PHYSIOLOGIC RESPONSES OF SAVANNA BROWN GOATS AND YANKASA SHEEP TO HARMATTAN AND HOT-DRY SEASONS

By

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DECLARATION

This is to certify that I carried out the study reported in this thesis in the Department of Veterinary Physiology and Pharmacology, Ahmadu Bello University, Zaria, under the supervision of Dr. E. C. I. Molokwu, Dr. Y. O. Aliu and Professor A. Singh.

The work of other investigators is acknowledged and referenced. No part of this thesis has been submitted elsehwere for a degree or diploma.

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THESIS APPROVAL

This thesis, by Moses Omachi Igono, meets the regulations governing the degree, Master of Science of Ahmadu Bello University and is approved for its contribution to scientific knowledge and literary presentation.

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This thesis is dedicated to my personal friend, Prince Michael, who through thick and thin has been my guardian.

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INTRODUCTION

Goats and sheep are highly prolific multipurpose small ruminants producing meat, milk, fibre, skin and to a less extent manure. In a survey by the Federal Office of Statistics (1972) the average number of goats and sheep per household in Nigeria was reported to be 2.98 and 1.0 respectively. About 50.2% of rural households were involved in goat rearing while 25.4% reared sheep. Thus, goats and sheep may be considered the most important domestic animals to man in Nigeria as they are found in almost every village, satisfying diverse societal needs.

There is a dearth of reliable population data on any animal species in Nigeria. However, the population of goats and sheep have been estimated at 24.0 and 11.7 million respectively (FAO, 1981). The goat contributes about 30% of Nigeria's total meat supply while the sheep contributes 11%. About 60 per cent of the nation's goats and sheep are herded in the savanna zone where 98% of the 60 million hectares of natural grazing land lies (Ademosun, 1973; Adu *et al.*, 1979; Adu and Ngere, 1979).

There are two breeds of goat in Nigeria: the West African dwarf goat, found mainly in the forest zone and the West African long-legged goat predominantly found in the savanna zone (Mason, 1969). Varieties of the long-legged breed include Borno white, Kano brown,

Damagaram dapple-grey, Katsina light-brown and Sokoto red. The Savanna brown goats are Sokoto red x Kano brown crosses indigenous to the Guinea savanna zone (Molokwu and Igono, 1978). Mason (1969) described three breeds of sheep in West Africa: the West African dwarf sheep, the West African long-legged sheep and the Macina. The first two are found in Nigeria. The West African dwarf sheep also known as Nigerian dwarf sheep is found south of latitude 14^{o}N while Balami, Yankasa and Uda which are varieties of the West African long-legged sheep occur in the savanna zones.

A paradox in the efforts being made in Nigeria to improve animal production and productivity has been the apparent neglect of the influence of climate; rather, emphasis has been on the herd population and treatment of diseases when the need arises.

But, an animal's physiologic responses are programmed to meet the biotic and physical variables of the environment. For example, under heat stress, the major physiologic responses are directed towards reducing heat gain processes and intensification of heat loss mechanisms but during cold stress emphasis is on heat gain and conservation.

Animals communicate with their physical environment through the neuroendocrine and nervous systems. Long-term adaptive responses are mediated via the endocrine glands. Adrenal corticoids and thyroid hormones (thyroxine, T4 and triiodothyronine, T3) play significant roles in physiological responses and metabolic alterations induced by environmental stresses. For instance, the important role of thyroid function in physiological adaptations is related to

the fact that thyroid hormones are potent metabolic mediators (Yousef, 1979). In this way, thyroid hormones influence the thermal balance of an animal.

The wide distribution of goats and sheep in Nigeria's diverse ecophysiological zones has been taken as evidence of their adaptibility to their various habitats. However, the influence of the different tropical climates on adrenal gland and thyroid gland activities has not been studied in the Savanna brown goat and Yankasa sheep.

The objectives of this study are:

1. to measure the plasma levels of cortisol, triiodothyronine (T3) and thyroxine (T4) of Savanna brown goats and Yankasa sheep during the harmattan and hot-dry season;

2. to study the effects of the two seasons on body temperature and heat tolerance;

3. to compare the adaptive responses of body temperature, heat tolerance, adrenal cortisol and thyroid gland hormones to harmattan and hot-dry seasons in the goat and the sheep; and

4. to measure and compare the onset and duration of estrus, and the length of estrous cycle during the two seasons.

Chapter 1

REVIEW OF THE LITERATURE

Physical Environmental Profile

The well-being and productivity of animals are affected by and related to their physical environment. For animal production to make meaningful contribution to human food needs, it requires a thorough understanding of how the various elements of climate influence animal function. One of the ways of obtaining such knowledge is to assess the components of the animal's environment (Yeck, 1971). The establishment of an environmental profile and the selection of the most efficient genotype under such a profile could result in about 30% increase in production when combined with improved management and husbandry practices (McDowell, 1972; Hodgson, 1973; Johnson, 1976).

Recognition of the impact of meteorologic factors in animal production in Nigeria led to the development of the "Fulani Pastoral Calender" by nomadic herders (van Raay and de Leeuw, 1974). *Seeto* (April - June) is the stormy period with occasional rains that preceeds the rainy season proper. *Dungu* (June - September), the rainy season is characterized by lush pasture. A three-week period of excessive rains in the middle of the rainy season is denoted as *Yuka*, during which herdsmen and their cattle are constantly moving in search of relatively dry grazing grounds. The hot ecoperiod (September - December) following the rains and during which pasture is in good condition is referred to as *Yamde*. *Nyaile* begins in November when

grazing shifts from savanna grass lands to crop residue browsing following harvest. *Dabunde* (December - February) is the harmattan ecoperiod dominated by the cold, dry, dust-ladden northeast wind. The very hot ecoperiod immediately following the harmattan is denoted as *Cheedu* (February - April). The "Fulani Pastoral Calender" demonstrates in simple but practical terms how a good understanding of climatic factors such as temperature, rainfall, and vegetation can be used to formulate suitable animal husbandry practices. Unfortunately, these ecoperiods have quantitative limitations and cannot be used to assess environmental influences on animal production.

Quantitative scientific data of climate are needed for proper evaluation of environmental effects on animal production because any recommendations to modify management, and introduce systems to minimize adverse environmental influences or constraints to production require the availability of these data (Johnson and Vanjonack, 1976). Information on the average expected climatic conditions, their variations and extremes are valuable in determining the general feasibility of livestock production and improvement programs, the probable needs for shelter, and the best animal management practices to adopt (McDowell, 1972; Johnson, 1976).

Igono and Aliu (1982) described three distinct seasons for the Nigerian guinea savanna zone, viz; hot-dry, hot-humid, and harmattan. The hot-dry season lasts March to April. Afternoon temperature during this season is in the range of 33 to 39^{0}C; it is also characterised by low relative humidity (21 to 33%) and high evaporation rate (226 to 262 mm). The hot-humid season which lasts

from May to October, is traditionally the rainy season: it has high temperature maxima of 29 to 33°C, high relative humidity (57 to 69%) and low evaporation rate (144 to 164 mm). The harmattan season, November to February, is dust-laden, rain-free, and has high temperature maxima (29 to 35°C) but low temperature minima (9 to 16°C). The relative humidity is very low (14 to 20%) and evaporation rate moderate (182 - 205 mm).

Domestic animals tend to maintain a near-constant internal environment while performing productive functions of economic importance to man (Scott, 1981). Ambient temperature ranging between 4 and 24°C are ideal for these functions (McDowell, 1966). However, disruptive external environmental influences, such as those described for the Nigerian guinea savanna zone above, challenge this constancy of internal environment. Animals, react to and compensate for changes in the external environment employing various homeokinetic mechanisms necessary for survival.

Endocrine Aspects of Thermoregulation

Changes in meteorological factors either stimulate or depress compensatory mechanisms in an animal's energy, thermal, hormonal, water and mineral balance. Nevertheless, the body strives to maintain a near-constant internal environment. Thus, animals are continuously making compensatory physical and physiological changes to ensure optimal function. The meteorologic complex may act directly via cutaneous receptors and central nervous system to elicit neuroendocrine responses mediated by the hypothalamus and the pituitary gland. Also,

environmentally-induced changes in body temperature and consequently temperature of the blood perfusing the hypothalamic region may elicit similar neuroendocrine responses. The hypothalamus controls the secretory activity of the pituitary gland through "releasing" or :inhibitory" hormones.

The pituitary or hypophysis occupies a central position among endocrine glands. It secretes at least nine distinct hormones and thereby virtually influences most biologic functions in higher mammals. "Trophic" pituitary hormones control the functioning of their particular "target" glands. These include adrenocorticotrophic hormone (ACTH) for the adrenal gland; thyroid stimulating hormone (TSH) for the thyroid gland; follicle-stimulating hormone (FSH) and luteinizing hormone (LH) or interstitial cell-stimulating hormone (ICSH) for the gonads. The other pituitary hormones include the growth hormone (GH), prolactin, melanocyte-stimulating hormone (MSH), antidiuretic hormone (ADH) and oxytocin (Goodman, 1974; Johnson, 1976).

Adaptation to environmental extremes reduces the stress of the environment on the organism. Functional adjustments to maintain thermal balance in climatic extremes may involve the immediate reflex responses of the nervous system or the slow but long-lasting endocrine modifications. Hormones do not act independently; they act through modification of genetic and cellular metabolic processes. Hormones may alter the amount, quality, and rate of cellular functions and thus they provide the background upon which nervous and metabolic adjustments take place. Consequently, they are part of the ecophysiological patterns that fit animals to their niches (MacFarlane, 1963; MacFarlane and Good, 1974).

Thermal information for the brain regulatory system may arise from the abdominal cavity and the spinal cord; these inputs reinforce the information coming from the skin to the brain for thermal control (Rawson, 1976). Temperature sensitive nerve cells have been identified in the spinal cord, the anterior hypothalamus and to a less extent, in the reticular formation (Nakayama *et al.*, 1963). In the preoptic area of the brain, the rate of firing changes with temperatures; some cells fire more rapidly when it is cold than when it is hot. Activity of the cold-sensitive neurones produces shivering and vasoconstriction while that of the heat-sensitive nerve cells causes vasodilation and sweating (MacFarlane, 1978).

The hypothalamus controls pituitary activity by neuro-hormones called "releasing" or "inhibiting" factors or hormones. In the pituitary-hypothalamic complex, thermal and chemical receptors in the preoptic anterior hypothalamus (POAH) influence the secretion from the pituitary of TSH, ACTH and GH. These secretory actions are mediated by hypothalamic releasing hormones; for thyrotropin, thyrotropin-releasing hormone (TRH); corticotropin, corticotropin-releasing hormone (CRH); and growth hormone, growth hormone-releasing hormone (GHRH).

Various factors modulate the hypothalamic control of the pituitary via different mechanisms. The secretory activity of the pituitary may alter the secretion rates of hypothalamic releasing hormones through the feedback pathway. Another factor that influences

the release of the hypothalamic neurohormone is the modifying effect of hormonal feedback from target glands or tissues. The level of utilization of these hormones as determined by the rate of growth and productive performance may play a role in the level of neuroendocrine activity (Johnson, 1976).

Thyroid Stimulating Hormone

The release of thyroid hormones is controlled by the anterior pituitary "thyroid stimulating hormone" (TSH). The mechanism of action of TSH is fairly clear. TSH is initially bound to specific TSH receptor sites on the surface of throid glands cells (Pastan *et al.*, 1963). It then activates the enzyme, adenyl cyclase and the concentration of cyclic 3' 5' adenyl monophosphate (cAMP) in thyroid cells is increased (Sutherland and Robinson, 1966). The increase cAMP may then mediate a variety of morphologic and metabolic effects in the thyroid such as increased colloid resorption, release of thyroid hormones, glucose oxidation and phosphorylation of lipids. There is an accompanied increase of calcium ions to enable cAMP produce its effects. Cyclic AMP enhances the synthesis and iodination of thyroglobulin as well as the release of thyroid hormone (Field, 1970; Mason and Wilkinson, 1973).

Insufficient data are presently available to indicate whether TSH increases or decreases on acute exposure to heat. Sanchez and Evans (1972) reported variable plasma TSH values in rams exposed to 20°C for 45 days and 32°C for 100 days; but Johnson (1972) found TSH turnover rates to be significantly higher at 18°C as compared to at 35°C.

Thyroid Hormones

The thyroid gland, through its hormones, affects the intergrity and function of every major system in a homeotherm. It is involved in basal metabolism, temperature regulation, reproduction, lactation, growth and mineral metabolism. Thyroid homones together with the nervous system maintain an effective communication and intergration between the internal and external environments. Thus, studies regarding the effects of environmental factors on thyroid gland activity have been numerous (Kamal *et al.*, 1962; MacFarlane, 1963; Collins and Weiner, 1968; Yousef and Johnson, 1971; Etta, 1971).

Various parameters have been used in an attempt to establish reliable indices of thyroid function in man and domestic animals. Anatomical approaches have included the histological examination of thyroid epithelial cell heights, morphologic changes in acini colloid and cytologic studies. Chemical analysis of the iodine content of thyroid glands, protein bound iodine (PBI), effective throxine ratio (ETR) and butanol extractable iodine (BEI) have all been employed. Tracer techniques using radioiodine have been used in measures of thyroid iodine uptake, thyroid secretion rate (TSR), thyroid degration rate (TDR), thyroid distribution space (TDS), and thyroid utilization rate. Indirect evidence of thyroid activity have also been obtained through measurements of basal metabolic rate and serum cholesterol (MarFarlane, 1963; Heroux, 1967; Collins and Weiner, 1968; Yousef and Johnson, 1971; MacFarlane *et al.*, 1974; Webster, 1976).

MacFarlane *et al.*, (1974) working with the goat and using

various indices of thyroid function reported the following values: PBI, 4.7µgI/100ml; plasma thyroxine, 7.2µg/100ml.; TSR 8.3µg/kg./24h. or 19.9µg.kg$^{0.75}$/24h. Comparative values for the sheep are PBI, 3.9µg/100ml.; plasma throxine, 6.1µg/100ml.; and TSR, 6.9µg/kg/24h. or µg/kg.$^{0.75}$/24h. In another report, MacFarlane and Good (1974) summarized the ranges of plasma thyroxine and TSR for caprine as 8.7-11.8µg/dl and 3.506.0µg/kg/24h. or 11-20µg/kg.$^{0.75}$/24h; comparative values for the ovidae are: plasma thyroxine, 6.5-8.0µg/dl, and TSR, 3.5-5.5µg/kg./24h. or 9-16µg/kg.$^{0.75}$/24h. Table 1 summarizes the seasonal variations in thyroid function using various indices abstracted from literature.

It has long been an article of faith that adaptation to cold involves the increase in the secretion rates of thyroid hormones. This assumption follows the observations in man and rats, that cold and hyperthyroidism have similar effects on metabolic rate (Heroux, 1967; Webster, 1976). However, field studies with domesticated animals show no specific relationship between metabolic rate and plasma levels of thyroxine. Although there are reports of seasonal fluctuations in the rates of thyroxine secretion, the rise observed during the cold season may be due to other factors because the effects of thyroxine are slow in onset and decay; therefore, it is unlikely that the effects of thyroid hormones will be rapid enough to make a significant contribution to a precise control system (Webster, 1974; MacFarlane, 1976).

Although evidences to the effect on heat on thyroid acti-

TABLE 1

Seasonal Variations In Thyroid Activity Of Goat And Sheep

Condition	Index	Value	Source
Goat:			
Winter	^{131}I Uptake	0.62mg/100kg/day	Flamboe and Reineke, 1957
	^{131}I Uptake per cent	16.0	Flamboe and Reineke, 1959
	Biologic half-life	7.25	
	TSR	0.187mg/45kg/day	
Summer	^{131}I Uptake	0.15mg/100kg/24h.	Flamboe and Reineke, 1957
	^{131}I Uptake per cent	34	Flamboe and Reineke, 1959
	Biologic half-life	12.55	
	TSR	0.09mg/45kg/day	
Sheep:			
Winter	TSR	0.24mg/24h.	Henneman *et al.*, 1959
Summer	TSR	0.04mg/24h.	
Winter	Plasma T_4	7.0 ± 1.1µg/100ml	Sutherland and Irvine, 1974
Summer	Plasma T_4	5.6 ± 1.2µg/100ml	
Moderate	Cold	7µg/l	Webster, 1976.
		4.5µg/kg/24h.	

vity are conflicting, most investigators using a variety of indices of thyroid function are agreed that in various laboratory and domestic animals thyroid activity is depressed and therefore the release of thyroid on exposure to heat (Kamal *et al.*, 1962; Yousef and Johnson, 1971). Dempsey and Astwood (1943) found that at 10^{o}C, the thyroid gland of rats produces 9.5µg/day; at 25^{o}C, 5.2µg.; and at 35^{o}C, 1.7µg of thyroxine. The Missouri group (Johnson and Ragsdale, 1960a and 1960b) using heifers reared at either 10^{o}C or 20^{o}C, reported a gradual and progressive decrease of thyroid ^{131}I release rate when kept at 27^{o}C for 15 days, 32^{o}C for 11 days, and 35^{o}C for 5 days as compared to the rates at 21, 10, and 3^{o}C. Brooks *et al.*, (1962) reported an inverse relationship between environmental temperature and the rate of l-thyroxine secretion of rams over the range of ambient temperatures from 8^{o} to 31^{o}C. While some workers have presented evidence that TSR decreases significantly in goats and sheep exposed to high ambient temperatures, others have presented contrary evidence (Henneman *et al.*, 1955; Flamboe and Reineke, 1957 and 1959; Hoersch *et al.*, 1961; Brooks *et al.*, 1962; Sanchez and Evans, 1972; Sutherland and Irvine, 1974; MacFarlane and Good, 1974).

MacFarlane and Good (1974) in a study with sheep on a fixed ration at 4^{o}C and at 30^{o}C found the same rate of thyroxine turnover. They also reported that TSR increased at the rate of 1mg/kg/24h for each extra kg of feed above the fixed ration. Thus, MacFarlane (1978) concluded that thyroid secretion is regulated by the amount of food consumed and this is more pronounced in cold than hot

environments.

Yousef (1979) reported that T4 and T3 secretion rates decreased after 3 days exposure to 40°C in llama (*Lama glama* and donkey (*Equus asinus*) on the same diet but exposure to 8°C had no discernable effects on T4 but increased T3 in both species. Earlier, Scott *et al.*, (1976) established significant correlations between metabolic rate and thyroid hormones. Since the donkey has a higher metabolic rate than the llama and El-Nouty *et al.*, (1978) showed that the difference in metabolic rate of these families may not be related to thyroxine secretion rates, the thyroid hormone-metabolic rate paradox shown by these two families may not have any relationship to feed intake as suggested by MacFarlane and Good (1974).

