THE EFFECT OF SEASON AND NUTRITION ON THE REPRODUCTIVE POTENTIAL AND SEXUAL CHARACTERISTICS OF BOER GOAT BUCKS

by

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DEDICATION

- *To my father and mother for their encouragement, faith in me and everlasting love. Thank you for guiding me to and through this wonderful opportunity and helping me to achieve this goal.*

- *To my brothers and sisters Doret, Ardu, Liana, Paulette and Erik for their contribution in supporting me throughout my years of study.*

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DECLARATION

I hereby declare that this dissertation submitted by me to University of the Free State for the degree, **Magister Scientiae Agriculturae**, is my own independent work and has not previously been submitted by me at another University. I furthermore cede copyright of the dissertation in favour of the University of the Free State.

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CHAPTER 1

GENERAL INTRODUCTION

Goats provide a small, but nevertheless acceptable and affordable source of animal protein in the form of meat and milk. This is particularly important for the low-income rural communities of South Africa, who cannot afford to satisfy their basic nutritional needs. In these areas, household food security is a major problem.

Commercial farmers have also recently discovered the economical benefits of farming with goats. Most of these farmers farm with goats in a mixed farming system, to browse the roughage and scrubs that are not utilised by cattle and sheep. In this way better and more efficient use is made of the veld. Goats are also known to be capable of utilizing plants on farms that due to its inaccessible terrain or thick arboreous vegetation cannot be used by other ruminants. For these reasons goats are often used to open the veld for cattle to graze in cases of bush encroachment.

Boer and indigenous goats can be regarded as very adaptable, thriving in all climatic regions of South Africa, including the tropical, sub-tropical bush and semi-arid regions of the Karoo and greater Kalahari. Goats are also able to maintain their dietary protein intake during droughts and dry seasons by being hardier, less selective in diets than other ruminants and being able to more readily tolerate poor nutrition and even certain toxic plants. Goats are also more resistant to parasites and diseases than other ruminants. Goats and in this case the Boer goat, with their excellent reproductive performance which can be seen as an indicator of their environmental compatibility.

Boer goats have a reputation for high fertility, with conception rates averaging 98% for does bred under good management and nutrition environments (Campbell, 1984). Reproductive efficiency is one of the main factors determining the overall productivity of livestock farming operations. It thus determines the number of excess stock for sale and the meat and milk available for human consumption. However, there are two major factors that influence and sometimes determine or limit the reproductive performance of goats. These factors are season and nutrition. The effect

of these factors on the female has been extensively studied, but researchers have neglected to study their effects on buck fertility and/or reproductive activity.

Seasonal variations in sexual activity in small ruminants are mainly due to changes in daylight length as well as veld quantity and quality throughout the year. Photoperiod as such determines the circannual activity rhythms of the hypothalamus-hypophysis-testis axis. Thus, for some small ruminant breeds in temperate climates, shorter days from summer to fall are stimulants for reproduction activity, and longer days from winter to spring reduce or inhibit this activity. On the other hand, tropical breeds are known to be less seasonal. Very little is known regarding the seasonal sexual activity patterns of the Boer goat under sub-tropical South African farming conditions. Several reports have demonstrated that Boer goat females are able to breed outside the natural "short day" breeding season. These goats are less seasonal than most other breeds. It is important however to investigate the seasonality in the buck. If proven that the buck is not seasonal in terms of sexual activity, this characteristic may be useful in producing and marketing weaners throughout the year, with advantages to the farmer. The effect of season on the quality and quantity of natural veld available to the animals cannot be ignored. For instance, animals have a much better body condition when grazing on spring and summer veld than animals that grazed on winter and fall pasture – due to seasonal effects (rainfall and ambient temperature) on the veld or pasture.

Nutritional restrictions are a major constraint to small ruminant production in tropical and subtropical areas, due to its effect on reproduction and fertility. These nutritional deficiencies delay the onset of puberty, increase the interval between parturitions and depress the libido as well as production and semen characteristics in the buck.

