravid WAD under different feeding regimes.

ToF	Axillary	Rectal	ToM	Axillary	Rectal	THI	AT (°C)	RH (%)
Morning	38.51 <sup>ab</sup>	38.80 <sup>a</sup>	6:00	38.26 <sup>c</sup>	38.57 <sup>c</sup>	24.72 <sup>c</sup>	24.99 <sup>c</sup>	91.63 <sup>a</sup>
Afternoon	38.56 <sup>a</sup>	38.82 <sup>a</sup>	12:00	38.56 <sup>b</sup>	38.81 <sup>b</sup>	30.02 <sup>a</sup>	31.93 <sup>a</sup>	65.83 <sup>b</sup>
Evening	38.45 <sup>b</sup>	38.60 <sup>b</sup>	18:00	38.72 <sup>a</sup>	38.96 <sup>a</sup>	28.88 <sup>b</sup>	30.60 <sup>b</sup>	66.25 <sup>b</sup>
SEM	0.023	0.018	SEM	0.023	0.018	0.319	0.415	1.649
P-Value	0.009	0.009	P-Value	<0.001	<0.002	<0.001	<0.001	<0.001
ToF x ToM		6:00	12:00	18:00	SEM	P-value	Excursion	
Axillary	Morning	38.41 <sup>ab</sup>	38.54 <sup>bA</sup>	38.60 <sup>bA</sup>	0.026	<0.001	0.19	
	Afternoon	38.08 <sup>cB</sup>	38.81 <sup>aA</sup>	38.80 <sup>aA</sup>	0.022		0.72	
	Evening	38.28 <sup>bB</sup>	38.33 <sup>cB</sup>	38.75 <sup>aA</sup>	0.049		0.47	
Rectal	Morning	38.74 <sup>ab</sup>	38.75 <sup>bB</sup>	38.91 <sup>bA</sup>	0.038	<0.001	0.17	
	Afternoon	38.46 <sup>bB</sup>	38.99 <sup>aA</sup>	39.01 <sup>aA</sup>	0.038		0.55	
	Evening	38.52 <sup>bC</sup>	38.70 <sup>bB</sup>	38.97 <sup>abA</sup>	0.030		0.45	

Note: abc= Means within the same column but with different superscripts are statistically ( $P<0.05$ ) significant. ABC= Means along the same row but with different superscripts are statistically ( $P<0.05$ ) significant; ToF: Time of feeding; ToM: Time of temperature measurement; THI: Temperature humidity Index; AT: Ambient Temperature; RH: Relative humidity.