However, in hot conditions, the reduction in thyroid activity may play a role in maintaining thermal balance via the slowing in metabolism and thus heat output. Rubner (1902) and Plaut and Wilbrand (1922) referred to this depression of metabolism as "second chemical thermoregulation." The reduced glandular activity may be concerned with homeothermy and this may be reflected in growth and productive performance (Collins and Weiner, 1968).

Various explanations have been advanced for the reduction in thyroid activity during heat exposure. Mansfeld (1943) and Mansfeld (1946) in an attempt to explain the relationship between the depression of metabolism and reduced thyroid gland activity claimed that the thyroid gland secretes a special metabolic inhibitory substance, so-called "Thermothyrin A." Collins and

Weiner (1968) argued that this cannot be the case because no worker has been able to confirm the existence of the heat-reducing principle in serum. Another probable mechanism is that since thyroxine is not used rapidly in heat, a feedback inhibition of thyrotropin production may occur. This assumption is supported by the slow ^{131}I turnover in heated animals (MacFarlane, 1963).

Brown-Grant (1956a and 1956b) found that adrenal steroids, particularly cortisone, corticosterone, and cortisol, reduced ^{131}I turnover of the thyroid. Cortisol has been shown to either increase renal inactivation of thyrotropin or interfere with the action of thyrotropin in the thyroid gland (Ackerman *et al.*, 1961). The relation between the adrenal cortex and the thyroid gland is complex but the inhibition of thyroid activity by adrenal steroids has been shown to exist.

Thyroid hormones and catecholomines are of major importance in cold stimulated nonshivering thermogenesis and a synergism has been found to exist between these hormones such that the calorigenic action of the catecholamines is potentiated by thyroxine (Carlson, 1960). This was further substantiated by the work of Anderson *et al.*, (1967) who reported that markedly hypothyroid goats maintain thermal homeostasis in cold by compensatory increase in adrenalin secretion.

Adrenocorticotropic Hormone

One of the most common responses of an animal to stressor activation involves the hypothalamic-pituitary-adrenal axis. Adrenocorticotropic hormone (ACTH) is secreted by the anterior pituitary as the mediating substance. Corticotrophs of the pituitary gland which synthesize and secrete ACTH are located mostly in the *pars distalis* but some have been identified in the *pars intermedia* (Sayers and Portanova, 1975).

Adeno-hypophysial corticotrophs require regular stimulation by corticotropin releasing hormone (CRH), a peptide elaborated by the medial eminence of the hypothalamus. However, the hypothalamus may not be the only source of CRH. In the dog, monkey and rats, other body tissues such as the liver and kidney, have been shown to produce CRH; this has been dubbed "tissue-CRG" (Egdahl, 1960; Wise *et al.*, 1963; Witrorsch and Brodish, 1972). Also, vasopressin induces ACTH secretion but the physiologic mechanisms of vasopressin regulation of ACTH remains unclear (Sayers and Portanova, 1975).

ACTH is a peptide (molecular weight, 4,500) containing 39-amino acids. The initial 24-amino acid fragment, $ACTH_{1-24}$, is as potent as the parent 39-amino acid molecule; the C-terminal sequence, starting with amino acid 25, may be considered carrier amino acids (Sayers and Portanova, 1975).

The physiologic function of ACTH is the stimulation and secretion of adrenal cortical hormones. The action of ACTH on the adrenal cortex is initiated by the stereospecific binding of ACTH to specific protein receptors on the adrenal gland cell membrane.

This results in the activation of adenylate cyclase and subsequent generation of cellular cAMP (Tauton *et al.*, 1969). Thus, cAMP, acts as the second messenger within the adrenal cortex and mediates the effect of ACTH on steroidogenesis (Haynes and Berthert, 1957). The adrenal cortex, secretes corticoids in response to circulating levels of ACTH; this in turn may be inhibited by increasing levels of circulating corticoids. In addition to these feedback mechanisms, neural responses to environmental stimuli, originating either externally or internally, indirectly affect ACTH secretion rates via neuro-endocrine pathways that may involve the hypothalamus (Willett and Erb, 1972).

Marple *et al.*, (1972) studied the effects of humidity and temperature on porcine plasma ACTH. They found that when both temperature and humidity were low, ACTH level was not affected but when humidity alone was increased and temperature remained low (4.4°C), plasma ACTH increased significantly. Also, at 32.2°C, and low humidity, plasma ACTH rose significantly higher than control; however, increasing the humidity at 32.2°C caused a slight decrease in plasma ACTH.

Cortisol

Extreme environmental conditions impose considerable stress on an animal's endocrine systems. The adrenal cortex secretes hormones that are essential to life and play an important role in adaptive responses to widely differing environmental conditions (Yousef *et al.*, 1971). Cortisol, is an important hormone from the adrenal cortex of most mammals. It affects a wide range of activities

in the body including the metabolism of carbohydrates, proteins and fats, and inflammatory processes (McDonald, 1975).

Environmental stress, directly or indirectly stimulates neurones of the hypothalamus to release CRH; the RH influences the pituitary to release ACTH and ACTH stimulates the adrenal cortex to secrete corticosteroids. The stimulation of the pituitary-adrenal axis to cold has received more attention than that of high temperatures (Collins and Weiner, 1968).

In the attempt to assess the physiological response occasioned by environmental stimuli, various parameters of adrenocortical activities have been used. However, none of these indices takes into account all the relevant thermal parameters. Indirect methods for measuring adrenocortical activity include the observation of increase polymorphs, leukopenia, lymphopenia and esinophilia. Also, measurements of adrenal gland constituents, such as cholesterol ascorbic acid have been used as indices especially in acute stress exposure. During chronic stress, the enlargement of the adrenal gland resulting from contiuous hyperactivity is a more germane method (Collins and Weiner, 1968). Urinary steriod excretion, circulating levels of glucocorticoids, incorportion of ^{32}P, hydrocortisone secretion rate (HSR), hydrocortisone distribution space (HDS) and the half-life of labelled isotopes have all been used to assess adrenal activity under various environmental conditions (Robinson *et al.*, 1955; Yousef *et al.*, 1971; Christison and Johnson, 1972).

Inspite of the differences in methods, it appears that

both acute and chronic exposure of man to heat reduces the excretion of 17-Ketosteroids (17-KS). Ketogenic steroid excretion in man is lowered at temperatures above 30°C; also there is a seasonal change in excretion of these steroids (MacFarlane, 1963). Robinson *et al.*, (1955) observed that injection of 30 IU corticotropin daily raised urinary 17-KS to 22mg/day and 50 IU to 32mg/day. They concluded that in the sheep, 17-KS represents cortisol. Cortisol, is the main metablic steroid produced by the sheep. Robinson and Morris (1960) followed the 17-KS excretion throughout the year by the Romney Marsh sheep; the highest excretion rate of 20mg/day was recorded in late winter and the lowest value (2.5mg/day) was observed in mid summer. These observations led to the conclusion that environmental conditions during winter causes a vigorous mobilization of cortisol.

The secretion rate of cortisol is markedly increased during exposure to either acute cold in the laboratory or to the fluctuating and unpredictable stress of the winter (Panaretto and Vickery, 1970; Yousef *et al.*, 1971; Abilay *et al.*, 1975). Webster (1976) reported plasma cortisol level of 31µg/100ml and a corresponding secretion rate of 1500µg/kg/day during winter compared to 9µg/100ml and a secretion rate of 326µg/kg/24h in a thermoneutral environment. Linder (1959) reported normal values of cortisol in peripheral plasma as 0.6µg/100ml for sheep and 0.8-1.9µg/100ml for the goat.

Plasma adrenal corticoids of swine (Maple *et al.*, 1972) significantly increased in response to low temperature (4.4°C) and low humidity (2.9mm/Hg) as compared to the control environment

(21.1°C, 11.4mm. Hg); at 4.4°C plasma corticoids fell significantly. At high temperature and low humidity (32.2°C, 10.5mm. Hg) plasma corticoids was lower when compared to control conditions. However, elevation of humidity (10.5 to 31.8mm.Hg) while at 32.2°C resulted only in a slight increase in corticoids.

Studies in rats, sheep and cattle suggest that adrenal glucocorticoid activity is reduced during heat acclimation. Acute exposure (4h) of cattle to high temperature (42°C) increased glucocorticoids of plasma (Christison and Johnson, 1972) but prolonged exposure (24 days) to high environmental temperature resulted in lower plasma glucocorticoids.

Effect of Physical Environment on Homeothermy

Ambient temperature, humidity, windspeed and solar radiation are meteorologic factors which may interfer with a homeotherm's total body heat either by interfering with heat dissipation or by imposing an external heat load (Bianca, 1976). Environmental heat may be considered a systemic stressor that evokes a series of generalized functional changes in the homeotherm (Kamal and Johnson, 1971).

Among the various body functions, maintenance of normal body temperature may be the best single expression of a homeotherm's thermal balance. Maintenance of normal body temperature represents the resultant of all the processes of heat gain and heat loss by the body. Body temperature which can easily and accurately be measured through the rectum, remains relatively stable under average heat stress (Bligh, 1957; Bianca, 1961). Rectal temperature is a function

of adaptation of the thermoregulatory system to environmental heat factors and the ability of the system to respond to the thermal environment (Eyal, 1963).

Many studies on the tolerance of various farm animals to environmental heat have been based on a comparison of rectal temperatures. It is assumed that body temperature as a measure of heat tolerance does not vary much, but any deviation from normal indicated that the animal cannot maintain homeokinesis despite maximal physiological effects to do so (Eyal, 1963; Bligh, 1976).

A change in deep body temperature is used as an index of meteorological stress, while the absence of any change is used as an index of tolerance. In this way, it is possible to compare the abilities of different species, breeds, or individuals to remain in a state of homeokinesis at varying degrees of meteorological stress (Bligh, 1970).

Heat adaptation is a complex character that depends on the integrity of various systems such as the respiratory, circulatory, excretory, nervous, endocrine and enzymatic (Kamal, 1976). While some homeotherms maintain a near-constant body temperature by effecting a balance between heat production and heat loss, others respond by allowing deep body temperature to move passively towards the ambient temperature without immediate activation of thermoregulatory mechanisms i.e. body temperature lability. Heat intolerant animals, on exposure to heat stress, increase body temperature in the direction of ambient temperature despite maximal use of thermoregulatory mechanisms (Bligh, 1970; Johnson, 1971).

Numerous physiological indices of heat tolerance based on rectal temperature have been defined: these include the Iberia Heat Tolerance Test (Rhoad, 1944); R-value heat tolerance test (Lee and Phillips, 1948); Benezra's index of adaptability (Benezra, 1954); the tripzoidal mean rectal temperature (McDowell *et al.*, 1955); lines of equal effect (Barrada, 1957); final rectal temperature (Bianca, 1963); and the rate of rectal temperature rise (Brown *et al.*, 1969).

A thermally stressful environment activates an animal's hemokinetic mechanisms. In the process, extra energy which is not available for productive process is expended. Thus, the more an animal combats meteorological stress, the less is its capacity for producing meat and milk (Bianca, 1976). A major ill-effect of heat stress on a homeotherm is a displacement of its body temperature from the normal range (Bianca, 1963). Hyperthermic animals lose their appetite; the resulting decrease in caloric intake reduces the animal's heat burden via a lowered heat production, but the animal's productivity will be adversely affected (Eyal, 1963; Bianca, 1976; Bligh, 1976).

Bligh *et al.*, (1965) reported the highest body temperature in the Welsh Mountain sheep to be 39.8^{o}C and the lowest 37.9^{o}C. The mean nychthermeral variation in body temperature was 0.95^{o}C with no discernible seasonal change. According to Grell (1977), the average body temperature of domestic sheep is 39^{o}C ± 1.5^{o}C with a range of 37.5 - 40.5^{o}C as reported by Terrill (1968).

Acute heat stress in Merino sheep characterized by rapid respiration begins at a rectal temperature of about 39.5°C; open mouth panting begins at 41°C, while gasping and staggering sets in at 43°C (Lee, 1950). *Muscular weakness incordination, tremors and* convulsion may occur at rectal temperatures above 42°C; this usually terminates in death.

As with other physiologic parameters in the goat, there are very few measurements on rectal temperature in the goat; the usual conclusion is that these parameters are similar to that of the sheep! Rectal temperature in goats is in the range of 38.3 - 40.7°C (Attah, 1977; Williamson and Payne, 1978).

Effects of Seasons on the Length of Estrous Cycle and the Duration of Estrus

Estrus involves the hormonal and cytological events as well as the behavioral manifestations of mammals occuring at the stage in the reproductive cycle during which the female accepts the male (Jarosz *et al.*, 1971). The primary sexual behaviour of the ewe is seeking out the ram; the subsequent interactions lead to copulation (Pelletier *et al.*, 1977).

Banks (1964) described the sequence of secondary behavioural interactions during estrus. The ram approaches the ewe and "noses" her anorectal or perineal region. This is followed by "nudging" when the ram turns his head to the side of the ewe thus bringing the ram's shoulder in contact with the ewe's flank. In the process, the ram once in awhile strikes out, at the ewe's flank, with the front leg next to the ewe and utters a series of low vocalizations assisted by rapid tongue movements.

The behaviour of the ram initiates urination in the ewe which immediately assumes a micturation stance with or without successful urination. The ram then "sniffs" the urine and displays the "flehmen reaction" which is characterized by an extension of the neck with a raising up of the head; the external nares are drawn back in a flared position and the upper lips are curled back (Pelletier *et al.*, 1977). A successful teasing leads to mounting and ultimate servicing of the ewe by the ram. The behavioural feedback of an estrus ewe is varied (Banks, 1964). Sometimes, she may nudge the ram's head or genitalia in addition to tail wagging and turning the head backwards to look at the ram. However, the characteristic pattern of receptivity is the ewe "standing still" when teased by the ram (Pelletier, 1977).

In does, signs of estrus are similar to those described for the ewe. However, Ott and Memon (1980) suggested that in the doe, the most dependable sign of estrus is the doe's response to the buck; a doe in heat will actively seek out the buck and will stand to be mounted by the buck.

The period between one heat period and the next successive heat is considered an estrous cycle; this has been found by various workers to be appreciably constant in various breeds of animals. (McKenzie and Terrill, 1937; Hafez, 1952; Anderson, 1964). The length of estrous cycle in ewes ranges from 14 to 19 days (Terrill, 1974) while in the does it ranges 18 to 21 days (Devendra, 1978). Table 2 summarizes the cycle length of various breeds of goats and sheep.

TABLE 2

Length of Estrous Cycle of Various Breeds of Goats and Sheep

Goat Breed	Length of Estrous Cycle (Days)	Reference	Sheep Breed	Length of Estrous Cycle (Days)	Reference
Milch goat	21	Hofmeyer, 1969	Blackface Merino	13-23	
			Blackface Leicester	15-24	
Granada	20.68 ± 1.9	Carrera Butterworths, 1968	Dorset Horn	6-23	Hafez, 1952
			Romney Marsh	13-21	
West African	20.4	Kirkpatrick and Akindele, 1974	Suffolk	7-23	
			Welsh Mountain	12-20	
Angora	19.4 ± 0.5	Asdell, 1964	Awassi	15 1/2-20	Schindler and Amir, 1972
Toggenburg	19.82	Jarosz, 1971	Uda	17.77 ± 0.28	Gaillard, 1979
African Pygmy	5-27	Parer, 1963	Yankasa	17-20	Kuteyi *et al.*, 1978
	24	Jarosz, 1971		16-28	
Sicilian goat	8	Corteel, 1977	West African Dwarf	15-22	Ngere *et al.*, 1979
				3-40	Akpokodje & Fayemi, 1975
				9-26	Orji & Steinbach, 1975

Estrous cycles have been classified by Hafez (1952) as "single," 26 or less days and "multiple," more than 26 days. Single cycles were further subdivided into three subgroups, viz: "short cycle," less than 14 days; "normal cycle," 14 to 19 days; and "long cycle," 19 to 26 days. A multiple cycle is made up of a number of normal cycles; thus multiple cycles are considered to contain one or more silent heats. Subdivisions of the multiple cycles include: "double cycle," 27 to 37 days with one silent heats; "quadrauple cycle," 58 to 75 days with four silent heats. Silent heat is used in this context to mean ovulation without manifestation of behavioural estrus.

Seasonality of estrous activity have been reported in various domestic animals. Exteroceptive factors including ecological, bio-climatological, and social factors influence seasonality in mammalian reproduction (Hafez, 1952). Breeding seasons, during which female animals mate have been defined for sheep, goats, and horses (Thibault and Levasseur, 1974) especially in temperate climates.

Climatic factors may interact in a manner that influences the physiological functions of an animal. Estrus manifestation is associated with the ovarian cycle (Hulet *et al.*, 1975). Under conditions of severe thermal stress, ceasure of ovarian functions may occur so that the female will not exhibit estrus and consequently will not mate. Ulberg (1967) explained that environmental factors influence an animal's hormone system, which, in turn, brings about changes in physiological function.

Chang and Fernandez-Cano (1959) subjected Sprague-Dawley female rats to 39.5^{o}C for five hours on two successive days; during the process rectal temperature rose by 3^{o}C. Successful mating of these

rats was observed after 14 days compared with 4-7 days, i.e. one estrous cycle, in controls. They concluded that during acclimatization to heat, it is probable that anoestrus conditions occur in rats.

Zakari *et al.*, (1981) noted a gradual lengthening of estrous cycle from the harmattan to the hot-dry season in Bunaji and Bokoloji cows in the Nigerian guineas savanna zone. The hot-dry season had the longest cycle length, 27.3 ± 2.14 days compared to 21.3 ± 1.03 in the hot-wet season. They also found that among the anoestrus cows during the unfavourable season, 55% of them had static ovaries while the remaining 45% had functional ovaries.

Onset and cessation of the ovarian cycle may be influenced by daylength and ambient temperature (Hafez, 1952; Dutt and Bush, 1955; Hulet *et al.*, 1975). Seasonality in estrous activity of various breeds of goats and sheep have been reported (McKenzie and Terrill, 1937; Phillips *et al.*, 1943; Hafez, 1952; Dutt and Bush, 1955; Carrera and Butterworths, 1968; Shelton and Spiller, 1977; Ott and Memon, 1980).