The objective of this study was to monitor and evaluate the effects of nutrition and season on the potential fertility of young Boer goat bucks in terms of sexual activity, testicular and seminal characteristics – with the aim of increasing reproductive efficiency in the Boer goat.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Boer goats under good managerial and nutritional environments have a reputation for a high fertility rate, especially in the doe. The contribution of the buck or male in the attainment of this achievement (e.g. high kidding rate), however is often neglected or ignored. Reproduction efficiency is one of the main factors determining the overall productivity of the Boer goat as it determines the excess stock available for sale (meat) or breeding (Van der Nest, 1997).

To determine the reproductive potential of the seasonal Boer goat buck, it is essential to evaluate the semen quality and the sexual characteristics associated with successful fertility. These characteristics fluctuate especially according to season. The low fertility often observed in mid-summer, is not necessarily due to a drop in fertility of the does, but principally linked to the quality of sperm produced during this period by the male (Corteel, 1978). It was also suggested that the fertilizing capacity of goat spermatozoa drastically reduces during certain months of the year (Greyling & Grobbelaar, 1983). According to Hafez and Hafez (2000) and Loubser (1981), sperm quality can be defined in terms of semen volume, pH, colour, sperm motility, concentration or density of the ejaculate, percentage live and abnormal sperm. Closely related to these semen characteristics are certain scrotal and hormonal aspects, which are indicative of spermatogenesis. These aspects are reflected by scrotal circumference and testicular volume (as an indicator of testicular size), scrotal skin thickness (as a possible indicator of fat deposition around the testes), libido or sex drive and serum testosterone levels in the male (Greyling & Taylor, 1999; Schwalbach *et al.*, 2000).

2.2 INDICATORS OF SEMEN QUALITY AND SEXUAL CHARACTERISTICS AND FACTORS INVOLVED

2.2.1 Semen volume

Semen production as reflected by semen volume or ejaculate volume in males, is influenced by a variety of factors such as breed, age, environment (daylight length, ambient temperature, humidity, etc.), nutrition, reproductive management, method of semen collection, etc. – which results in a large variation of the semen characteristics (Folch, 1983; Karagiannidis *et al.*, 2000).

Greyling and Grobbelaar (1983), as well as Loubser and Van Niekerk (1983b) quoted a mean semen volume over a period of time of 1.56 ml and 1.06 ml in Boer and Angora bucks, respectively. The mean semen production in Spanish goats has been shown to vary between 0.4 ± 0.05ml in the spring and 1.01 ± 0.06ml in autumn (Perez & Mateos, 1996), while an annual mean of 1.05 ± 0.01 ml has been quoted by Roca *et al.* (1992), for the same breed. Comparatively means of 1.43 ± 0.04ml and 1.40 ± 0.04ml for semen volume have been quoted over all four seasons in Chios and Friesian sheep breeds, respectively (Karagiannidis *et al.*, 2000).

The volume of semen produced during the breeding season in Angora bucks was found to increase from February (end of summer) and reach a peak between March and July (onset of autumn to onset of winter), whereafter it gradually declined (Loubser & Van Niekerk, 1983b). High ambient temperatures have always been considered to be a factor effecting sperm quality. However studies tend to show that sperm quality in goats are not affected by high summer temperatures. Spermatozoa present in the epididymis appear unaffected, while damage can be induced in the testes during the latter stages of spermatogenesis (Braden & Mattner, 1970; Roca et al., 1992).

Regarding semen volume in mature Boer goats, Greyling and Grobbelaar (1983), recorded fairly constant ejaculate volumes throughout the year, with a peak (2.03 ± 1.21ml) in July (mid-winter). The artificial vagina also yielded significantly ($P<0.01$) less semen (1.56ml vs 2.48ml), compared to semen collected by the technique of

electrical stimulation. Treatment by controlled lightning to overcome the photoperiodic effect of the season, eliminated seasonal variation in semen production in Alpine and Saanen bucks (Delgadillo *et al.*, 1991). In the ram or buck, it has been proposed that light (photoperiod) acts on gonadotrophin (GnRH) release – via the hypothalamus, which in turn controls reproduction according to (i) a gonad-independent mechanism and (ii) a change in the magnitude of the feedback in relation to the increase or decrease in day light length (Pelletier & Ortavant, 1975).