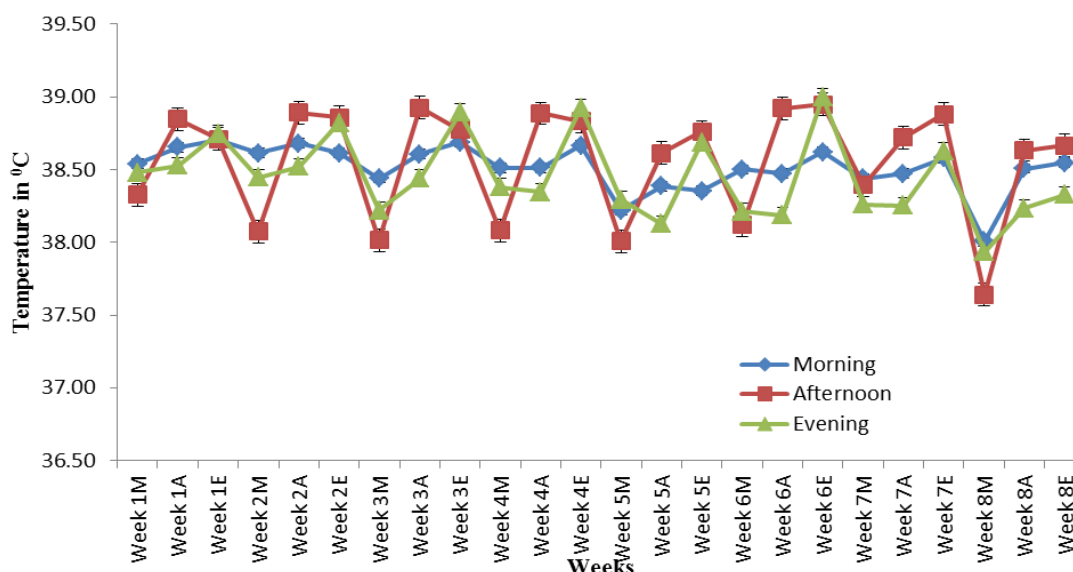
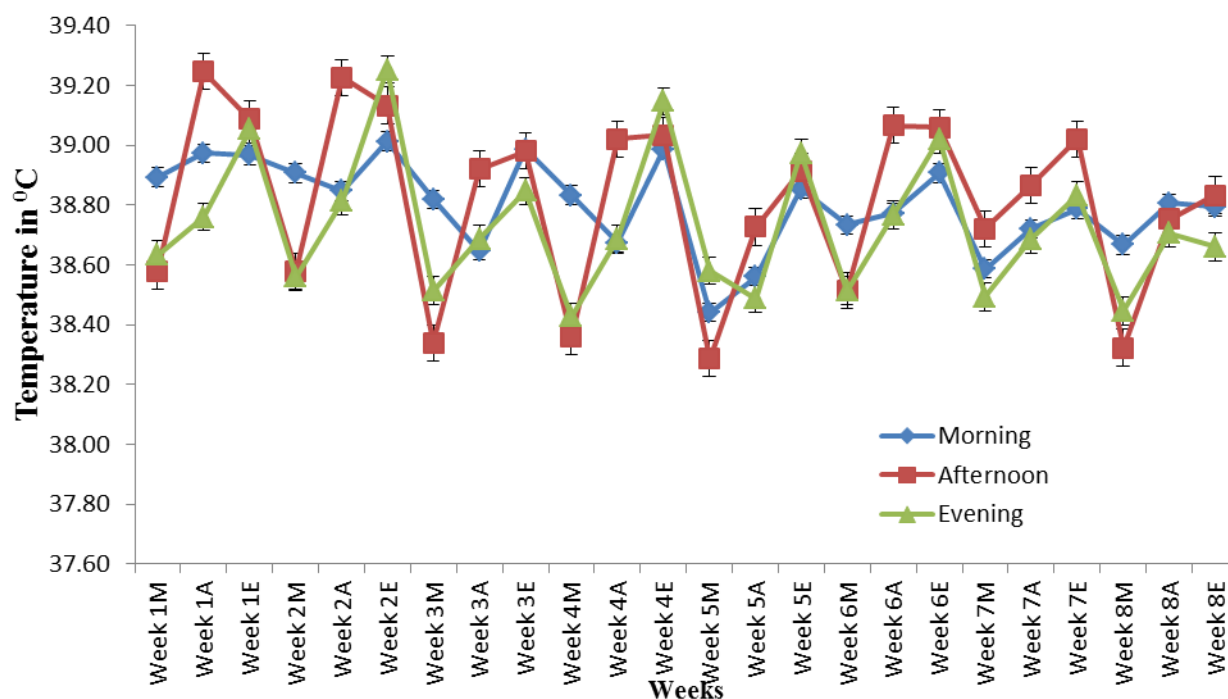


Figure-3. Overall axillary temperature for gravid WAD does under different feeding regimes. The M depicts 06:00h measuring time, the A depicts 12:00h measuring time while the E represents 18:00h measuring time. This showed the rhythm of axillary temperature at each measuring time for the three times measurement per week. It shows that the time does were fed actually entrained the pattern of distribution of their temperature. In the morning-fed does, the temperature rhythms were fairly consistent throughout the day for each week. In evening and afternoon-fed does, the temperature rhythms greatly fluctuate.



**Figure-4.** Overall rectal temperature for gravid WAD does under different feeding regimes. The M depicts 06:00h measuring time, the A depicts 12:00h measuring time while the E represents 18:00h measuring time. This showed the rhythm of axillary temperature at each measuring time for the three times measurement per week. It showed that the time pregnant does were fed actually entrained the pattern of distribution of their temperature. In the morning-fed does, the temperature rhythms were fairly consistent throughout the day for each week. In evening and afternoon-fed does, the temperature rhythms greatly fluctuate.

## 4. DISCUSSION

### 4.1. Axillary and Rectal Temperature of WAD Bucks

The physiological state of domestic livestock is key to their productivity [13]. West African dwarf does are adapted to the tropical humid condition, but could be stressed by the high ambient temperature [14]. Heat stress as a prevailing challenge in the tropics compromises livestock welfare. Consumption of nutrient at inappropriate time has the potential to cause misalignment of thermoregulatory mechanism in the body [5]. Diet-induced thermogenesis is associated with food ingestion which causes acute rise in body temperature in various species due to increase energy expenditures [4]. Food anticipatory behavior is often accompanied by increases in body temperature [15]. The increase in temperature in evening-fed bucks may be due to the additive effects of rhythmically increasing body temperature, increased activity due to food anticipation behavior and diet-induced metabolic heat. In morning-fed bucks, the lower rectal temperature despite metabolic heat may be due to lower morning ambient temperature. Body temperature is usually low in the morning and high in the evening [16]. Thus, lower rectal temperature in afternoon-fed bucks compared to evening-fed bucks might be because the core body temperature had not peaked at the time of feeding. The rise in both axillary and rectal temperature from dawn to dusk in bucks fed at the different times of the day shows that body temperature exists in circadian rhythm with lower temperature in the morning and high temperature in the evening. This is because body temperature rises with increasing environmental temperature [17]. Interaction of time of feeding and time of measurement showed that feeding time induced body temperature changes. This agrees with Salfer and Harvatine [5] who reported that body temperature can be entrained by feeding time, resulting in a shift in the rhythm of core body temperature. The high rectal temperature in evening-fed bucks and its similarity with axillary temperature in morning-fed buck at 06:00h suggests that the rate of elimination of metabolic heat overnight was slower due to high relative humidity. High relative humidity reduces the rate of dissipation of body heat due to decline in efficiency of evaporative cooling [18]. Feeding cattle at night in hot weather reduced metabolic heat during daytime when ambient temperature is high, while more heat production will be shifted to night when the ambient temperature is low [10]. Temperature