Goats and sheep are seasonally polyestrous in the temperate zones i.e. they exhibit a number of behavioural estrus during the breeding season which in the northern hemisphere extends from September to January. Because this period is characterised by short day lengths, these two species have been referred to as "short-day" breeders (Ott and Memon, 1980).

The seasonal restriction to mating in goats and sheep may be considered a limitation in the sense it does not allow for all-year production in these species. However, the seasonal

breeding characteristics of goats and sheep may very well be a strategy that ensures that the offspring are born when feed resources and environmental factors are more suitable for survival (Ott and Memon, 1980).

The duration estrous is affected by the same factors that influence length of estrous cycle. The duration of estrus in the ewe is about 30 hours while it ranges from 32 to 42 hours in the doe (Robertson, 1977). Table 3 summarizes the duration of estrus in various breeds of goats and sheep.

TABLE 3

Duration of Estrus in Various Breeds of Goats and Sheep

Breed of Goat	Duration of Estrus (H)	Reference	Breed of Sheep	Duration of Estrus (H)	Reference
Milch goat	up to 36	Hofmeyer, 1969	Blackface Merino	6-37	
Granada	34.3 ± 8.1	Carrera and Butterworths, 1968	Blackface Leicester	24-35	
Angora	39.2 ± 1.9	Asdell, 1964	Dorset Horn	32-56	Hafez, 1952
			Romney Marsh	32-43	
Toggenburg	48	Jarosz, *et al.*, 1971	Welsh Mountain	33-52	
West African Dwarf	24-40	Kirpatrick and Akindele, 1974	Awassi	16-84	Schindler and Amir, 1972
			Uda	38-48	Gaillard, 1978
				12-15	Kuteyi *et al.*, 1978
			Yankasa	13-17	Kuteyi *et al.*, 1978
			West African Dwarf	28-38	Ngere *et al.*, 1979
				8-96	Akopkodje and Fayemi, 1975
				47.52 ± 2.88	Orji and Steinbach, 1975

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Chapter II

PLASMA CONCENTRATIONS OF CORTISOL, TRIIODOTHYRONINE, AND THYROXINE OF SAVANNA BROWN GOATS AND YANKASA SHEEP DURING HARMATTAN AND HOT-DRY SEASONS

Introduction

Radioimmunoassay of hormones is providing an invaluable contribution to the understanding of physiologic mechanisms of animals adaptation to various environments (Johnson, 1972). Hormones provide slow but persistent relaxation of stress as they modulate tissue and cellular adjustments under continued exposure to stress. Hormones affect heat production in an animal through their influence on metabolism and enzyme induction (Johnson, 1967). Thyroid hormones, for instance, are potent metabolic mediators (Yousef, 1979) and a significant positive correlation has been established between metabolic rate and thyroid levels for a large number of species (Yousef and Johnson, 1975; Scott, *et al.*, 1976).

The ideal ambient temperature range for most domestic animals falls between 4 and 24^{o}C (McDowell, 1966; Johnson, 1967). However, ambient temperatures in the Nigerian guinea savanna zone during the day exceed this temperature range (Igono and Aliu, 1982). Thus, physiologic responses of animals within this climatic zone will be significantly modified by the high ambient temperatures. In addition, the routine goat and sheep husbandry practices in this zone lack provisions to accommodate the adverse effects of climate. The combined effects of climate and husbandry procedures may cause circulating levels of hormones to fluctuate between seasons. Since adaptation to the

physical environment depends on a complex endocrine interplay and adrenal cortical and thyroid hormones play key roles in mammalian adaptive functions (MacFarlane, 1971; Yousef, 1976), the present study was designed to evaluate adrenal and thyroid gland comepensations in Savanna brown goat and Yankasa sheep during the harmattan and hot-dry seasons.

Materials and Methods

Experimental Animals

Thirteen of each clinically healthy adult Savanna brown does and Yankasa ewes weighing 12.9 ± 0.28 and 20.43 ± 0.59 kg respectively at the start of the experiment were used. The animals were grazed during the day and housed in two pens in a shed with concrete floor in Veterinary Medicine farm after grazing and at night; the goats and sheep were separated during grazing and housing. A feed supplement of wheat bran mixed with either corn or cotton seed and dry gamba (*Panricum maximum*) hay was provided after grazing; clean drinking water was available *ad libitum*.

A period of two weeks was allowed for preconditioning. During this period, the animals were each exposed to the experimental procedures every other day. Following this and during the early harmattan, samples were collected at weekly intervals; thereafter, samples were collected every other day each third week. On sampling days, blood was collected between 05:30 and 06:00h. Ten ml of blood was obtained by jugular venipuncture from each animal using a 19-gauge needle. Each sample was immediately transferred into a 15-ml. test tube containing one drop of heparin as anticoagulant. The

samples were kept in an ice box until centrifuged. Each animal was weighed after each sampling and the weight recorded.

The samples were centrifuged at 2000g for 20 minutes. The plasma from each sample was harvested into two sample bottle and kept frozen at -20^{o}C until analysed. Meteorologic data over the seasons available at the Meteorology Unit, Institute of Agricultural Research (IAR), about two kilometers northwest of the experimental site were obtained while ambient temperatures at 06:00 and 14:00 hours were recorded.

Hormone Assay Procedures

Triiodothyronine (T3) Each plasma from both goats and sheep were analysed for T3 using Amerlex T3 radioimmunoassay (RIA) kits (Amersham International Ltd., Buckinghamshire, England). Procedural details for the preparation of standard and assay protocol are presented in Appendix I

The precipitate was counted in a gamma scintillation counter (Auto Gamma 4000, Beckman Instruments., Fullerton, California, U. S. A.). The counts per minute (cpm) of both standards and unknown were corrected by subtracting blank counts; subsequent calculations used the corrected cpm. Percentage binding of labelled thyroxine was calculated according to the equation:

$$\frac{B}{B_o} \times 100$$

where B_o = mean corrected cpm for zero standard; and

and B = mean corrected cpm for different standards.

The slope of the regression line for the standard curve was calculated using the linear regression equation:

$$b = \frac{(x_i - \bar{x})(y_i - \bar{y})}{(x_i - \bar{x})^2}$$

where b = slope of the standard curve:

x_i = concentration of T3 (ng/ml) in differnt standards;

$\bar{x}$ = mean T3 (ng/ml) concentration of all standards;

y_i = per cent binding for different standards; and

$\bar{y}$ = mean per cent binding for all standards.

In order to calculate the concentration of T3 in plasma, the following linear regression equation was used:

$$x_i = \frac{y_i - \bar{y} + b\bar{x}}{b}$$

where x_i = ng/ml of T3 in unknown;

y_i = per cent binding of the unknown;

$\bar{y}$ = per cent binding for all standards;

b = slope of standard curve; and

$\bar{x}$ = ng/ml of T3 of all standards.

Throxine (T4) Plasma sample were assayed for T4 using Amerlex T4 RIA kits (Amersham International Ltd., Buckinghamshire, England). The assay procedure outlined in Appendix I is similar to that of T3 except samples for T4 analysis were incubated at room temperature for at least 45 minutes followed by centrifugation at 25°C. All calculations were done as described for T3.

Cortisol Amerlex cortisol RIA kits (Amersham International Ltd., Buckinghamshire, England) were used to assay plasma cortisol according to the method outlined in Appendix I. The cpm of each standard was plotted against the concetration of a semi-log graph and fitted to the best curve. The amount of cortisol in each unknown sample was determined from the plot.

Statistical Analyses

Data were analysed using a factorial analysis of variance. The main effects and interactions were compared using the Type IV mean square as an error term. The protected least square difference and Duncan's New Multiple Range Test (Duncan, 1955) were used to compare treatment means (Snedecor and Cochran, 1980). Significance level was set at 5%. The data and statistical design are logged in Appendix 1.

Results

Three months after the study began, one of the 13 goats died of heartwater while a second sustained fracture and was removed from the study group. Only the data for the remianing eleven goats were used for anlaysis. A rather high mortality due to heartwater was encountered with the sheep such that after the first 3 months of study, only six ewes survived but another four died during the last week of study. Only the data of the six ewes that survived into the third month were used for analysis.

The mean air temperature, relative humidity, and calculated THI values during the 1980/81 harmattan and 1981 hot-dry season are given in Table 1. Mean ambient temperature during peak

harmattan (December to January) appear to be within the comfort range, i.e. below 27°C. This tends to give an erroneous picture because typical harmattan days are characterized by cold nights with the minimum ambient temperature consistently below 14°C but warm to hot days with the afternoon air temperature reaching 33°C on certain days. During the hot-dry season, minimum night air termperatures as high as 25°C were usual while afternoon air temperatures were in the range of 35 to 39°C.

Average temperature-humidity-index (THI) (i.e. the average of 09:00 and 15:00 hrs) values during the harmattan were between 60 and 70 but THI values were between 70 and 83 during the hot-dry season. Relative humidity during both seasons were below 35%. There were occasional light showere from mid April during the late hot-dry season.

The analysis of variance (ANOVA) for the effect of period and species on plasma cortisol given in Table 2 show significant differences between main effects. Except during the late hot-dry period, plasma cortisol was significantly ($P>0.0001$) higher in goats; 2.85µg/dl., compared to sheep 1.73µg/dl., (Table 5). In both goats and sheep, plasma cortisol levels were significantly higher ($P\geq0.01$) during the harmattan compared to the hot-dry season. (Table 6)

Table 3 shows the ANOVA for the effects of period and species on plasma T3. Individual differences within the species were not significant but period and species significantly ($P\geq0.0001$) affected plasma T3 levels. Plasma levels of T3 were higher ($P>0.05$) in goats during the hot-dry season (Table 6) compared to the harmattan. Table 4 shows that period and species have significant effects on plasma thyroxine. However, plasma thyroxine was significantly higher

($P > 0.05$) in sheep than in goats over all periods (Table 5). In both species, both T3 and T4 were significantly higher during the hot-dry season than during the harmattan (Table 6).

Discussion

The seasonal variations in circulating levels of cortisol observed in this study is similar to earlier reports in goats (Paterson and Linzell, 1971; MacFarlane, 1982), sheep (Paterson, 1964; Guerrini and Bertchinger, 1982), cattle (Ingraham *et al.*, 1979; Johnson, 1980) and reindeer (Yousef *et al.*, 1971; Ringberg *et al.*, 1978). The decrease in plasma cortisol observed during the hot-dry season may be related to the calorigenic effects of cortisol (Yousef, 1975); this decline may probably be associated with a depression in chemical thermogenesis thereby facilitating acclimatization to the hot season. Guerrini and Bertchinger (1982) made a similar observation in a hot-dry enviornment; they also noted that the decline in plasma cortisol in Merino weathers was associated with increased water intake which is an adaptive mechanism during heat exposure. Using plasma cortisol to indicate stress, the goats were more stressed than the sheep during both seasons.

The evidence that thyroid activity is stimulated during exposure to cold environments have been voluminous, contradictory and confusing. An increase in circulating levels of thyroid hormones in sheep during cold exposure has been reported by some researchers (Henneman *et al.*, 1955; Hoersch *et al.*, 1961; Sutherland and Irvine, 1974; Westra and Christopherson, 1976; Valtorta *et al.*, 1982). MacFarlane *et al.*, (1974) found the protein bound iodine concentration

of dry, tropical sheep in summer to be 7μgI/100ml compared to 3.6μgI/100ml in winter. Hopkins *et al.*, (1978) concluded that the half-lives of circulating thyroxine and triodothronine suggest that the peripheral effects of a suppressed thyroid hormone secretion rate would not be dynamic enough to fit the diurnal pattern of temperature changes seen in tropical sheep.

The productive performance of an animal is highest when the meterological factors are within the zone of indifference (Bianca, 1976). Outside this zone, the animal has to combat meteorologic stress. The process requires expenditure of extra energy, so that less energy is available for productive performance. In order to maximize production in the brown goat and Yankasa sheep, there maybe the need to provide shelter or develop management programs to temper the effects of heat encountered during the day while grazing at pasture during the hot-season and the cold during harmattan.

Summary

Plasma levels of cortisol and thyroid hormones of indigenous goat and sheep in the Nigerian guinea savanna zone were measured during the harmattan and hot-dry seasons. During both seasons, plasma cortisol was significantly higher ($P > 0.0001$) in goats compared to sheep. Acclimiatization to the harmattan involved the mobilization of adrenal corticoids. Plasma concentration of thyroid hormones were higher ($P > 0.005$) during the hot-dry compared to the harmattan season.

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TABLE 1

Mean (±SD) Meteorologic Data During 1980/81 Harmattan and 1981 Hot-Dry Season*

Period	N	Mean ambient temperature (^{o}C)				Relative humidity (%)	THI **
		Min.	Max.	Dry bulb	Wet bulb		
Early harmattan (Nov. 20-Dec. 10)	21	13.9 ± 1.37	31.1 ± 1.97	28.3 ± 1.75	15.85 ± 1.67	20.9 ± 6.67	72.6 ± 2.68
Harmattan (Dec. 11-Jan. 31)	53	11.3 ± 1.56	27.6 ± 2.87	24.0 ± 2.65	12.5 ± 1.94	17.0 ± 4.31	65.7 ± 6.20
Hot-dry (Feb. 1-Apr. 23)	81	17.8 ± 2.72	34.0 ± 5.03	31.1 ± 3.36	16.6 ± 3.39	17.3 ± 12.81	74.8 ± 4.40
Late hot-dry (Apr. 24-May 1)	8	20.9 ± 2.42	33.8 ± 2.20	29.7 ± 2.46	23.4 ± 1.01	56.6 ± 7.73	78.3 ± 2.37

*Data collated from the Meteorological Unit, Institute of Agricultural Research, Ahmadu Bello University, Zaria. N = number of days.

**THI = the average of 09:00 and 15:00 hrs estimations.

TABLE 2

ANOVA for the Effect of Season and Species on Plasma Cortisol

Source	Degrees of freedom	Sum of squares	Mean square	F-value	P
Total	315	1251.63	3.97		
Species	1	51.18	51.18	15.89	0.0001
Period	3	100.92	33.64	10.44	0.0001
Animal (Species)	11	80.09	7.28	2.26	0.01
Period*Species	3	2.16	0.72	0.22	ns
Error	297	957.04	3.22		

Species: goat versus sheep. Period: early harmattan; harmattan; hot-dry; and late hot-dry. Main effects and interactions were tested using the Type IV mean square as an error term.

TABLE 3

ANOVA for the Effects of Season and Species on Plasma Triiodothyronine of Goats and Sheep

Source	Degrees of freedom	Sum of squares	Mean square	F-value	P
Total	265	326.36	1.23		
Species	1	11.57	11.57	12.22	0.0006
Period	3	32.21	10.74	11.33	.0001
Animal (Species)	11	17.92	1.63	1.72	ns
Period*Species	1	8.05	8.05	8.50	.003
Error	249	235.85	0.95		

Species: goat versus sheep; Periods: early harmattan, harmattan, hot-dry and late hot-dry. Main effects and interactions were tested using the Type IV mean square as an error term.

TABLE 4

ANOVA for the Effect Season and Species on Plasma Thyroxine

Source	Degrees of freedom	Sum of squares	Mean square	F-value	P
Total	315	5094.15	16.17		
Species	1	466.08	466.08	37.50	.0001
Periods	3	265.39	88.46	7.12	.0002
Animal (Species)	11	188.12	17.10	1.38	ns
Period*Species	3	73.11	24.37	1.96	ns
Error	297	3690.97	12.43		

Species: goat versus sheep. Periods: early harmattan; harmattan; hot-dry; and late hot-dry. Main effects and interactions were tested using the Type IV mean square as an error term.

TABLE 5

Mean Values of Plasma Cortisol(µg/dl), T3(µg/ml) and T4(ng/ml) by Breeds at Different Periods

Period	Goat			Sheep			Goat - Sheep		
	Cortisol	T3	T4	Cortisol	T3	T4	Cortisol	T3	T4
Early harmattan	3.66	2.11	8.03	2.67	1.12	11.01	0.99[a]	0.59[c]	-2.98[b]
Harmattan	3.41	1.61	10.09	2.12	1.52	13.04	1.29[b]	0.09	-2.95[c]
Hot-dry	2.44	2.51	9.35	1.05	ND	14.38	1.39[b]	ND	-5.03[c]
Late hot-dry	1.88	2.71	11.32	1.06	ND	13.79	0.82	ND	-2.47
All Periods	2.85	1.86	9.70	1.73	ND	13.06	1.12[b]	ND	-3.36[c]

a= P> 0.05; b= P> 0.0005; c= P> 0.0001 (ANOVA)

TABLE 6

Seasonal Comparisons of Plasma Cortisol, Triiodothyronine (T3) and Thyroxine (T4) of Goats and Sheep

	A	B	C	D	A-B	A-C	A-D	B-C	B-D	C-D
Cortisol (µg/dl)										
Goat	3.66	3.41	2.44	1.88	0.25	1.22[c]	1.78[d]	0.97[c]	1.53[c]	0.56
Sheep	2.67	2.12	1.05	1.06	0.55	1.62[d]	1.61[a]	1.07[b]	1.06	-0.01
T3(ng/ml)										
Goat	2.11	1.62	2.51	2.70	0.49[a]	-0.40[a]	-0.59[a]	-0.87[d]	-1.08[d]	-0.19
Sheep	1.12	1.53	ND	ND	ND	-0.41	ND	ND	ND	ND
T4(µg/dl)										
Goat	8.03	10.09	9.35	11.32	-2.09[b]	-1.26	-3.23[c]	0.74	-1.23	-1.97
Sheep	11.01	13.04	14.38	13.73	-2.03[b]	-3.37[c]	-2.78	-1.38	-0.75	0.59

A = Early harmattan; B = Harmattan; C = Hot-dry; D = Late hot-dry.
ND = not determined; a = $P > 0.05$; b = $P > 0.01$; c = $P > 0.005$; d = $P > 0.001$

Chapter III

EFFECTS OF HARMATTAN AND HOT-DRY SEASONS ON THE RECTAL TEMPERATURE AND HEAT TOLERANCE OF SAVANNA BROWN GOATS AND YANKASA SHEEP

Introduction

Goat and sheep husbandry practices in Nigeria are varied comprising mainly of the extensive, subsistence, and partially intensive systems. In the extensive system, the animals graze available natural unimproved pasture during the day and pass the night on road tarmacs, deserted houses, and porches of houses (Adu, 1980). In the subsistence production, a few goats and sheep are kept by family for domestic purposes of meat and as a quick source of income. The animals are housed in huts or kitchens at night when they are usually tethered. A common pratice is to save kitchen wastes such a yam, cassava or plantain peelings and feed such to the animals as supplementary feeds while tethered overnight. They are let out in the morning to fend for themselves. During the day, goats and sheep roam about the countryside as they graze and browse in unutilized public lands and along highways (Ademosun, 1973; Devendra, 1978).