Nutritional management

Nutritional stress can delay the onset of puberty and decrease sperm production in the buck. Young males are more susceptible to nutritional shortages than mature animals (Mukasa-Mugerwa & Ezaz, 1992). The efficiency of spermatogenesis is higher in adult rams, compared to pubertal rams (Toe *et al.*, 1994). In addition, nutritional effects can have an influence on the endocrine system and also on the spermatogenic function of the testes (Jainudeen & Hafez, 2000). Prolonged and severe malnutrition, especially in terms of energy or protein deficiency leads to a decrease or cessation of spermatogenesis. It has also been suggested that underfeeding and malnutrition can interfere with the regulation of the hypothalamic-pituitary axis, thereby altering gonadal steroid production (Mann & Lutwak-Mann, 1981).

In general, breed as such, does not have an effect on the volume of semen produced. Greyling and Grobbelaar (1983), however observed the quality of semen, following collection by the electrical stimulation, to be higher in the Angora buck, compared to that in the Boer goat. Results regarding semen quality in rams indicate that efficient spermatogenesis or sperm production is established later in the natural breeding season for the more seasonal breeds, like e.g. the Texel (Mandiki *et al.*, 1997). Sheep breeds used in commercial cross breeding programs were found to be more sensitive to photoperiod as such, compared to more hardy, indigenous breeds (Folch, 1983).

2.2.2 Semen colour

The colour of an ejaculate has always been used as an indicator of either semen concentration (density) and possible semen contamination (Greyling & Grobbelaar, 1983). Evans and Maxwell (1987), quote the colour of the ejaculate in small stock to range from a creamy to a milky colour, according to the sperm density of the ejaculate

(3000-4000 x 10^6 sperm per ml). Contamination of the ejaculate can be assessed by abnormal colour occurrences. For example a reddish discoloration of the ejaculate could be indicative of blood being present in the sample. The source of this blood can vary. A yellowish colour (and smell) can assess the presence of urine in the ejaculate sample. This phenomena is common in bucks collected by electrical stimulation due to the overstimulation of the sex glands. A grayish colour is an indication of the presence of leukocytes and possible inflammation of the male reproductive tract (Greyling & Grobbelaar, 1988; Hafez & Hafez, 2000). In general, colour is not affected by factors such as age, season, breed and management. It has been suggested that nutrition and more specifically carotene levels can colour the semen sample (give it a more yellowish colour). However, any factor that has an influence on sperm concentration (density) can indirectly have an effect on ejaculate colour (Greyling, 2001).

2.2.3 Sperm mass motility

Sperm motility as recorded by the mass and individual activity of sperm, has over a long time successfully been used as an indicator of semen quality (Chemineau *et al.*, 1991). Ram semen with more than 85% motility is considered to be of high quality (Hafez & Hafez, 2000).

The parameters used to evaluate sperm motility have included: (i) percentage of sperm that are motile (normal – 70 to 90%), (ii) percentage of sperm which show progressive movement, (iii) sperm velocity (based on a subjective scale of 0-stationary to 5-fast) and (iv) longevity of sperm motility in raw semen at room temperature (20 to 25°C) or a chilled temperature (4 to 6°C) respectively and several endogenous and exogenous factors (Hafez & Hafez, 2000). Mandiki *et al.* (1998) found that sperm motility did not vary greatly over seasons, although Colas (1980) suggested photoperiod to have an effect on sperm motility. Studies done on Boer bucks (ambient temperature ranging between 25-35°C) did not show significant seasonal variation in sperm motility (Greyling & Grobbelaar, 1983), although the motility tended to be lower from June to October (winter to the onset of autumn). High ambient temperature also tends to have an effect on the sperm motility in rams during summer. Karagiannidis *et al.* (2000) reported a low sperm motility during high

ambient temperatures. Lack of proper nutrition can also reduce the reproductive efficiency in males (Bearden & Fuquay, 2000). Malnutrition, particularly low energy intake in the male, reduces growth rate, delays puberty and if severe enough, can permanently impair sperm output and is associated with a reduction of inter alia, sperm motility (Hafez & Hafez, 2000).