range in this study for axillary and rectal temperature was 37.77-39.19°C and 37.71-39.20°C, respectively. This is lower than the skin and rectal temperatures range reported as 37.52-39.76°C and 38.13-40.88°C, respectively [19]. This excursive range in this study falls between 0.4-1.90°C reported by Ayo, et al. [20]; Piccione, et al. [21]. The AT in this study was similar to 25.50-37.75°C reported by Minka and Ayo [22]; Aro, et al. [23]. The THI in this study shows that the bucks were heat stressed. The range observed in morning-fed bucks was tightly regulated by the SCN, whereas the feeding of other bucks at “wrong time” of the day disrupted the temperature rhythm, causing fluctuations in the body temperature Figure 1, Figure 2. This depicts that feeding time can entrain body temperature rhythms. Thus, to manage heat stress in bucks fed once a day, feeding in the morning or evening could be the best strategy.

#### 4.2. Axillary and Rectal Temperature of Gravid Does

Average axillary and rectal temperature of gravid does fed in the evening was lower than WAD does fed in the morning and afternoon. This may be due to increased ability of evening-fed does to transfer heat load from the visceral part to the skin surface area resulting in increased level of heat dissipation. This result is similar to Niu and Harvatiné [6] that reported decreased temperature in evening-fed cattle which is an indication of alteration in central clock. The result of this study agrees with the report that the thermal effect from food during the morning was higher than in the evening [3]. Increasing temperature from dawn to dusk throughout the measuring time shows that body temperature exists in a rhythm which occur repeatedly. Interaction of time of feeding and time of measurement showed that axillary and rectal temperature progressively increases in all feeding regimes. Meal timing is an important factor affecting the thermal effect of foods [4]. The increased axillary and rectal temperature at 06:00h and 12:00h in gravid does fed at this time compared to 18:00h is an indication of diet-induced thermogenesis. This increase is a result of the feed consumed, increasing ambient temperature and increased food anticipatory activity around the usual time of feeding. Feeding in the morning increased the heat load during the late morning to early afternoon while feeding in the afternoon increased heat load in the cooler hours of the day when heat losses from the animal through conduction and radiation were more efficient [24]. At 18:00h, similarity between the axillary and rectal temperature of afternoon and evening-fed pregnant does indicate that the heat load in afternoon-fed does was not quickly dissipated. The axillary and rectal temperature range was 38.08-38.80°C and 38.46-39.01°C respectively with an excursion range of 0.17-0.72 °C. The morning-fed does had a tight excursion in axillary and rectal temperature compared other feeding time. This indicate the regulatory mechanism of morning-fed does has not be disrupted compared to pregnant does in other feeding regimes which fluctuated greatly Figure 3, Figure 4. The temperature in this study is in the range reported for skin temperature and rectal temperature as 37.52-39.76°C and 38.13-40.88°C respectively [19]. The excursion range in our study is lower than 0.4-1.90°C reported in Ayo, et al. [20]; Piccione, et al. [21]. This may be due to the different physiological state of the goats used. The goats in our study were pregnant. Circulating hormone during pregnancy can influence the body temperature of animals causing 0.5-1°C reduction in maternal temperature during pregnancy [25, 26]. However, the rectal temperature in our study is similar to 38.80-39.28°C reported by Shittu, et al. [8] for WAD does from the third to fifth month of pregnancy. In contrast, it is lower than the 40.84-41.22°C reported for rectal temperature in WAD does at 3-5 months of gestation [27]. Thus, feeding does in the evening can be a feeding strategy to manage heat stress in pregnant goat.

## 5. CONCLUSION

The time of feeding of a goat can affect the daily average axillary and rectal body temperature range of the goat. Feeding bucks or pregnant goat does once daily in the afternoon or evening, causes change in the rhythm of body temperature compared to those fed in the morning. Farmers should avoid feeding their goats in the afternoon period. This study shows that feeding goat early in the morning or late in the evening is a good adaptive strategy to

manage heat stress in bucks. Feeding in the evening is a good adaptive strategy to manage heat stress in pregnant does.

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**Competing Interests:** The authors declare that they have no competing interests.

**Acknowledgement:** All authors contributed equally to the conception and design of the study.

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