The Fulani herdsmen practice a migratory husbandry determined by the availability of feed and water (van Raay and de Leeuw, 1974); they tend their goats and sheep together with their cattle. At night, goats and sheep may be tethered to a rope line. However, when there are 50 or more of these small ruminants, they are usually herded separately by the younger herdsmate during the day and kraaled at night.

On government farms and most research institutions, goats and sheep are allowed to graze on improved or unimproved pasture during the day. When they return from grazing, the animals are herded in sheds or barns and offered concentrate supplements and water; at other times hay or silage may be provided (Adu *et al.*, 1979; Adu and Ngere, 1980; Molokwu and Umunna, 1980).

Three seasons have been described for the Nigerian guinea savanna zone (Igono and Aliu, 1982). The thermal aspects of the environment during these seasons are stressful. Futhermore, the husbandry practices described above lack provisions for shelter against the heat stress encountered while grazing during the day. Consequently, the demands on the themoregulatory capacity of indigenous goat and sheep to maintain homeothermy are both fundamental and urgent.

Among the various physiological paremeters used to assess envrionmental heat effects, body temperature has been considered a reliable index of thermal balance (Bianca, 1961; Shanklin *et al.*, 1967; Bligh, 1970). The rectum is the traditional site of internal body temperature measurement, both in clinical diagnosis and in environmental physiology research (Wiersma and Stott, 1970). In heat tolerance test, a shift in body temperature above the normal range is taken to indicate an inability to establish thermal equilibrium by physiologic means. In such tests, it is assumed that while animals may vary in their capacity to control the production and dissipation of heat, the tolerated degree of body temperature lability is constant (Johnson, 1971). In this way, the ability of animals to maintain the dynamic near-constant internal environment

necessary for survival and productive performance at varying degrees of metorological stress can be compared.

Animals exhibit duirnal variations in body temperature (Bligh *et al.*, 1965). Some, notably the camel and donkey exhibit thermolability as a means of adapting to the fluctuations in their environmental temperature (Schmidt-Nielsen *et al.*, 1957). Fluctuations in body temperature have also been reported for various breeds of goat and sheep under varying experimental conditions.

Despite its relevance to farm animal husbandry, the capacity of Nigerian breeds of goat and sheep to adapt to the seasonal variations of their natural habitat have received little attention. But the backbone to successful animal production involves the selection and upgrading of breeds adapted to their environment. The selection process requires information relating to the heat tolerance and thus adaptability of the available species within their habitat. The present study was designed to evaluate the effects of the harmattan and the hot-dry season on rectal temperature and heat tolerance of Savanna Brown goat and Yankasa sheep indigenous to the Nigerian guinea savanna zone.

Materials and Methods

The Environment

The study was conducted under the same climatic conditions decribed in Chapter II.

Animals

The animals used have been described (Chapter II). The data for all eleven goats were analysed.

Experimental Design

A preconditioning period of two weeks was allowed during which

the animals were exposed to the experimental procedures. During this period, afternoon rectal temperature was found to be maximal between 14:00 and 15:00 hours. Thus, subsequent afternoon measurements were made between these two hours.

During each measurement, the animals were together as a herd. Handling procedures were careful to avoid unnecessary disturbance. Morning rectal temperatures (Tre) were taken on each experimental day between 05:30 and 06:30h (06:00Tre) using a digital thermometer with the probe fully inserted into the rectum for at least 2 min. Thereafter the animals were allowed to graze for the next 8 hours. On return from grazing, they were allowed about 10 min. to settle before afternoon Tre (14:00Tre) were taken; following 14:00Tre measurements, supplementary feed and water were allowed. The frequency and distti-bution of rectal temperature measurements have been outlined in Chapter II.

Data used in this chapter are logged in the Appendix. A factorial analysis of variance was used to analyse data. Differences among means were tested using Duncan's New Multiple Range Test (Duncan, 1955). The least statistical difference (LSD) was used to test for significant differences between treatment means (Snedecor and Cochran, 1980). Linear correlation analysis was run between rectal and ambient temperatures to establish any significant relation-ships. Significance was set at 5% level.

The heat tolerance coefficients (HTC) of the animals were calculated using a modified Rhoad's formula (1944) (See appendix page 110):

HTC=100 - 18 (14:00Tre - 06:00Tre)

By this modification, each animals' 06:00Tre was used as its reference rather than a "normal" value for Tre. Thus, actual individual responses were ascertained in terms of per cent rise in Tre.

Results

The harmattan season consists of the early harmattan and harmattan periods while the hot-dry and late hot-dry make up the hot-dry season. Morning ambient temperature during the early harmattan accounted for 6% of the variation in afternoon air temperature; the comparative values for the harmattan, hot-dry and late hot-dry were 32, 60, and 70 respectively. During the harmattan, ambient temperatures at the times of measurement accounted for 4 and 26 per cent of the variation in goat 06:00Tre and 14:00Tre, respectively; the comparable values for sheep were 13 and 14. Ambient temperatures during the hot-dry periods had a negative relationship with Tre; 06:00Tre and 14:00Tre of goats declined by 3 and 17%, respectively, in comparison to 13 and 17% for sheep. At the 06:00Tre measurements, all the goats and sheep were observed to shiver.

The mean and ranges of rectal temperature and heat tolerance of the brown goat and Yankasa sheep during the study is given in Table 1 The ANOVA for 06:00Tre given in Table 5 show that individuals within species differed significantly ($P>0.01$) during the different periods. The overall mean 06:00Tre for goat, 38.1^{o}C, was significantly lower ($P>0.05$) than the comparable value for sheep, 38.3^{o}C. Mean 06:00Tre for both species during the hot-dry season compared favourably but mean 06:00 Tre (Table 2) for goats (38.2^{o}C) during the harmattan was significantly lower ($P>0.05$) than for sheep (38.6^{o}C). A significant positive correlation

($P > 0.01$) existed between morning air temperature and 06:00Tre during the harmattan (Table 3). Goats maintained a rather stable 06:00Tre throughout the study (Table 4) but sheep 06:00Tre during the harmattan season was significantly higher ($P > 0.05$) than during the hot-dry season.

Table 6 presents the ANOVA for the effects of period and specie on 14:00Tre; only period had significant effect ($P > 0.0001$) on 14:00Tre. Mean 14:00Tre for goats (39.3°C) during the study did not differ significantly from that of the sheep (39.1°C). However, mean 14:00Tre for goats, 39.8°C, during the harmattan (Table 2) differed significantly ($P > 0.001$) from that of the sheep, 39.5°C but species differences in 14:00Tre during the hot-dry season did not occur. During the harmattan, ambient temperatures correlated positively with Tre (Table 3) for both species; on the other hand, significant negative correlations existed between the same factors during the hot-dry season.

During all the periods, 14:00Tre in both goat and sheep were significantly greater ($P > 0.0001$) than 06:00Tre. Table 3 shows that 06:00Tre correlated positively with 14:00Tre during all periods; in sheep the relationship was highly significant ($P > 0.001$) excepting during the late hot-dry period while in the goat, significant relationship existed only during the early harmattan and hot-dry periods. One and 24 per cent of the variability in 14:00Tre for goats during the harmattan and hot-dry periods respectively were attributable to 06:00Tre; the comparable values for sheep were 20 and 50.

The ANOVA for the variation in HTC due to species and period is Table 6. The HTC for sheep during the harmattan season, 81.8, was

significantly higher ($P>0.0001$) compared to the value obtained for goat, 70.6; however, HTC's during the hot-dry season for both species compared favourably (Table 2). In both goats and sheep, average HTC during the hot-dry season were significantly greater ($P>0.05$) than during the harmattan. Overall, HTC averaged 83.7 for sheep; this was significantly higher ($P>0.05$) than the mean HTC for goats, 79.7.

Table 7 gives the ANOVA for the effect of time, period, and species on 06:00Tre and 14:00Tre. Significant species and species-period interactions were not observed.

Discussion

One adverse effect of environmentally imposed heat load on farm animals is a displacement of their body temperature from the normal range. An elevated body temperature may lead to aberrations in the physiologic reactions and compensations that maintain homeokinesis. In the process, energy which could have been used for productive purposes is used in combating thermal stress; this ultimately reduces the animals' efficiency of production (Bianca, 1976). For instance, Younis *et al.*, (1977) while comparing the performance and heat tolerance of Awassi ewes found that unshorn ewes that had higher rectal temperatures also had low live-weight gains and poor efficiency of feed conversion.

The shivering observed in both species suggests a shift from chemcial to physical thermogenesis and also indicates that the ambient temperature during the harmattan nights (range, 9 to 14^{0}C) were below the lower critical temperature for indigenous goat and sheep. Metabolic response to cold exposure has two components, viz, an initial rise in

heat production via increased metabolic rate in addition to shivering thermogenesis (Slee, 1974). The additive effects of these mechanisms probably explains the higher absolute value of 06:00Tre in both species during the harmattan compared to the hot-dry season. On the other hand, acclimatization to high environment temperatures, as occured during the hot-dry season, involves a decrease in metabolic rate which may be reflected in the maintenance of lower Tre. The wider variation and higher absolute values for Tre during the harmattan suggest that the harmattan might have been more stressful than the hot-dry season.

Responses in Tre of the brown goat and Yankasa sheep to harmattan and hot-dry seasons show that while the sheep was remarkably thermostable during both seasons, the goats adopt an interesting strategy of accumulating more heat during the day and loosing same at night during the alternating cold-night and warm-day conditions that prevailed during the harmattan. In order to achieve this objective, the goat maintains a significantly lower 06:00Tre compared to the sheep. The thermoregulatory advantage of this phenomenum is that a lower Tre before exposure to heat indicates a low starting point for the animal in its defence against hyperthermia (Bianca, 1959). Although a low initial Tre may not prevent hyperthermia *per se*, it may delay its onset and lessen its severity (Wolf and Mounty, 1974).

For both species, the harmattan appeared more stressful than the hot-dry season. This may be due to the ambient temperatures at the time of Tre measurement. For instance, morning ambient temperature accounted for 60.3% of afternoon air temperature during the hot-dry season compared to only 32.3% during the harmattan. The positive

association between ambient and rectal temperature during the harmattan suggest that more heat accumulated in the body than is lost while negative correlation between the same factors during the hot-dry season indicates that heat loss overrides heat gain. A possible factor might have been the cooling effect of the southwest wind (speed 13.1 ± 3.52 km h^{-1}) which dominated the hot-dry season compared to the cold dust laden northeast harmattan winds (speed 12.7 ± 3.85 km h^{-1}).

The heat tolerance of Savanna Brown goats and Yankasa sheep measured either in terms of fluctuations or the modified Rhoad's index compared favourably with other breeds of goat (Appleman and Delouche, 1958; Johnson, 1971; Quartermain and Broadbent, 1974; Attah, 1977; Bianca and Kunz, 1978) and sheep (Hafez *et al.*, 1956; Symington, 1960; Eyal, 1963; Bligh *et al.*, 1965; Mittal and Ghosh, 1979).

Individual differences in Tre responses were observed in both goat and sheep. Hopkins *et al.*, (1978) made a similar observation with Merino sheep; in addition, they reported that animals with high body temperatures were low producers. On this basis, they were able to enumerate selection guidelines for increased productivity. It would be interesting to compare body temperature and productivity of animals maintained in sheds with those maintained under the present experimental conditions.

Summary

From measurements of rectal temperature (Tre) at 06:00h (06:00Tre) and 14:00 (14:00Tre), heat tolerance was determined in

adult cycling Savanna Brown goats and Yankasa sheep indigenous to the Nigerian guinea savanna zone during the harmattan and hot-dry seasons. Absolute and mean Tre as well as the difference between 14:00Tre and 06:00Tre (Tre) were greater ($P > 0.05$) during the harmattan compared to the hot-dry season. Both goat and sheep were observed to shiver during harmattan nights. Morning Tre did not vary between seasons in the goat but was significantly higher during the harmattan than during the hot-dry season for sheep. 14:00Tre was significantly higher ($P > 0.01$) for both species during the harmattan compared to the hot-dry season. Yankasa sheep had a significantly higher ($P > 0.05$) 06:00Tre but a lower ($P > 0.01$) 14:00Tre than the brown goat during the harmattan. Significant differences in 06:00Tre and 14:00Tre did not occur during the hot-dry season. Heat tolerance determined in terms of per cent rise of 14:00Tre over 06:00Tre reference values were higher for both genotypes during the hot-dry season compared to the harmattan. Over the harmattan the sheep was more tolerant than the goat but the heat tolerance values for both species during the hot-dry season compared favourably.

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TABLE 1

Mean (±SD) Rectal Temperature (^{o}C) of Savanna Brown Goat and Yankasa Sheep During the Harmattan and Hot-Dry Seasons

Period	Goat (n=11)	Sheep (n=6)
Early Harmattan		
06:00Tre	38.2 ± 0.80 (36.9 - 40.7)	38.7 ± 0.67 (37.9 - 40.5)
14:00Tre	39.8 ± 0.45 (39.1 - 41.2)	39.6 ± 0.76 (38.3 - 41.2)
Harmattan		
06:00Tre	38.2 ± 0.78 (36.5 - 39.9)	38.4 ± 0.61 (37.4 - 40.2)
14:00Tre	39.8 ± 0.72 (36.6 - 41.5)	39.4 ± 0.58 (37.9 - 40.2)
Hot-Dry		
06:00Tre	38.1 ± 0.48 (37.0 - 40.2	38.0 ± 0.43 (37.2 - 38.8)
14:00Tre	38.8 ± 0.79 (37.2 - 41.6)	38.7 ± 0.79 (37.5 - 40.5)
Late Hot-Dry		
06:00Tre	38.0 ± 0.25 (37.2 - 38.4)	38.3 ± 0.70 (37.5 - 39.5)
14:00Tre	38.7 ± 0.36 (37.9 - 39.4)	38.8 ± 0.49 (38.2 - 39.3)

Ranges given in parenthesis

TABLE 2

Comparison of Rectal Temperatures (^{o}C) and Heat Tolerance Coefficients of Goats and Sheep During Harmattan and Hot-Dry Seasons

	Season	Goat	Sheep	Goat-Sheep
06:00Tre	Early Harmattan	38.2	38.7	-0.5**
	Harmattan	38.2	38.4	-0.2*
	Hot-Dry	38.1	38.0	0.1
	Late Hot-Dry	38.0	38.3	-0.3
14:00Tre				
	Early Harmattan	39.8	39.6	0.2**
	Harmattan	39.8	39.4	0.4**
	Hot-Dry	38.8	38.7	0.1
	Late Hot-Dry	38.7	38.8	-0.1
Heat Tolerance				
	Early Harmattan	71.1	82.8	-11.2***
	Harmattan	70.2	80.7	-10.5***
	Hot-Dry	88.5	86.6	1.9
	Late Hot-Dry	87.1	91.0	-3.9

*P $<$ 0.05; **P $<$ 0.001; ***P $<$ 0.0001

TABLE 3

Linear Correlation Coefficients (r) Between Ambient And Rectal Temperatures (^{0}C) of Goat and Sheep During Harmattan Hot-Dry Seasons

Period	06:00Tre vs 14:00Tre		06:00Ta vs 06:00Tre		14:00Ta vs 14:00Tre	
	r	p	r	P	r	P
Early Harmattan						
Goat	0.270	0.04	0.202	ns	0.190	ns
Sheep	0.673	0.001	-0.007	ns	-0.270	ns
Harmattan						
Goat	0.112	ns	0.195	ns	0.516	0.0001
Sheep	0.442	0.001	0.357	0.01	0.373	0.01
Hot-Dry						
Goat	0.493	0.0001	-0.161	ns	-0.408	0.0001
Sheep	0.735	0.0001	-0.100	ns	-0.413	0.005
Late Hot-Dry						
Goat	0.292	ns	0.658	0.0001	0.054	ns
Sheep	0.566	ns	-0.160	ns	0.104	ns

ns=not significant at 5% level

TABLE 4

Comparison of Mean Rectal Temperature (^{o}C) and Heat Tolerance
In Savanna Brown Goat and Yankasa Sheep During
Harmattan and Hot-Dry Seasons

Breed	A	B	C	D	A-B	A-C	A-D	B-C	B-D	C-D
Goat										
06:00Tre	38.2	38.2	38.1	38.0	0.0	0.1	0.2	0.1	0.2	0.1
14:00Tre	39.8	39.8	38.8	38.7	0.0	1.0[d]	1.0[d]	1.0[d]	1.1[d]	0.1
Mean Tre	39.0	39.0	38.5	38.4	0.0	0.5[d]	0.5[d]	0.6[d]	0.5[d]	0.1
HTC	71.1	70.2	88.5	87.1	1.1	-17.4[d]	-16.0[d]	-18.3[d]	-16.9[d]	-1.4
Sheep										
06:00Tre	38.7	38.4	38.0	38.2	0.3[a]	0.7[d]	0.5	0.4[c]	0.1	-0.2
14:00Tre	39.6	39.4	38.7	38.8	0.2	0.9[d]	0.8[b]	0.7[d]	0.6[d]	-0.1
Mean Tre	39.2	38.9	38.3	38.5	0.3[c]	0.9[d]	0.7[c]	0.6[d]	0.4	-0.2
HTC	82.9	80.7	86.7	92.1	2.1	-3.9	-9.3	-6.0[a]	-11.4	-5.4

[a] $P < 0.05$; [b] $P < 0.01$; [c] $P < 0.005$; [d] $P < 0.0001$

A = Early harmattan; B = harmattan; C = hot-dry; D = late hot-dry

TABLE 5

ANOVA For The Effect of Period
And Species On 06:00Tre

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F-Value	P
Total	423	170.67			
Species	1	1.78	1.78	4.87	0.02
Animal (Species)	15	10.91	0.71	1.99	0.01
Period	3	7.86	2.62	7.17	0.0001
Period * Species	3	5.05	1.68	4.61	0.003
Error	401	146.51			

TABLE 6

ANOVA For The Effect Of Period And
Species On Heat Tolerance

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F—Value	P
Total	423	1061.84			
Species	1	18.53	18.53	9.77	0.001
Animal (Species)	15	43.47	2.90	1.53	ns
Period	3	106.79	35.60	18.78	0.0001
Period * Species	3	28.36	9.45	4.99	0.002
Error	401	760.16			

ns=not significant at 5% level.