Different semen collection techniques, namely the use of the artificial vagina or electrical stimulation can also influence semen motility. Greyling and Grobbelaar (1983), reported than when Boer goat semen was collected with the aid of an artificial vagina, it yielded sperm with a significantly higher ($P<0.05$) motility, compared to semen collected by electrical stimulation. Delgadillo *et al.* (1991) measured endocrine parameters in goat bucks. During the non- breeding season, low LH and testosterone levels were recorded, which could explain the decrease in sperm progressive motility found during this period.

2.2.4 Sperm concentration

Sperm cell concentration is expressed as the number of cells per ml and must be known for each ejaculate in order to make available the maximum number of breeding units (straws), containing a given number of motile sperm per unit (Bearden & Fuquay, 2000). When evaluated macroscopically a thick, sticky ejaculate with a high density (concentration) of sperm can be an indication of the presence of leukocytes and possible inflammation (Greyling & Grobbelaar, 1988). The normal sperm concentration ranges from 3.5×10^6 to 6.0×10^6 sperm/ml in the ram and 2.5×10^6 to 5.0×10^6 sperm/ml in the buck (Hafez & Hafez, 2000).

The influence of different semen collection techniques and season on sperm concentration was stated by Greyling and Grobbelaar (1983), who found the density or sperm concentration of the ejaculate collected by means of an artificial vagina to be significantly higher compared to that following electrical stimulation. Sperm density declined to a minimum value in November (end of spring) in Boer goat bucks and in June (onset of winter) for the Angora goat bucks, with both collection techniques respectively. The same tendency for a higher progressive motility in the breeding season and a low progressive motility during the non-breeding season was recorded in Alpine, Saanen and Damascus goat bucks (Karagiannidis *et al.*, 2000).

The effect of nutrition on semen concentration can never be underestimated, as insufficient nutrient intake is associated with a reduction in sperm concentration (Schwalbach *et al.*, 2000). The influence of melatonin on goat sperm concentration was reported in studies by Trejo *et al.* (2000), who found that sperm concentration in young bucks could be effectively improved when treated with 3mg melatonin daily for a period of 40 days.

2.2.5 Percentage live sperm

According to Hafez and Hafez (2000), the total number of live sperm per insemination is more important than the percentage abnormal sperm and it was stated that the percentage of live sperm and the sperm motility were determinants of semen quality. This percentage live sperm, as an indication of semen quality, is markedly affected by high ambient temperature (Brooks & Ross, 1962). Regarding the percentage live sperm in Boer goat bucks, Greyling and Grobbelaar (1983), recorded a negative correlation between the percentage live sperm and the percentage abnormal sperm when semen was collected by means of the artificial vagina. A significant difference in percentage live sperm was noted between months, with the lowest values recorded in October and January (end of spring to the beginning of summer) for Boer goat bucks.

2.2.6 Percentage abnormal sperm

Morphologic abnormalities of sperm have the greatest impact on the fertility of livestock and when 20% or more of the sperm cells per an ejaculate are abnormal, the ram's potential fertility is questionable (Hafez & Hafez, 2000).

In rams, Colas (1980) and Colas *et al.* (1986) attributed the seasonal variation in sperm quality to the changes in daylight, with the larger proportion of sperm abnormalities occurring during periods of increased day length (outside the natural breeding season). The results presented in the studies of *Roca et al.* (1992), confirm this seasonal pattern in the occurrence of sperm abnormalities. The highest percentage of abnormal spermatozoa was recorded during the winter and the beginning of spring (increasing daylight length period).