TABLE 7

ANOVA For The Effect Of Time, Period And Species On 06:00Tre and 14:00Tre

Source	Degree of Freedom	Sum of Squares	Mean Square	F-value	P
Total	847	694.99			
Species	1	0.11	0.11	0.27	ns
Time	1	98.42	98.42	236.98	0.0001
Species*Time	1	2.94	2.94	7.03	0.008
Period	3	52.43	17.48	42.08	0.0001
Period*Species	3	2.68	0.89	2.15	ns
Period*Time	3	15.04	5.01	12.07	0.0001
Period*Species*Time	3	5.13	1.71	4.14	0.006
Animal (Species	15	14.10	0.94	2.26	0.004
Error	817	339.3			

ns=not significant at 5% level.

Chapter IV

PHYSIOLOGIC RESPONSES OF SAVANNA BROWN GOATS AND YANKASA SHEEP TO HARMATTAN AND HOT-DRY SEASONS

Introduction

Environmental stress consists of the external forces that tend to displace the maintenance of a dynamic equilibrium of the internal environment (homeokinesis) which is a fundamental need for normal cellular function and life (Attah, 1977; Stott, 1981). This steady state of physiologic processes in the face of continuously disruptive external influences is maintained by compensatory mechanisms involving readjustments in metabolic, behavioural, nervous and endocrine responses (Johnson, 1976; Wester, 1976; Young, 1981).

Acclimatization to environmental stress involves a complex of hormonal and physiologic changes within the animal. Adrenal responses to cold has been found to be associated with increase cortisol production in rats (Heroux, 1960) reindeer (Yousef *et al.*, 1971; Ringberg *et al.*, 1978), whitetailed deer (Bubenik *et al.*, 1975) and dairy cattle (Ingraham *et al.*, 1979).

It is less certain whether hyperthyrodism is involved in the response to cold because the effects of thyroxine are slow in onset (Webster, 1976). Therefore its role is probably more aligned with the slower adaptive changes rather than with rapid responses to acute cold (Young, 1981). Changes in thyroid activity

in animals exposed to either heat or cold appears to be interelated with appetite, food intake, digestive functions and body mass (Heroux, 1960; Good *et al.*, 1974; Westra and Christopherson, 1976; Kennedy *et al.*, 1977; Christopherson *et al.*, 1979).

Bianca (1976) has suggested that body temperature may be the best single physiologic parameter expressing to what extent an animals' thermoregulatory mechanisms have been successful in maintaining homeothermy. Physiologic indices based on rectal temperature responses have been reviewed by Bianca (1961) and Kamal (1976).

Species survival requires growth, maturation, and reproduction. Stott (1981) suggested the use productive performance and reproduction as the ultimate indices of environmental stress not only from an economic point of view but also as a composite of optimal physiologic functions. The closer the optimal environment is approached, the greater the response in production and reproduction (Johnson, 1967). In practical terms, however, the optimal environment is obtained through management and husbandry practices which manipulate the animals' environment to promote the most efficient production of meat, milk, hides and wool (Johnson, 1976; Stott, 1981; Young, 1981).

Growth, survival, reproduction and productive performance are closely related to adrenal and thyroid as well as other endocrine functions (Johnson, 1976; Webster, 1976; Yousef, 1979; Stott, 1981). Since an animal's endocrine activity is profoundly modulated by environmental stress, measurement of plasma hormones will provide important information in the assessment of environmental stress in livestock. The purpose of the present study was to determine the

effects of harmattan and hot-dry seasons on certain physiologic responses including rectal temperature, heat tolerance, and plasma concentrations of thyroxine (T4), triiodothyronine (T3), and cortisol.

Materials and Methods

Data Analysis

The seasonal trend in THI values during the experimental period, the average rectal temperature, heat tolerance, plasma concentrations of T3, T4 and cortisol were illustrated graphically. Data used in this chapter have been presented in Chapters II and III.

Results

Figures 1 and 2 summarize the data germane to the physiologic response of the Savanna brown goats and Yankasa sheep to the harmattan and hot-dry seasons. During the harmattan, especially in the month of December 06:00Tre in both species was above 38.5^{o}C; this was associated with 14:00Tre above 39^{o}C, HTC below 60 for the goat but above 70 for the sheep. Plasma T3 of the goat was initially about 2.0ng/ml but later dropped to about 1.0ng/ml; plasma T4 rose from about 5.0µg/ml to 9.0µg/ml and cortisol levels were fairly constant above 2.0µg/dl. In both species during the harmattan, there was a rise in thyroid hormones and cortisol but the rise in thyroid hormones were not significant.

However, during the hot-dry season both 06:00Tre and 14:00 Tre in both genotypes declined to about 38^{o}C leading to a high HTC value of above 80; plasma T3 levels remained relatively stable above

2ng/ml while plasma T4 concentrations which showed a decline for goat remained high for the sheep, but plasma cortisol concentration declined below 2.0µg/dl for both species.

Discussion

Various workers (Yousef and Johnson, 1975; Stott *et al.*, 1976) have reported significant positive relationships between thyroid hormones and metabolic rate for a number of small mammals. This means that thyroid hormones contribute to an animal's total body heat. Cortisol probably stimulates protein catabolism and in this way mobilizes amino acids for catabolism, gluconeogenesis, and the synthesis of new enzyme proteins in the liver (Heroux, 1960; Webster, 1976). These events especially during the harmattan make energy available for cold-induced thermogenesis.

The high heat tolerance coefficient values of the Yankasa sheep during the harmattan suggest it possibly depended more on physical and/or behavioral means of thermoregulation than the brown goat. Among the anatomical features of Yankasa sheep which can be considered to have beneficial thermoregulatory functions include the white hair coat which would reflect a greater proportion of radiant heat encountered during the day plus a layer of subcutaneons fat which acts as a good insulator at night. The brown goat on the other hand has a visceral fat layer.

In acclimatizing to the hot-dry season, both the brown goat and Yankasa sheep prefer to maintain rectal tempertures about 38.0°C; in the brown goat this capacity was associated with a decrease in plasma T4 and cortisol concentrations. Under the same conditions, and inexplicable rise in plasma T4 concentrations was encountered in

Yankasa sheep while its plasma cortisol levels declined. The lack of drop in plasma T3 in the goats and the dramatic rise in plasma T4 in Yankasa sheep during hot weather is contrary to expectation. In the light of this observation, it appears that factors other than ambient temperature may be influencing the activities of the thyroid gland. Other workers (Good *et al.*, 1974; Westra and Christopherson, 1976; Kennedy *et al.*, 1977; Christopherson *et al.*, 1979) have suggested that thyroid activity may be related to appetite, food intake, digestive functions and body mass.

Summary

The physiologic response of the Savanna brown goats and Yankasa sheep to the harmattan and hot-dry season was assessed by measuring rectal temperature, heat tolerance, and plasma cortisol, thyroxine, and triiodothronine levels. The hormones were measured by radioimmunoassay. Acclimatization of the brown goat and Yankasa sheep to the harmattan involved mobilization of thyroid hormones and cortisol for chemical thermogenesis. Thyroid gland response during the hot weather in both species appeared to be independent of ambient thermal conditions but a decrease in adrenocortical activity was observed in both species.

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FIGURE 1

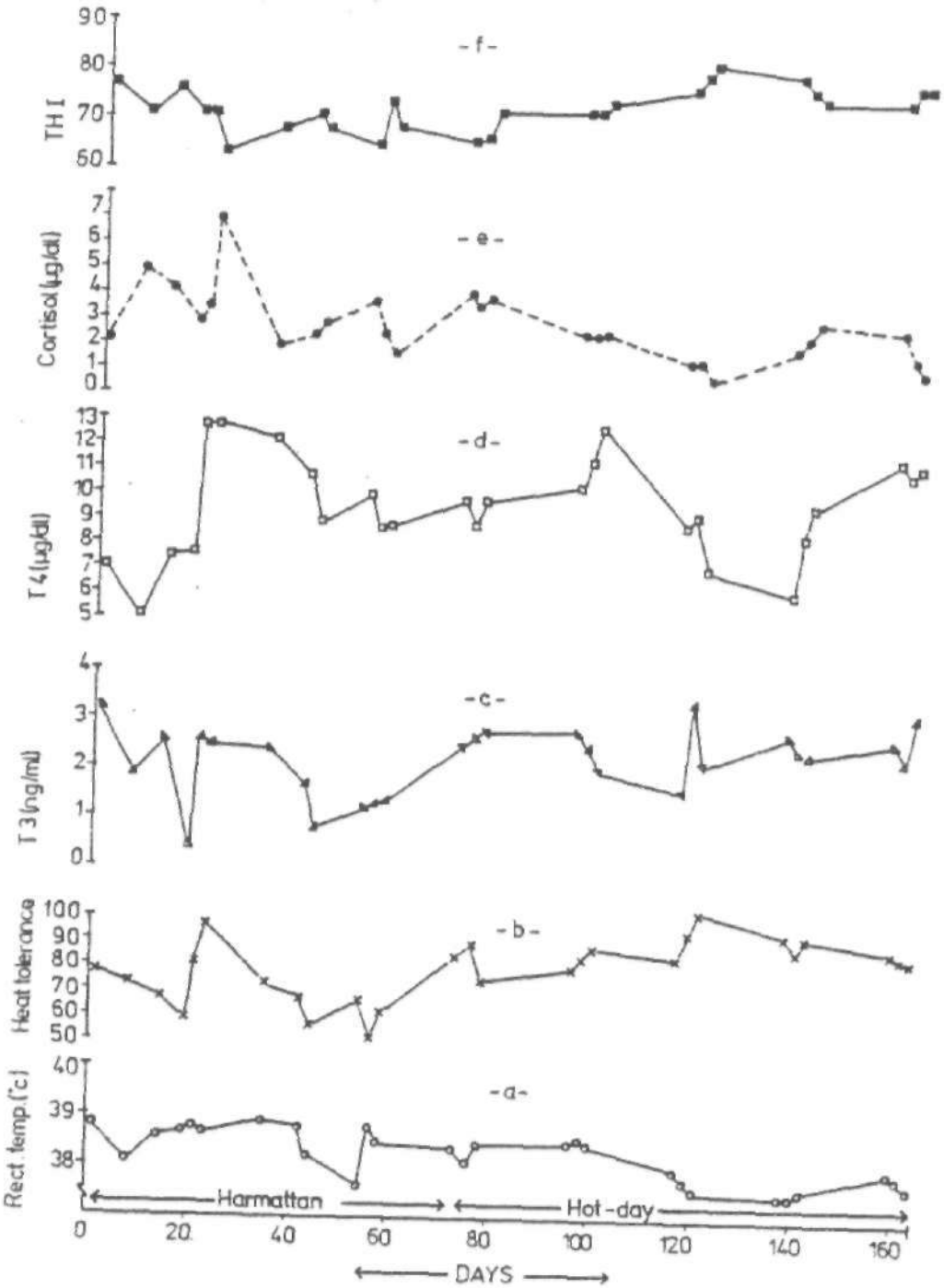

Fig. 1: Seasonal changes in average daily rectal temperature, (a) heat tolerance, (b) plasma concentrations of T3, (c) T4, (d) cortisol, (e) of Savanna brown goats and THI values, (f) of the day of sampling.

FIGURE 2

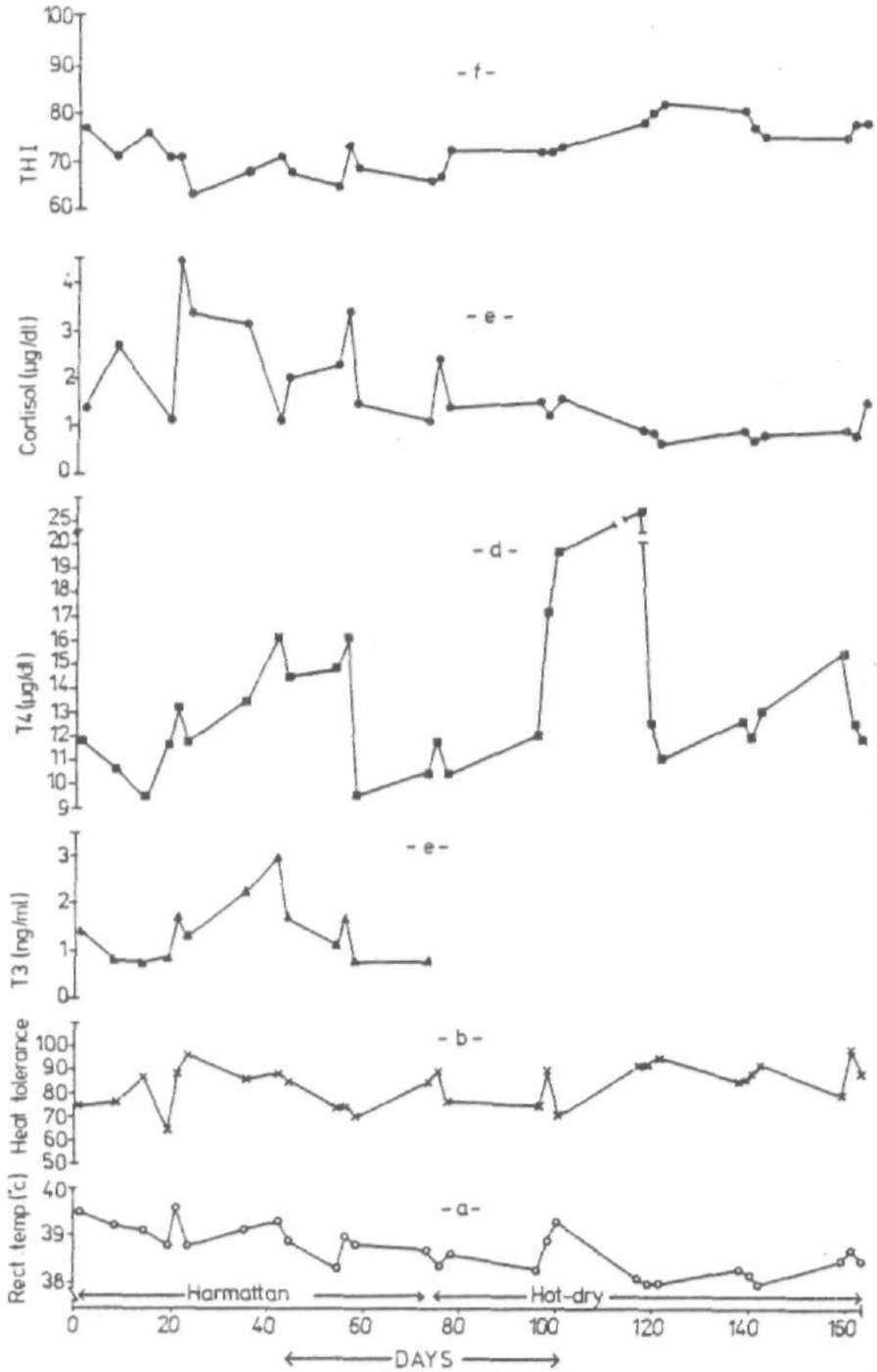

Fig. 2: Seasonal changes in average daily rectal temperature (a) heat tolerance, (b) plasma concentrations of T3 (c) T4, (d) and cortisol (f) of Yankasa sheep and THI values, (f) on the day of sampling.

Chapter V

ESTROUS CYCLE IN SAVANNA BROWN GOATS AND YANKASA SHEEP DURING HARMATTAN AND HOT-DRY SEASONS

Introduction

The reproductive performance of Nigerian breeds of goat and sheep have been evaluated by various workers (Kirkpatrick and Akindele, 1974, Orji and Steinbach, 1975; Molokwu and Igono, 1978; Kuteyi, 1978; Adu and Ngere, 1979; Adu *et al* ., 1979; Molokwu and Oliviera, 1981; Molokwu and Igono, 1982; Ngere and Mbap, 1982). The influence of climate on the reproductive performance of indigenous goats and sheep has not attracted much attention probably because reproduction in these breeds is not limited by photeperiod. Since reproductive efficiency is a phenotypic expression (Hafez), 1952) the combination of information on the impact of climate and breed characteristic in estrous phenomena could provide a firm basis on which to design efficient management and husbandry programs to alleviate the adverse effects of climate.

Reproductive efficiency in farm animals has been considered as the ultimate index of environmental effects both from an economic point of view and as a composite of optimal physiologic functions (Stott, 1981). However, the exhibition of estrus heralds successful reproductive activity in domestic ruminants. Estrus determines breeding and therefore conception rate and net kid/lamb crop. Thus, a logical first step in evaluating their reproductive

performance should begin with a clear detail of their estrous phenomena to provide the basic information necessary for planning either hand breeding or artificial insemination. In this study, the influence of the harmattan and hot-dry seasons on estrous cycle length, onset and duration of estrus of Savanna Brown goat and Yankasa sheep is examined.

Materials and Methods

One each of a vasectomized adult buck and ram were used in teasing eleven does and thirteen ewes, respectively. All animals were grazed freely between 08:00 and 13:00 hours; after grazing and at night they were housed in a shed with a concrete floor. The teasers were grazed and housed differently. A feed supplement of wheat bran mixed with either guinea corn or cotton seed and dry gamba (*Panicum maximum*) hay was provided; clean drinking water was available *ad libitum*.

Each day, during the harmattan and hot-dry season, the does and ewes were teased at 06:00, 14:00 and 22:00h for one hour. At the beginning of each hour-long observation, the teasers were introduced to the females and removed at the end of the period. During the 22:00 to 23:00h observation, electric light or kerosine lamps in case of power failure was used; at other times the lights were turned off.

A doe or an ewe was considered to be in estrus if she accepted the teaser. The observation hour during which standing heat was first observed, was taken as the onset of estrus, i.e., if standing heat was first observed during the 22:00-23:00h observation, the onset was recorded as 22:00h. The duration of estrus was taken as the interval between the first and last mating by a teaser.

Estrus was estimated to have commenced midway between the last negative observation and the first positive observation. Similarly, termination of estrus was calculated as the mid-point between the last positive observation and the first negative observation.

Estrous cycle length was determined as the interval between two successive heats. The first day of standing heat was taken as day 1 of the cycle. The day preceding the succeeding standing heat was counted as the last day of the cycle. Estrous cycle in sheep was classified using the method of Hafez (1952). In goats, the following suggested classification abstracted from literature was adopted.

Classification	Duration (days)	Reference
A. Single	30	
1. Aberrant	2-12	Phillip *et al.*, Shelton and Groff, 1974; Corteel, 1974.
2. Normal	18-26	Shelton & Groff, 1974; Smith, 1980; Molokwu and Oliviera, 1981.
3. Long	27-30	Corteel, 1977; Molokwu and Oliviera, 1981.
B. Multiple cycle	30	Based on the principles used by Hafez, 1952.
1. Double	36-52	
2. Triple	54-78	
3. Quadruple	80-120	

To test any significant differences between species and season in estrual period, the unpaired t-test was used (Armitage, 1971).

Results

Mean normal cycle length in the goat was 20.1 ± 2.09 and 22.0 ± 3.91 days during harmattan and hot-dry season, respectively; the comparative values for the sheep were 16.8 ± 0.58 and 16.4 ± 0.53, respectively. An aberrant cycle of 7 days was observed in the goat during the hot-dry season; in the sheep, four short cycles, in the range of 5 to 13 days were observed during the harmattan compared to one during the hot-dry season. While long cycles were not observed in the goat, two, 23 and 26 days, were observed in the sheep during the harmattan and one, 21 days, during the hot-dry season. One double cycle, 35 days and four triple cycle, 56 to 77 days, were observed in the goat during the harmattan compared to three double cycles, 35 to 43 days, and one triple cycle of 53 days during the hot-dry season. In the sheep, a triple cycle of 48 days was observed during the harmattan while two double cycles, each 30 days, were observed during the hot-dry season.

Estrous activity first observed at 22:00 and at 06:00h was considered as having begun at night while that of 14:00h was taken to have begun in the day. During the harmattan, 27.3% of estrous activity in the goat was first observed at night and 72.7% during the day; the comparable values for the sheep were 57.1 and 42.9. About 6 2% of observed estrus activity in the goat begun at night during the hot-dry season and 38.5% during the day; the commparable values for sheep were 70 and 30.

The seasonal variation in the duration of estrus is shown in Table 1. In the goat, estrual period did not differ significantly between the seasons but a significant decline ($P>0.05$) occured in

the sheep during the hot-dry season. The duration of estrus was significantly higher ($P > 0.01$) in the goat compared to the sheep during both seasons.

Discussion

Estrous phenomena in Savanna Brown goats and Yankasa sheep during the harmattan and hot-dry season resemble those of other breeds (McKenzie and Terrill, 1937; Phillips *et al.*, 1943; Hafez, 1952; Asdell, 1964; Carrera and Butterworths, 1968; Jarosz *et al.*, 1971; Thibault and Levasseur, 1974; Kirkpatrick and Akindele, 1974; Corteel, 1975; Robertson, 1977; Otchere and Nimo, 1978; Kuteyi, 1978; Adu and Ngere, 1979; Guillard, 1979; Ott and Memon, 1980; Molokwu and Oliviera, 1981; Thangevelu and Mushkerjee, 1982; Ngere and Mbap, 1982). The goat preferred coming into heat during the day during the harmattan but the sheep did not show such variation. During the hot-dry season, both species, preferred coming into heat at night. Evidently, the animals tend to prefer coming into heat when it is not too cold or too hot; the variations observed may be related to the adaptive mechanisms to the ambient thermal conditions.

The duration of estrus in Yankasa sheep observed in this study is at variance with that of Kuteyi (1978). The method of study by Kuteyi (1978) involved four observations at irregular intervals made only during the day; this probably explains the narrow range (13 to 17 hours) reported. From the observation made in this study, it is suggested that estrus detection at 12-hour intervals may suffice in both goat and sheep. Furthermore, since it is not possible to predict

which animals would have a short or long estrual period, it is recommended that breeding especially in the sheep should follow immediately after the first observed standing heat and repeated every 12 hours thereafter until estrus subsides. This approach is more relevant during the hot-dry season so as to contain the significant decrease in estrual period.

Irregular cycle lengths have physiologic, pathologic and economic importance. Most farmers first think of pregnancy when estrus is not observed within the expected days; this is further confused by the difficulty in determining early pregnancy in goats and sheep. Cycles of long duration may be symptoms of existing pathologies such as retained corpora lutea, cystic ovaries or early embryonic death followed by resorption (Roberts, 1971). Short cycles have been associated with the low circulating progesterone levels (Ott *et al.*, 1979; Diniz, 1980) in goats while McKenzie and Terrill (1937) reported anovulation with short cycles in sheep. The duration of an irregular cycle adds to the number of days an animal is fed while not producing; the cost of feeding, management and husbandry in addition to the medical care together increase the overall cost of production. There is need to further study the mechanisms of irregular estrous cycle and partition reproductive losses arising therefrom. Such information can provide useful guidelines in desgning management and health programs to minimize losses in reproductive efficiency arising from abnormal estrous activity.

Summary

An investigation was conducted to establish the effects of harmattan and hot-dry seasons on the estrous cycle in Savanna Brown goats and Yankasa sheep indigenous to the Nigerian guinea savanna. Mean cycle lengths were 20.1 ± 2.90 and 22.0 ± 3.91 days in the goat during harmattan and hot-dry season, respectively; the comparative values for sheep were 16.8 ± 0.58 and 16.4 ± 0.53. Irregular (short and long) cycles were observed in both species. About 73% and 42.9% of observed estrus, in goat and sheep respectively, began during the day during the harmattan; during the hot-dry season, the comparable values were 38.5 and 30, respectively. Season had no effect on the duration of estrus in the doe but in the ewe, the estrual period decline significantly ($P > 0.05$) during the hot-dry season. The duration of estrus was significantly higher ($P > 0.01$) in the brown goat compared to Yankasa sheep during both seasons. It is concluded that twice daily observations at 12-hour intervals will suffice to detect heat in both species.

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TABLE 1

Duration of Estrus in Savanna Brown Does and Yankasa Ewes During Harmattan and Hot-Dry Seasons

	No. of Observations	Duration of Estrus (Hours)	
		Range	X ± S. D.
Harmattan			
Does	12	16-120	45.3 ± 9.05
Ewes	21	8-88	33.6 ± 5.87
Hot-Dry			
Does	10	15-56	33.6 ± 4.74
Ewes	19	8-48	24.0 ± 5.45

APPENDIX I

APPENDIX I

Table 1: Preparation of Reagents for T3 or T4 Standard

1. Tap the vials of freeze-dried serum to dislodge any large particles from the stoppers.
2 Carefully remove the tear-off aluminium closures and the rubber stoppers using a hand forceps; place the stopper in an inverted position on a clean dry surface.
3. Gently add 500 µl double-glass deionized distilled water to each vial and replace the stoppers.
4. Allow the vials to stand for 10 minutes at room temperature.
5. The contents of the vials may be further mixed by gental inversion and swirling until complete solution is obtained; vigorous agitation and foaming should be avoided.
6. ^{125}I-triiodothyronine and Amerlex T3 antibody suspension should be allowed to equilibrate at room temperature before use.
7. Amerlex T3 antibody reagent should thoroughly mixed by gentle shaking and swirling to ensure a homogenous mixture.
8. Reconstituted standards should be stored at 2-4^{o}C but must be used up within 10 days or stored at -20^{o}C for up to 4 weeks.

TABLE 2

Amerlex T3 Kit Assay Protocol

	Standards (ng T3/ml)						Unknowns			
	0	0.4	-1.0	-2.0	-4.0	-9.0	1	2	3	etc.
Tube	1,2	3,4	5,6	7,8	9,10	11,12	13,14	15,16	17,18	
Standard serum*	25	15	15	15	15	25	-	-	-	
Unknown serum	-	-	-	-	-	-	25	25	25	
^{125}I-triiodothyronine	500	500	500	500	500	500	500	500	500	
Amerlex T3 antibody suspension	50	500	500	500	500	500	500	500	500	

Vortex mix

Cover tubes and incubate at 37°C for one hour

Centrifuge for 15 min. at 3000 rpm at 4°C

Decant supernatant; keep tubes inverted on a pad of absorbent tissues and blot gently to remove the last drops of liquid

Count

*All volumes are in microliters

TABLE 3

Amerlex T4 RIA Kit-Assay Protocol

	Standards (μgT4/100ml)					Unknown	Unknown	Unknown
	0	2.5	6	12	25	1	2	3
Tube numbers	1,2	3,4	5,6	7,8	9,10	11,12	13,14	15,16
Standard	25	25	25	25	25	-	-	-
Unknown serum	-	-	-	-	-	25	25	25
^{125}I-Thyroxine	500	500	500	500	500	500	500	500
Amerlex T4 antibody suspension	500	500	500	500	500	500	500	500

Vortex mix. Incubate at room temperature for at least 45 minutes.

Centrifuge

Decant and count.

All volumes are in microlitres.

TABLE 4

Amerlex Cortisol RIA Kit Assay Protocol

	Cortisol Standard (µg/100ml)						Unknowns		
Tube##	0 1,2	1 3,4	4 5,6	10 7,8	28 9,10	60 11,12	1 13,14	2 15,16	etc. etc.
Standard plasma*	50	50	50	50	50	50	-	-	
Unknown plasma	-	-	-	-	-	-	50	50	
^{125}I-labelled cortisol derivative	200	200	200	200	200	200	200	200	
Amerlex cortisol antibody suspension	200	200	200	200	200	200	200	200	

Vortex mix.

Cover tube and incubate for 1 hour at 37°C.

Centrifuge at 25°C for 15 min. at 3000 rpm.

Decant supernatant by a gentle continuous movement.

so that the precipitate will not be disturbed.

Keep the tubes inverted onto a tissue placed on to a

tissue paper to drain for 3 to 10 min.

Blot the rims of the tubes.

Count.

*All volumes are in microlitres.

```
1                                   S T A T I S T I C A L   A N A L Y S I S   S Y S T E M                    12:52 TUESDAY, MAY 11, 1982

NOTE: THE JOB AMRT HAS BEEN RUN UNDER RELEASE 79.5 OF SAS AT THE UNIVERSITY OF MISSOURI (006381).

NOTE: SAS OPTIONS SPECIFIED ARE:
      SORT=4


1          DATA ONE;
2          INPUT AN DATE DAY SPECIE PERIOD AMRT PMRT 22-24 HT 25-28 AMAT PMAT T3 36-38
3          T4 40-43 CORT 45-48;
4          AMRT=AMRT/10;PMRT=PMRT/10;T3=T3/100;T4=T4/100 ;CORT=CORT/100;
5          CARDS;

NOTE: MISSING VALUES WERE GENERATED AS A RESULT OF PERFORMING
      AN OPERATION ON MISSING VALUES.
      EACH PLACE IS GIVEN BY: (NUMBER OF TIMES) AT (LINE):(COLUMN).

      158 AT 4:30   108 AT 4:40   108 AT 4:53

NOTE: DATA SET WORK.ONE HAS 424 OBSERVATIONS AND 13 VARIABLES. 176 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.23 SECONDS AND 180K.

430        PROC PRINT;

NOTE: THE PROCEDURE PRINT USED 0.58 SECONDS AND 172K AND PRINTED PAGES 1 TO 8.

431        PROC SORT;BY PERIOD SPECIE;

NOTE: 4 CYLINDERS DYNAMICALLY ALLOCATED PER SORT WORK DATA SET.
NOTE: DATA SET WORK.ONE HAS 424 OBSERVATIONS AND 13 VARIABLES. 176 OBS/TRK.
NOTE: THE PROCEDURE SORT USED 0.75 SECONDS AND 180K.

432        PROC CORR;BY PERIOD SPECIE;
433        VAR AMRT AMAT PMRT PMAT;

NOTE: THE PROCEDURE CORR USED 0.23 SECONDS AND 172K AND PRINTED PAGES 9 TO 16.

434        PROC GLM;
435        CLASSES AN PERIOD SPECIE;
436        MODEL T3 T4 CORT AMRT PMRT HT=SPECIE AN(SPECIE) PERIOD SPECIE*PERIOD;
437        MEANS AN(SPECIE) SPECIE PERIOD SPECIE*PERIOD/DUNCAN;
438        LSMEANS AN(SPECIE) PERIOD|SPECIE/PDIFF;

NOTE: THE PROCEDURE GLM USED 2.16 SECONDS AND 208K AND PRINTED PAGES 17 TO 64.

439        DATA T&C;SET ONE;
440        Y=AMRT;T=1;OUTPUT;
441        Y=PMRT;T=2;OUTPUT;

NOTE: DATA SET WORK.T&C HAS 848 OBSERVATIONS AND 15 VARIABLES. 153 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.10 SECONDS AND 180K.

442        PROC GLM; CLASSES AN PERIOD SPECIE T;
443        MODEL Y=SPECIE|T|PERIOD AN(SPECIE);
444        LSMEANS SPECIE|T|PERIOD/PDIFF;
```

OBS	AN	DATE	DAY	SPECIE	PERIOD	AMRT	PMRT	HT	AMAT	PMAT	T3	T4	CORT
379	9	41081	24	1	3	37.9	38.2	946	24	35	.	.	.
380	10	41081	24	1	3	38.0	38.9	836	24	35	.	.	.
381	11	41081	24	1	3	37.7	38.1	928	24	35	.	.	.
382	1	41081	24	2	3	37.8	38.0	964	24	35	.	15.08	0.52
383	2	41081	24	2	3	37.7	38.3	892	24	35	.	12.08	0.48
384	3	41081	24	2	3	37.7	37.7	1000	24	35	.	6.62	0.70
385	4	41081	24	2	3	37.6	38.3	874	24	35	.	10.09	1.30
386	1	42781	25	1	4	38.3	38.8	910	24	33	2.62	7.60	4.30
387	2	42781	25	1	4	37.9	38.3	982	24	33	4.81	12.05	2.30
388	3	42781	25	1	4	38.2	38.6	928	24	33	1.31	10.55	1.65
389	4	42781	25	1	4	38.3	39.2	838	24	33	4.12	13.37	3.60
390	5	42781	25	1	4	38.0	38.9	838	24	33	1.42	9.07	2.30
391	6	42781	25	1	4	38.2	39.3	802	24	33	2.78	15.92	5.20
392	7	42781	25	1	4	38.3	38.9	892	24	33	1.86	12.71	0.29
393	8	42781	25	1	4	38.4	39.1	874	24	33	.	.	.
394	9	42781	25	1	4	38.4	39.3	874	24	33	.	.	.
395	10	42781	25	1	4	38.2	39.3	802	24	33	.	.	.
396	11	42781	25	1	4	37.8	38.7	838	24	33	.	.	.
397	1	42781	25	2	4	37.5	38.9	748	24	33	.	16.13	0.43
398	2	42781	25	2	4	38.3	39.1	856	24	33	.	14.93	1.40
399	1	42981	26	1	4	38.0	38.8	856	21	33	1.67	11.42	1.00
400	2	42981	26	1	4	37.9	38.4	910	21	33	3.51	10.20	1.15
401	3	42981	26	1	4	37.9	38.6	874	21	33	2.53	9.72	1.95
402	4	42981	26	1	4	37.8	38.8	820	21	33	2.63	13.66	1.85
403	5	42981	26	1	4	38.2	38.6	928	21	33	0.03	13.72	3.20
404	6	42981	26	1	4	38.1	38.4	946	21	33	3.55	10.17	2.30
405	7	42981	26	1	4	38.2	39.4	784	21	33	1.89	7.79	0.66
406	8	42981	26	1	4	38.3	38.5	964	21	33	.	.	.
407	9	42981	26	1	4	38.3	38.3	1000	21	33	.	.	.
408	10	42981	26	1	4	38.1	38.2	982	21	33	.	.	.
409	11	42981	26	1	4	38.0	37.9	1018	21	33	.	.	.
410	1	42981	26	2	4	38.0	38.2	964	21	33	.	12.51	0.48
411	2	42981	26	2	4	39.5	39.2	1054	21	33	.	12.41	1.08
412	1	50181	27	1	4	37.8	38.8	820	18	31	4.78	10.91	1.05
413	2	50181	27	1	4	37.9	38.3	928	18	31	2.90	14.12	0.52
414	3	50181	27	1	4	37.8	38.7	838	18	31	2.68	12.65	0.68
415	4	50181	27	1	4	37.6	38.5	838	18	31	3.88	10.43	0.52
416	5	50181	27	1	4	37.9	39.0	802	18	31	2.27	12.16	0.68
417	6	50181	27	1	4	37.6	38.4	892	18	31	2.73	9.83	1.75
418	7	50181	27	1	4	37.7	38.6	838	18	31	3.09	9.63	2.45
419	8	50181	27	1	4	37.2	38.7	730	18	31	.	.	.
420	9	50181	27	1	4	37.6	39.0	748	18	31	.	.	.
421	10	50181	27	1	4	38.2	39.1	838	18	31	.	.	.
422	11	50181	27	1	4	37.7	38.6	838	18	31	.	.	.
423	1	50181	27	2	4	37.8	38.2	988	18	31	.	13.02	1.30
424	2	50181	27	2	4	38.5	39.3	854	18	31	.	10.56	1.70