According to Hafez and Hafez (2000), heat stress is the cause of large numbers of damaged sperm and periods of high ambient temperature combined with high humidity may render a male temporarily infertile for a period of up to 6 weeks. In temperate areas, hot weather is therefore often associated with an increase in the proportion of sperm abnormalities in the ejaculate (Colas, 1980; Corteel, 1981; Barth & Oko, 1989). However in the studies of Roca *et al.* (1992), sperm quality was best during the hot seasons (summer and the first half of fall), which suggests that the sperm quality of Murciano-Granadina goats was not affected by the high summer temperatures in the Mediterranean region. However Braden and Mattner (1970) found considerable abnormal development of spermatozoa developing in the testes, at the time of elevating environmental temperatures in rams.

With the exception of sperm head abnormalities, most of the parameters studied by Schwalbach *et al.* (2000) (body weight, scrotal circumference, scrotal skin thickness, testicular volume, testicular weight, sperm cell abnormalities, sperm head abnormalities, sperm tail abnormalities), showed a distinct negative relationship with the underfeeding of Boer goat bucks on the occurrence of sperm cell abnormalities. From these results it was possible to conclude that undernutrition has a significant detrimental effect on semen quality in young Boer goat bucks.

2.2.7 Semen pH

The normal pH of buck semen varies between 6.4 and 6.7. When semen has a pH lower than this range, it can be attributed to low prostate and seminal fluid levels and a more alkaline semen could be an indication of inflammation of the accessory glands. (Greyling & Grobbelaar, 1988).

Studies done on Angora goat bucks by Loubser (1981), reported a linear increase in the semen pH from February to August (end of summer to end of winter). A mean pH of 6.81 with limited variation between rams was observed and significant differences were observed between months. This slightly elevated pH observed may be indicative of a low semen quality (Hulet & Ercanbrack, 1962; Loubser, 1981).

2.2.8 Scrotal circumference

Scrotal circumference can be seen as the most useful testicular measurement under farm conditions used to estimate the total number of spermatozoa produced per ejaculate per day. This parameter was found to be 40 % heritable and therefore fast genetic progress can be achieved in a flock by selecting for higher scrotal circumference (Cameron *et al.,* 1984; Bothma, 1991). Scrotal circumference as an indication of testicular size is influenced by several factors.

Schwalbach *et al.* (2000) recorded a significant detrimental effect of underfeeding on scrotal circumference and scrotal skin thickness in goat bucks. Despite the ability of the mature male to maintain sperm production and testosterone secretion under low levels of nutrition, the young male show retarded sexual development and delayed puberty (Hafez & Hafez, 2000).

Furthermore the effect of age was accentuated by Toe *et al.* (1994), who reported that in very old Ile-de-France rams, semen production decreased despite the greater scrotal circumference in spring, compared to the younger animals. Ahmed *et al.* (1996) confirmed a significant seasonal variation in scrotal circumference and this was consistent with the findings of Ritar (1991), who related the decrease in sperm quality during summer to the increase in daylight length and consequent decrease in testicular size.

Scrotal circumference in Ile-de-France rams were significantly lower when treated with an anabolic steroid (50mg nandrolone laurate) in studies done by Greyling *et al.* (1993), compared to controls, with a decrease of 24.5 % in scrotal circumference. In that study the scrotal circumference of the control animals was significantly correlated to body weight (r=0.85), weekly feed intake (r=0.54) and serum testosterone concentration (r=0.3), compared to the treated animals where the corresponding correlations were r=0.48 and r=0.31 for body weight and weekly feed intake respectively. Godfrey *et al.* (1996) found immunisation against GnRH in goats to be effective in suppressing the increase in testes size, male odour and antagonistic behavior that is associated with the seasonal breeding season. Immunisation against GnRH was successful in all goats and in 90% of the bucks the testes remained

underdeveloped for a long period of time following primary immunisation (Godfrey *et al.*, 1996).