OBS	AN	DATE	DAY	SPECIE	PERIOD	AMRT	PMRT	HT	AMAT	PMAT	T3	T4	CORT
1	1	112080	1	1	1	38.2	40.3	622	19	28	1.90	2.86	7.60
2	2	112080	1	1	1	38.8	39.5	874	19	28	3.53	9.62	0.94
3	3	112080	1	1	1	39.6	40.2	892	19	28	2.97	0.32	0.76
4	4	112080	1	1	1	37.9	39.7	676	19	28	4.63	7.66	1.35
5	5	112080	1	1	1	38.2	39.9	694	19	28	2.90	10.29	3.35
6	6	112080	1	1	1	39.1	39.8	874	19	28	3.06	8.15	1.90
7	7	112080	1	1	1	39.0	39.8	856	19	28	3.06	10.92	3.80
8	8	112080	1	1	1	38.8	40.0	784	19	28	.	.	.
9	9	112080	1	1	1	37.5	40.0	550	19	28	.	.	.
10	10	112080	1	1	1	38.6	39.8	784	19	28	.	.	.
11	11	112080	1	1	1	38.5	39.6	802	19	28	.	.	.
12	1	112080	1	2	1	39.5	41.0	730	19	28	0.77	6.44	2.05
13	2	112080	1	2	1	38.4	40.0	712	19	28	0.90	11.17	3.50
14	3	112080	1	2	1	38.5	39.5	820	19	28	2.37	8.63	1.75
15	4	112080	1	2	1	38.2	39.6	748	19	28	2.19	19.62	2.05
16	5	112080	1	2	1	38.2	39.9	694	19	28	1.41	13.32	0.82
17	6	112080	1	2	1	39.7	41.0	766	19	28	0.56	11.53	1.10
18	1	112780	2	1	1	38.8	39.2	928	18	27	1.44	2.87	3.20
19	2	112780	2	1	1	37.8	39.1	766	18	27	3.57	7.34	10.50
20	3	112780	2	1	1	37.5	39.6	622	18	27	1.63	6.73	4.00
21	4	112780	2	1	1	36.9	39.5	532	18	27	2.99	6.09	4.30
22	5	112780	2	1	1	37.3	39.2	658	18	27	2.08	1.35	5.10
23	6	112780	2	1	1	37.8	39.3	730	18	27	0.66	6.96	5.20
24	7	112780	2	1	1	38.6	39.4	856	18	27	0.93	4.63	1.90
25	8	112780	2	1	1	38.2	39.4	820	18	27	.	.	.
26	9	112780	2	1	1	37.0	39.1	622	18	27	.	.	.
27	10	112780	2	1	1	37.5	39.6	622	18	27	.	.	.
28	11	112780	2	1	1	37.4	39.7	586	18	27	.	.	.
29	1	112780	2	2	1	39.7	41.0	766	18	27	1.65	8.06	4.60
30	2	112780	2	2	1	37.9	39.5	712	18	27	0.80	9.30	3.00
31	3	112780	2	2	1	38.4	40.1	694	18	27	0.68	0.08	1.30
32	4	112780	2	2	1	38.0	39.5	730	18	27	0.31	9.35	3.40
33	5	112780	2	2	1	38.8	39.1	946	18	27	0.05	16.63	2.70
34	6	112780	2	2	1	38.2	39.9	694	18	27	0.26	9.94	0.90
35	1	120380	3	1	1	37.8	40.2	568	20	34	2.89	2.42	10.60
36	2	120380	3	1	1	38.5	39.3	730	20	34	1.83	9.16	0.62
37	3	120380	3	1	1	38.0	39.7	694	20	34	3.05	10.26	1.62
38	4	120380	3	1	1	37.5	40.5	460	20	34	1.93	9.23	0.66
39	5	120380	3	1	1	38.1	40.0	461	20	34	3.58	10.26	4.90
40	6	120380	3	1	2	38.8	39.8	820	20	34	3.24	5.28	5.40
41	7	120380	3	1	1	38.6	39.9	766	20	34	1.70	5.83	5.60
42	8	120380	3	1	1	38.0	39.8	676	20	34	.	.	.
43	9	120380	3	1	1	37.5	39.6	622	20	34	.	.	.
44	10	120380	3	1	1	39.0	39.3	946	20	34	.	.	.
45	11	120380	3	1	1	38.3	39.4	802	20	34	.	.	.
46	1	120380	3	2	1	39.2	39.2	1000	20	34	0.21	7.41	0.80
47	2	120380	3	2	1	38.1	39.3	784	20	34	0.23	9.30	1.45
48	3	120380	3	2	1	39.8	40.6	856	20	34	0.86	12.68	1.50
49	4	120380	3	2	1	38.7	39.2	910	20	34	1.26	8.76	0.80
50	5	120380	3	2	1	38.2	39.2	820	20	34	1.23	12.71	0.80
51	6	120380	3	2	1	38.5	39.2	892	20	34	2.21	6.14	1.23
52	1	120880	4	1	1	40.7	40.8	982	14	30	0.29	7.31	3.00
53	2	120880	4	1	1	37.1	39.1	640	14	30	0.01	8.67	2.10
54	3	120880	4	1	1	36.9	40.2	406	14	30	0.25	8.72	2.25

OBS	AN	DATE	DAY	SPECIE	PERIOD	AMRT	PMRT	HT	AMAT	PMAT	T3	T4	CORT
55	4	120880	4	1	1	37.1	40.6	370	14	30	0.55	8.02	2.60
56	5	120880	4	1	1	37.5	40.1	532	14	30	0.16	7.04	1.05
57	6	120880	4	1	1	37.4	40.3	478	14	30	0.13	9.13	6.10
58	7	120880	4	1	1	39.5	41.2	694	14	30	1.10	4.50	3.40
59	8	120880	4	1	1	38.7	40.2	730	14	30	.	.	.
60	9	120880	4	1	1	37.2	39.8	532	14	30	.	.	.
61	10	120880	4	1	1	37.7	39.5	676	14	30	.	.	.
62	11	120880	4	1	1	36.9	39.4	550	14	30	.	.	.
63	1	120880	4	2	1	39.2	39.2	1000	14	30	0.45	10.81	3.90
64	2	120880	4	2	1	38.1	39.3	784	14	30	0.26	9.55	1.80
65	3	120880	4	2	1	39.8	40.6	856	14	30	0.87	16.62	7.00
66	4	120880	4	2	1	38.7	39.2	910	14	30	1.93	12.48	8.00
67	5	120880	4	2	1	38.2	39.2	820	14	30	0.58	12.04	3.50
68	6	120880	4	2	1	38.5	39.2	892	14	30	1.18	8.43	1.95
69	1	121080	5	1	1	38.6	40.5	658	18	30	2.34	12.13	2.25
70	2	121080	5	1	1	38.7	39.1	856	18	30	2.38	13.84	3.30
71	3	121080	5	1	1	38.9	39.8	838	18	30	2.17	9.33	1.10
72	4	121080	5	1	1	38.3	39.6	766	18	30	3.16	14.67	3.70
73	5	121080	5	1	1	39.0	39.7	874	18	30	2.15	13.13	2.95
74	6	121080	5	1	1	39.0	39.9	838	18	30	3.28	15.49	4.70
75	7	121080	5	1	1	39.4	39.9	910	18	30	2.47	10.93	6.40
76	8	121080	5	1	1	38.7	39.5	856	18	30	.	.	.
77	9	121080	5	1	1	38.3	40.2	640	18	30	.	.	.
78	10	121080	5	1	1	38.5	39.8	766	18	30	.	.	.
79	11	121080	5	1	1	38.6	39.7	802	18	30	.	.	.
80	1	121080	5	2	1	40.5	41.2	838	18	30	0.22	9.16	4.80
81	2	121080	5	2	1	38.0	38.3	946	18	30	1.42	15.53	1.35
82	3	121080	5	2	1	38.3	40.3	640	18	30	1.98	14.14	4.30
83	4	121080	5	2	1	38.6	38.7	982	18	30	2.22	11.97	3.00
84	5	121080	5	2	1	38.6	38.8	964	18	30	2.02	13.70	3.90
85	6	121080	5	2	1	38.5	38.9	928	18	30	2.60	14.75	2.90
86	1	121280	6	1	2	37.7	39.0	766	12	21	1.32	8.50	9.40
87	2	121280	6	1	2	39.9	39.8	1018	12	21	1.98	13.30	13.00
88	3	121280	6	1	2	38.4	39.1	874	12	21	1.76	11.49	2.60
89	4	121280	6	1	2	38.7	38.8	982	12	21	2.92	13.47	4.40
90	5	121280	6	1	2	39.5	39.3	1036	12	21	2.60	9.14	4.70
91	6	121280	6	1	2	39.5	39.5	1000	12	21	3.63	15.54	8.60
92	7	121280	6	1	2	39.9	39.0	1162	12	21	2.97	16.12	6.10
93	8	121280	6	1	2	39.0	39.5	910	12	21	.	.	.
94	9	121280	6	1	2	38.9	39.5	890	12	21	.	.	.
95	10	121280	6	1	2	38.1	38.6	910	12	21	.	.	.
96	11	121280	6	1	2	39.1	38.8	1044	12	21	.	.	.
97	1	121280	6	2	2	40.1	40.1	1000	12	21	0.89	12.56	7.80
98	2	121280	6	2	2	38.1	38.6	91	12	21	0.99	3.65	2.70
99	4	121280	6	2	2	38.5	38.6	982	12	21	1.47	5.40	2.60
100	5	121280	6	2	2	38.9	38.6	1054	12	21	1.40	14.59	3.50
101	6	121280	6	2	2	38.1	38.8	874	12	21	1.45	7.79	1.50
102	1	122280	7	1	2	37.9	40.2	586	16	29	2.42	11.90	1.05
103	2	122280	7	1	2	39.2	39.9	874	16	29	3.90	16.46	0.29
104	3	122280	7	1	2	38.3	39.9	730	16	29	2.22	12.88	1.50
105	4	122280	7	1	2	39.0	40.0	820	16	29	1.93	12.88	2.70
106	5	122280	7	1	2	39.0	41.2	604	16	29	3.06	14.36	2.10
107	6	122280	7	1	2	38.1	39.8	694	16	29	0.75	10.60	4.30
108	7	122280	7	1	2	39.0	40.1	802	16	29	0.76	5.60	2.20

OBS	AN	DATE	DAY	SPECIE	PERIOD	AMRT	PMRT	HT	AMAT	PMAT	T3	T4	CORT
109	8	122280	7	1	2	39.5	40.1	892	16	29	.	.	.
110	9	122280	7	1	2	38.7	40.9	604	16	29	.	.	.
111	10	122280	7	1	2	39.3	40.1	856	16	29	.	.	.
112	11	122280	7	1	2	38.6	39.5	838	16	29	.	.	.
113	1	122280	7	2	2	38.9	40.0	802	16	29	2.03	10.80	1.75
114	2	122280	7	2	2	37.9	38.6	874	16	29	1.41	10.66	0.78
115	3	122280	7	2	2	38.7	39.5	856	16	29	2.51	14.71	0.72
116	4	122280	7	2	2	38.9	39.1	964	16	29	1.91	16.86	1.20
117	5	122280	7	2	2	38.8	39.4	892	16	29	2.25	14.68	1.00
118	6	122280	7	2	2	38.9	40.1	784	16	29	2.95	13.12	1.08
119	1	123180	8	1	2	38.0	40.4	568	17	32	0.61	6.90	1.25
120	2	123180	8	1	2	38.7	39.6	838	17	32	2.05	13.76	1.00
121	3	123180	8	1	2	38.2	39.7	730	17	32	1.11	11.68	2.25
122	4	123180	8	1	2	37.6	40.3	550	17	32	1.44	13.10	1.45
123	5	123180	8	1	2	38.3	40.0	694	17	32	0.22	8.81	2.40
124	6	123180	8	1	2	38.4	40.2	676	17	32	1.07	9.26	5.40
125	7	123180	8	1	2	39.3	41.0	694	17	32	1.67	12.01	3.60
126	8	123180	8	1	2	38.0	39.4	748	17	32	.	.	.
127	9	123180	8	1	2	38.5	39.7	784	17	32	.	.	.
128	10	123180	8	1	2	39.1	40.3	784	17	32	.	.	.
129	11	123180	8	1	2	38.4	39.2	856	17	32	.	.	.
130	1	123180	8	2	2	39.4	40.1	964	17	32	1.34	13.75	1.50
131	2	123180	8	2	2	38.2	39.3	802	17	32	3.38	15.25	2.25
132	3	123180	8	2	2	39.0	39.3	946	17	32	3.57	16.93	0.88
133	4	123180	8	2	2	38.8	39.2	928	17	32	3.33	18.43	1.50
134	5	123180	8	2	2	38.6	39.5	838	17	32	3.40	16.22	1.40
135	6	123180	8	2	2	39.0	39.7	874	17	32	2.94	15.80	4.50
136	1	10281	9	1	2	38.6	39.8	460	17	33	1.63	4.96	2.50
137	2	10281	9	1	2	37.9	39.7	694	17	33	0.49	12.08	2.00
138	3	10281	9	1	2	37.8	40.2	568	17	33	0.76	9.06	1.50
139	4	10281	9	1	2	38.1	40.2	442	17	33	0.15	11.51	1.05
140	5	10281	9	1	2	37.5	40.2	660	17	33	1.14	7.14	2.70
141	6	10281	9	1	2	37.2	39.5	496	17	33	1.14	9.82	4.80
142	7	10281	9	1	2	37.8	40.0	658	17	33	0.12	7.76	5.60
143	8	10281	9	1	2	37.7	39.7	604	17	33	.	.	.
144	9	10281	9	1	2	37.7	39.9	568	17	33	.	.	.
145	10	10281	9	1	2	38.0	40.1	676	17	33	.	.	.
146	11	10281	9	1	2	37.1	39.5	568	17	33	.	.	.
147	1	10281	9	2	2	38.5	40.0	730	17	33	2.11	12.31	1.80
148	2	10281	9	2	2	37.9	37.9	1000	17	33	0.56	12.94	3.10
149	3	10281	9	2	2	37.8	39.3	730	17	33	1.60	18.99	0.95
150	4	10281	9	2	2	38.3	39.1	856	17	33	0.94	15.10	0.81
151	5	10281	9	2	2	40.2	40.0	1036	17	33	2.93	13.92	4.20
152	6	10281	9	2	2	38.1	39.9	676	17	33	2.00	13.63	2.80
153	1	11281	10	1	2	37.9	40.2	582	11	23	0.85	8.23	1.25
154	2	11281	10	1	2	38.0	39.4	748	11	23	1.31	11.62	5.00
155	3	11281	10	1	2	36.6	38.9	586	11	23	1.30	11.48	3.80
156	4	11281	10	1	2	37.5	40.0	950	11	23	1.85	13.17	1.00
157	5	11281	10	1	2	37.0	39.4	568	11	23	0.24	5.80	2.00
158	6	11281	10	1	2	36.6	36.6	1000	11	23	1.33	8.35	7.00
159	7	11281	10	1	2	36.7	38.8	622	11	23	1.51	11.38	7.60
160	8	11281	10	1	2	36.5	39.0	550	11	23	.	.	.
161	9	11281	10	1	2	36.6	40.0	388	11	23	.	.	.
162	10	11281	10	1	2	37.7	40.3	406	11	23	.	.	.

OBS	AN	DATE	DAY	SPECIE	PERIOD	AMRT	PMRT	HT	AMAT	PMAT	T3	T4	CORT
163	11	11281	10	1	2	36.8	39.8	460	11	23	.	.	.
164	1	11281	10	2	2	37.6	39.0	748	11	23	0.60	13.36	1.50
165	2	11281	10	2	2	37.5	39.3	676	11	23	0.97	14.79	3.50
166	3	11281	10	2	2	37.6	38.5	838	11	23	0.62	18.60	4.80
167	4	11281	10	2	2	37.6	39.0	748	11	23	2.43	14.86	1.50
168	5	11281	10	2	2	37.4	39.0	712	11	23	1.11	13.88	4.80
169	6	11281	10	2	2	38.0	39.5	730	11	23	0.91	13.63	4.10
170	1	11481	11	1	2	36.7	40.8	262	11	32	0.86	5.33	0.96
171	2	11481	11	1	2	37.9	40.6	514	11	32	1.78	9.33	2.00
172	3	11481	11	1	2	38.2	40.7	550	11	32	1.20	13.10	4.20
173	4	11481	11	1	2	38.6	41.0	568	11	32	1.00	8.09	2.00
174	5	11481	11	1	2	38.2	40.2	604	11	32	1.07	7.71	2.75
175	6	11481	11	1	2	37.7	40.4	604	11	32	1.73	9.14	4.60
176	7	11481	11	1	2	38.5	40.7	460	11	32	1.17	7.94	5.60
177	8	11481	11	1	2	38.7	40.4	658	11	32	.	.	.
178	9	11481	11	1	2	38.7	41.5	496	11	32	.	.	.
179	10	11481	11	1	2	37.2	40.8	352	11	32	.	.	.
180	11	11481	11	1	2	36.6	40.0	388	11	32	.	.	.
181	1	11481	11	2	2	38.6	40.2	712	11	32	0.13	5.46	2.15
182	2	11481	11	2	2	38.6	39.5	838	11	32	1.47	14.34	2.10
183	3	11481	11	2	2	38.4	39.7	766	11	32	1.31	16.34	0.61
184	4	11481	11	2	2	38.2	39.8	712	11	32	2.36	15.91	0.58
185	5	11481	11	2	2	38.1	39.2	802	11	32	1.96	18.06	2.30
186	6	11481	11	2	2	38.3	40.0	694	11	32	1.94	15.91	0.98
187	1	11681	12	1	2	38.0	40.0	640	13	30	0.30	11.42	1.20
188	2	11681	12	1	2	37.8	39.8	640	13	30	4.13	5.19	1.30
189	3	11681	12	1	2	38.1	39.9	676	13	30	1.09	10.96	1.50
190	4	11681	12	1	2	37.2	40.9	334	13	30	1.22	11.81	2.50
191	5	11681	12	1	2	38.1	39.8	694	13	30	2.20	4.23	0.23
192	6	11681	12	1	2	38.2	40.2	640	13	30	0.24	13.13	4.00
193	7	11681	12	1	2	37.9	39.6	694	13	30	0.65	5.20	1.30
194	8	11681	12	1	2	38.4	39.4	820	13	30	.	.	.
195	9	11681	12	1	2	38.6	40.5	658	13	30	.	.	.
196	10	11681	12	1	2	37.9	39.9	640	13	30	.	.	.
197	11	11681	12	1	2	37.4	39.2	676	13	30	.	.	.
198	1	11681	12	2	2	38.5	39.8	766	13	30	1.77	8.07	0.62
199	2	11681	12	2	2	38.0	39.9	658	13	30	0.28	12.69	0.60
200	3	11681	12	2	2	38.0	39.5	730	13	30	1.25	11.46	0.86
201	4	11681	12	2	2	37.7	39.2	730	13	30	0.22	12.53	1.30
202	5	11681	12	2	2	38.0	39.2	784	13	30	0.92	10.69	1.40
203	6	11681	12	2	2	37.9	40.2	586	13	30	0.33	11.19	1.30
204	1	13081	13	1	2	38.2	39.9	604	12	28	2.20	10.32	0.94
205	2	13081	13	1	2	37.9	39.2	766	12	28	2.78	6.59	7.00
206	3	13081	13	1	2	38.1	39.2	802	12	28	3.10	8.55	2.60
207	4	13081	13	1	2	38.8	38.6	1036	12	28	3.85	9.38	2.40
208	5	13081	13	1	2	38.4	39.7	766	12	28	2.15	8.27	1.65
209	6	13081	13	1	2	38.9	39.5	892	12	28	1.38	12.01	7.40
210	7	13081	13	1	2	39.1	38.8	1054	12	28	2.17	7.35	6.80
211	8	13081	13	1	2	38.3	39.3	820	12	28	.	.	.
212	9	13081	13	1	2	38.3	39.5	784	12	28	.	.	.
213	10	13081	13	1	2	38.0	40.0	640	12	28	.	.	.
214	11	13081	13	1	2	38.4	38.3	1018	12	28	.	.	.
215	1	13081	13	2	2	38.9	39.2	946	12	28	1.45	7.95	1.70
216	2	13081	13	2	2	37.9	38.0	982	12	28	0.14	8.36	1.40

OBS	AN	DATE	DAY	SPECIE	PERIOD	AMRT	PMRT	HT	AMAT	PMAT	T3	T4	CORT
217	3	13081	13	2	2	38.2	39.1	838	12	28	0.91	13.02	1.55
218	4	13081	13	2	2	39.3	40.1	856	12	28	0.10	13.06	1.50
219	5	13081	13	2	2	38.4	38.9	910	12	28	0.59	10.22	5.20
220	6	13081	13	2	2	38.1	40.2	622	12	28	0.41	10.52	3.00
221	1	20381	14	1	3	37.7	39.3	712	17	29	1.97	11.35	2.10
222	2	20381	14	1	3	38.0	38.7	874	17	29	3.39	5.19	1.20
223	3	20381	14	1	3	38.1	38.9	856	17	29	3.20	10.96	2.20
224	4	20381	14	1	3	38.5	38.0	1090	17	29	2.10	11.83	5.00
225	5	20381	14	1	3	38.6	38.9	946	17	29	2.01	4.23	3.00
226	6	20381	14	1	3	38.3	38.9	892	17	29	3.66	13.12	7.00
227	7	20381	14	1	3	38.7	39.3	892	17	29	2.63	5.20	4.80
228	8	20381	14	1	3	38.1	38.0	1016	17	29	.	.	.
229	9	20381	14	1	3	38.1	38.7	892	17	29	.	.	.
230	10	20381	14	1	3	37.7	39.1	748	17	29	.	.	.
231	11	20381	14	1	3	37.2	39.1	838	17	29	.	.	.
232	1	20381	14	2	3	37.9	38.3	928	17	29	.	13.95	2.20
233	2	20381	14	2	3	37.5	38.5	820	17	29	.	12.88	0.84
234	3	20381	14	2	3	37.6	38.1	946	17	29	.	11.87	1.30
235	4	20381	14	2	3	38.5	39.5	820	17	29	.	8.55	1.05
236	1	20581	15	1	3	37.9	40.3	568	19	33	2.34	10.25	0.60
237	2	20581	15	1	3	38.1	39.4	766	19	33	2.57	9.61	5.20
238	3	20581	15	1	3	38.0	39.5	730	19	33	2.93	8.97	4.40
239	4	20581	15	1	3	38.0	39.9	658	19	33	2.18	10.54	4.60
240	5	20581	15	1	3	38.9	39.2	946	19	33	3.67	9.84	4.80
241	6	20581	15	1	3	38.0	39.3	946	19	33	1.88	9.22	3.50
242	7	20581	15	1	3	38.5	40.2	694	19	33	3.90	10.34	4.50
243	8	20581	15	1	3	38.5	39.5	820	19	33	.	.	.
244	9	20581	15	1	3	37.7	39.5	676	19	33	.	.	.
245	10	20581	15	1	3	37.8	40.2	568	19	33	.	.	.
246	11	20581	15	1	3	37.7	39.4	694	19	33	.	.	.
247	1	20581	15	2	3	38.3	40.0	694	19	33	.	11.42	1.00
248	2	20581	15	2	3	37.6	39.2	712	19	33	.	9.62	1.50
249	3	20581	15	2	3	37.7	38.2	910	19	33	.	9.85	2.70
250	4	20581	15	2	3	38.3	39.8	730	19	33	.	10.87	0.70
251	1	22381	16	1	3	38.6	39.0	928	20	34	2.53	9.57	2.90
252	2	22381	16	1	3	39.4	41.6	604	20	34	2.11	9.67	3.70
253	3	22381	16	1	3	37.8	39.2	748	20	34	3.49	10.38	5.40
254	4	22381	16	1	3	38.3	39.5	784	20	34	3.48	11.52	1.35
255	5	22381	16	1	3	38.1	39.1	820	20	34	2.32	9.95	1.90
256	6	22381	16	1	3	38.2	39.1	832	20	34	2.48	10.34	2.90
257	7	22381	16	1	3	38.5	39.1	892	20	34	3.00	11.02	2.25
258	8	22381	16	1	3	38.3	38.9	892	20	34	.	.	.
259	9	22381	16	1	3	38.3	39.0	874	20	34	.	.	.
260	10	22381	16	1	3	38.3	39.1	856	20	34	.	.	.
261	11	22381	16	1	3	38.1	38.9	856	20	34	.	.	.
262	1	22381	16	2	3	38.1	39.5	748	20	34	.	10.52	1.20
263	2	22381	16	2	3	37.8	39.2	748	20	34	.	13.56	0.94
264	3	22381	16	2	3	38.2	39.2	820	20	34	.	11.18	1.75
265	4	22381	16	2	3	38.2	39.8	712	20	34	.	12.86	0.84
266	1	22581	17	1	3	38.2	39.7	730	19	33	2.41	12.04	2.10
267	2	22581	17	1	3	40.0	41.0	820	19	33	1.83	11.12	1.85
268	3	22581	17	1	3	38.3	39.0	874	19	33	1.96	13.37	1.35
269	4	22581	17	1	3	38.4	39.3	838	19	33	2.71	11.10	4.80
270	5	22581	17	1	3	38.2	39.2	820	19	33	3.44	11.29	1.90

OBS	AN	DATE	DAY	SPECIE	PERIOD	AMRT	PMRT	HT	AMAT	PMAT	T3	T4	CORT
271	6	22581	17	1	3	38.2	39.4	784	19	33	2.61	9.68	2.90
272	7	22581	17	1	3	38.7	39.4	874	19	33	2.83	11.43	2.25
273	8	22581	17	1	3	38.2	39.8	766	19	33	.	.	.
274	9	22581	17	1	3	38.3	39.9	892	19	33	.	.	.
275	10	22581	17	1	3	37.0	39.9	478	19	33	.	.	.
276	11	22581	17	1	3	38.0	39.2	784	19	33	.	.	.
277	1	22581	17	2	3	38.7	39.1	928	19	33	.	20.20	0.52
278	2	22581	17	2	3	38.4	39.1	874	19	33	.	19.97	2.80
279	3	22581	17	2	3	38.5	39.1	892	19	33	.	12.82	1.05
280	4	22581	17	2	3	38.8	39.4	892	19	33	.	15.73	1.05
281	1	22781	18	1	3	38.3	39.6	766	18	33	2.17	12.48	2.25
282	2	22781	18	1	3	40.2	40.7	910	18	33	3.38	12.72	2.00
283	3	22781	18	1	3	38.2	39.2	820	18	33	2.20	14.07	1.05
284	4	22781	18	1	3	38.7	38.9	964	18	33	3.05	12.76	2.90
285	5	22781	18	1	3	38.4	38.6	964	18	33	0.63	11.76	2.57
286	6	22781	18	1	3	38.5	39.1	892	18	33	1.31	11.92	2.30
287	7	22781	18	1	3	38.7	39.5	856	18	33	1.11	13.51	4.90
288	8	22781	18	1	3	38.3	39.2	838	18	33	.	.	.
289	9	22781	18	1	3	38.2	38.4	964	18	33	.	.	.
290	10	22781	18	1	3	38.3	39.3	820	18	33	.	.	.
291	11	22781	18	1	3	38.6	38.6	1000	18	33	.	.	.
292	1	22781	18	2	3	38.7	40.2	730	18	33	.	21.07	1.50
293	2	22781	18	2	3	38.5	39.9	748	18	33	.	16.44	1.65
294	3	22781	18	2	3	38.5	40.5	640	18	33	.	19.27	2.30
295	4	22781	18	2	3	38.1	39.6	730	18	33	.	21.95	0.62
296	1	31681	19	1	3	39.0	39.6	892	24	37	0.84	7.90	1.40
297	2	31681	19	1	3	37.6	38.1	910	24	37	2.01	12.51	0.56
298	3	31681	19	1	3	37.7	39.2	730	24	37	2.14	6.99	1.92
299	4	31681	19	1	3	37.6	38.6	820	24	37	2.86	8.34	1.40
300	5	31681	19	1	3	37.9	38.4	910	24	37	1.44	8.73	1.70
301	6	31681	19	1	3	39.0	40.4	748	24	37	0.99	9.53	2.50
302	7	31681	19	1	3	37.7	38.6	910	24	37	0.72	8.34	0.71
303	8	31681	19	1	3	39.7	39.8	982	24	37	.	.	.
304	9	31681	19	1	3	37.8	38.5	874	24	37	.	.	.
305	10	31681	19	1	3	37.8	38.8	820	24	37	.	.	.
306	11	31681	19	1	3	37.8	38.6	856	24	37	.	.	.
307	1	31681	19	2	3	37.2	38.1	830	24	37	.	26.50	0.88
308	2	31681	19	2	3	38.1	38.1	1000	24	37	.	23.80	0.62
309	3	31681	19	2	3	37.9	38.6	1054	24	37	.	26.16	1.25
310	4	31681	19	2	3	38.4	39.5	802	24	37	.	24.54	0.86
311	1	31881	20	1	3	38.2	38.1	1018	24	36	3.39	5.88	4.30
312	2	31881	20	1	3	38.0	37.7	1054	24	36	2.26	9.67	1.15
313	3	31881	20	1	3	37.5	37.6	982	24	36	4.14	8.94	0.73
314	4	31881	20	1	3	38.6	38.4	1036	24	36	3.71	11.63	1.80
315	5	31881	20	1	3	37.9	40.0	856	24	36	2.74	9.44	0.57
316	6	31881	20	1	3	38.4	38.6	712	24	36	3.37	11.94	1.75
317	7	31881	20	1	3	38.5	38.3	982	24	36	4.25	7.77	0.51
318	8	31881	20	1	3	38.1	38.6	964	24	36	.	.	.
319	9	31881	20	1	3	38.1	38.6	910	24	36	.	.	.
320	10	31881	20	1	3	37.9	38.5	874	24	36	.	.	.
321	11	31881	20	1	3	38.0	38.1	982	24	36	.	.	.
322	1	31881	20	2	3	37.3	37.6	946	24	36	.	20.59	1.30
323	2	31881	20	2	3	37.8	38.2	928	24	36	.	11.16	0.46
324	3	31881	20	2	3	37.9	37.7	1036	24	36	.	11.16	0.82

OBS	AN	DATE	DAY	SPECIE	PERIOD	AMRT	PMRT	HT	AMAT	PMAT	T3	T4	CORT
325	4	31881	20	2	3	38.3	39.4	802	24	36	.	6.64	0.90
326	1	32081	21	1	3	37.9	37.5	1072	25	38	2.35	11.67	0.68
327	2	32081	21	1	3	37.9	37.7	1036	25	38	3.05	4.88	0.52
328	3	32081	21	1	3	38.0	37.9	1018	25	38	1.38	9.02	0.94
329	4	32081	21	1	3	38.4	38.2	1036	25	38	2.42	1.13	0.84
330	5	32081	21	1	3	38.5	38.2	1054	25	38	3.30	8.93	0.58
331	6	32081	21	1	3	38.1	38.1	1000	25	38	1.18	5.01	0.48
332	7	32081	21	1	3	38.2	38.2	1000	25	38	1.63	8.95	1.60
333	8	32081	21	1	3	38.3	38.0	1054	25	38	.	.	.
334	9	32081	21	1	3	37.9	37.7	1036	25	38	.	.	.
335	10	32081	21	1	3	38.6	38.8	964	25	38	.	.	.
336	11	32081	21	1	3	37.5	37.7	964	25	38	.	.	.
337	1	32081	21	2	3	37.5	37.5	1000	25	38	.	13.30	0.76
338	2	32081	21	2	3	37.7	38.0	946	25	38	.	7.60	0.80
339	3	32081	21	2	3	37.9	37.7	1036	25	38	.	12.01	0.20
340	4	32081	21	2	3	38.4	39.0	892	25	38	.	10.33	0.58
341	1	40681	22	1	3	37.9	37.4	1090	23	36	3.74	4.05	3.20
342	2	40681	22	1	3	37.8	37.7	1018	23	36	2.53	5.10	1.90
343	3	40681	22	1	3	37.9	38.8	838	23	36	4.17	10.88	0.98
344	4	40681	22	1	3	37.8	39.2	748	23	36	3.14	14.84	1.30
345	5	40681	22	1	3	37.9	37.6	1054	23	36	2.69	2.08	1.20
346	6	40681	22	1	3	38.0	39.3	766	23	36	1.99	3.37	2.60
347	7	40681	22	1	3	37.8	37.3	1090	23	36	1.63	3.04	3.20
348	8	40681	22	1	3	38.1	37.7	1072	23	36	.	.	.
349	9	40681	22	1	3	37.8	37.3	1090	23	36	.	.	.
350	10	40681	22	1	3	38.0	39.2	784	23	36	.	.	.
351	11	40681	22	1	3	37.5	37.2	1054	23	36	.	.	.
352	1	40681	22	2	3	37.8	38.7	838	23	36	.	16.52	0.58
353	2	40681	22	2	3	38.0	38.8	856	23	36	.	11.49	0.63
354	3	40681	22	2	3	37.8	38.7	838	23	36	.	10.50	0.60
355	4	40681	22	2	3	37.2	37.9	910	23	36	.	11.89	1.65
356	1	40881	23	1	3	37.6	38.4	856	19	37	3.24	9.67	0.84
357	2	40881	23	1	3	37.6	38.0	928	19	37	3.09	7.75	6.40
358	3	40881	23	1	3	37.7	38.4	874	19	37	1.47	10.48	1.80
359	4	40881	23	1	3	37.6	38.8	784	19	37	3.07	6.64	1.05
360	5	40881	23	1	3	38.1	38.6	910	19	37	2.12	6.61	1.85
361	6	40881	23	1	3	37.6	38.2	892	19	37	2.76	9.04	2.60
362	7	40881	23	1	3	37.7	38.2	910	19	37	1.66	9.05	2.30
363	8	40881	23	1	3	38.1	38.4	946	19	37	.	.	.
364	9	40881	23	1	3	37.9	38.2	946	19	37	.	.	.
365	10	40881	23	1	3	38.4	38.9	910	19	37	.	.	.
366	11	40881	23	1	3	37.8	38.4	892	19	37	.	.	.
367	1	40881	23	2	3	37.7	38.2	910	19	37	.	15.93	0.47
368	2	40881	23	2	3	38.8	38.7	874	19	37	.	12.60	0.74
369	3	40881	23	2	3	37.6	37.8	964	19	37	.	13.68	0.80
370	4	40881	23	2	3	37.3	37.9	892	19	37	.	5.95	0.74
371	1	41081	24	1	3	37.8	38.4	910	24	35	3.23	7.48	1.85
372	2	41081	24	1	3	38.1	38.8	874	24	35	2.62	10.01	6.20
373	3	41081	24	1	3	37.7	38.4	874	24	35	0.74	13.09	2.00
374	4	41081	24	1	3	37.7	38.1	928	24	35	3.68	12.35	0.58
375	5	41081	24	1	3	38.0	38.0	1000	24	35	0.89	7.45	6.74
376	6	41081	24	1	3	37.7	38.1	928	24	35	1.48	9.29	2.55
377	7	41081	24	1	3	38.2	38.2	1000	24	35	3.78	8.32	1.90
378	8	41081	24	1	3	38.4	38.2	1036	24	35	.	.	.

MODIFICATION OF THE RHOAD FORMULA

The modified Rhoad Formula used in this study was based on the fact that the animals appeared to have cooled off sufficiently at night as reflected in the 06:00Tre. Ingraham *et al.*, (1979) found afternoon rectal temperature to be more highly correlated with morning rectal temperature than afternoon THI. This is an indication that the animal stores the heat for the day on top of what it started the day with; in this regard, the modified Rhoad Formula is a good measure of the per cent rise in rectal temperature.

The point needs to be made though, that the modified Rhoad Formula may not be a good measure of heat tolerance since rectal temperature may vary with different periods in a given season. Observation of an elevated 06:00Tre is an indication that the animal did not cool off sufficiently during the night and may thus be under a twenty four hour stress. In such instances, the modified Rhoad Formula should not be used because it does not reflect the continuous heat stress the animal is exposed to during each twenty four hour period.

PHYSIOLOGIC RESPONSES OF SAVANNA BROWN GOATS AND YANKASA SHEEP TO HARMATTAN AND HOT-DRY SEASONS

By

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AN ABSTRACT OF A THESIS

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wider variation in rectal temperture during the harmattan.

The present data indicate that acclimatization of the brown goats and Yankasa sheep to harmattan involves the moblization cortisol for chemical thermogenesis. However, during the hot-dry season, decrease in adrenocortical activity was observed.

Mean normal estrous cycle length for the Savanna brown goats and Yankasa sheep were 21.0 ± 0.87 and 16.5 ± 0.39 days respectively. The duration of estrus was significantly ($P>0.01$) higher in the brown goat than in Yankasa sheep during both seasons. Estrual period decreased significantly ($P>0.05$) in the sheep during the hot-dry season. During the harmattan, 72.7% of estrus activity in the brown goat began during the day while 61.5% started at night during the hot-dry season; comparative values for Yankasa sheep were 57.1 and 70% respectively.

In the attempt to evaluate and compare the physiologic responses of Savanna brown goats and Yankasa sheep to harmattan and hot-dry seasons, studies were conducted to measure the circulating levels of triiodothyronine (T3), thyroxine (T4), and cortisol. Other physiologic responses measured included rectal tempterature, heat tolerance, length of estrous cycle, onset and duration of estrus.

Thirteen each of adult cycling Savanna brown goats and Yankasa sheep were used after preconditioning for two weeks. The animals were grazed during the day and housed in pens under a common roof after grazing and at night. A feed supplement of wheat offal mixed with either guinea corn or cotton seed was provided; water was available *ad libitum*. Thyroid hormones (T3 and T4) and cortisol were analysed using radioimmunoassay. Rectal temperature was measured using a digital therometer at 06:00h and at 14:00h after 8h exposure to field conditions and a modified Rhoad's formula was used to calculate heat tolerance. Estrus was observed thrice daily at 8-hour intervals.

Plasma levels of T3, T4, and cortisol of Savanna brown goats during the harmattan were 1.86ng/ml, 9.66µg/ml and 3.54µg/dl respectively; comparable values for Yankasa sheep were 2.64, 12.03 and 2.4. During the hot-dry season, plasma levels of T3, T4, and cortisol of the brown goats were 2.61, 10.34µg/ml and 2.16µg/dl respectively. Sheep plasma T4 and cortisol were 14.09µg/dl and 1.40µg/dl respectively.

Afternoon rectal temperature of goat and sheep rose by 1.7 and 1.0^{o}C. Thus, while the sheep was remarkably thermostable during both seasons, the goat adopted a thermoregulatory strategy that involved