2.2.9 Testicular volume

Testis size (or volume) is correlated with semen volume (Mandiki *et al.*, 1998) and acts as a good indicator of the quantity sperm that can be produced (Knight, 1977). However Fresno *et al.* (2000) did not find a significant relationship between semen quality and the testis volume in goat bucks.

It has been reported that continual exposure of rams to short day light maintains testicular size and function at near-maximum levels (Langford *et al.*, 1989 ; Pérez & Mateos, 1993b). The Malagueña breed of bucks recorded a higher annual seminal production, possibly due to being less sensitive to photoperiod. This seminal production was more consistent throughout the year, compared to that of the Verata breed of goat. The sensitivity of testicular size to photoperiod has been shown to differ within breeds (Shresta *et al.*, 1983; Colas *et al* ., 1990; Baril *et al.*, 1993). Mandiki *et al.* (1997) demonstrated that in spring the decrease in testicular size was more prominent in Texel compared to Ile-de-France rams – this corresponded to a higher spermatozoa production in the Ile-de-France rams.

It has been shown that nutritional management may influence testicular growth and the onset of puberty in rams (Mukasa-Mugerwa & Ezaz, 1992), and that undernutrition can reduce testicular volume (Thwaites, 1995; Schwalbach *et al.*, 2000). Prolonged severe malnutrition, particularly energy or protein deficiencies and even water insufficiency leads to a depression or cessation of spermatogenesis and a decrease in semen quality in most species. These effects are accompanied by a decrease in size of the testes and accessory sex glands. Atrophy of the interstitial and Sertoli cell populations may also accompany these changes. These changes are accompanied by reduced plasma testosterone and LH concentrations. It has been suggested that underfeeding, protein malnutrition, and certain hypovitaminoses somehow interfere with the regulation of the hypothalamic-pituitary axis, thereby altering gonadal steroid production. In addition, responses of the accessory sex glands to testosterone stimulation are reduced (Mann & Lutwak-Mann, 1981). Colas *et al.* (1986) and Langford *et al.* (1989) claim that the amplitude of seasonal changes

in testicular size are closely related to that observed in the gonadal function of certain breeds. The range in the ratio of testicular weight to live weight in a large number of species varies between 0.02 and 0.5%, with rams and bucks occupying the upper limit of this range. There is a functional significance in certain species with large testicles and in the case of rams and goats it is to mate a large number of males and females in a very short period of time. A measure of this capacity would be very useful for making the best use of superior males and for planning the mating management (Mandiki *et al.*, 1998).

2.2.10 Scrotal skin thickness

Scrotal skin thickness is measured as a possible indicator of fat deposition around the testes. Schwalbach *et al.* (2000) recorded a significant negative relationship of underfeeding with scrotal skin thickness – with a mean scrotal skin thickness of 2.03mm for Boer goat bucks that were underfed for 30 days (diet consisting only of *Themeda trianda* – CP of 3.84%), compared to a mean scrotal skin thickness of 2.51mm for Boer goat bucks that were supplemented with a well balanced diet (71% *Themeda trianda*, 22% maize, 5.5% molasses and 1.8% urea – CP of 8.1%).

2.2.11 Libido

Despite the production of normal numbers of fertile sperm, rams may have low fertility due to their inability to breed sufficient numbers of ewes. These low-service frequencies result from a lack in libido, poor dexterity or the interference (competition) from other rams (Jainudeen & Hafez, 2000).

Seasonal changes in libido can be related to the modulatory effect of photoperiod on the hypothalamo-hypophyseal activity responsible for changes in serum testosterone and LH levels. In South Africa, the Angora ram for example, was been found to be sexually inactive during January (summer), followed by a dramatic increase in sexual activity - which reaches a peak value in April (autumn). Sexual activity then decreased from June to September (winter - spring), entering a period of sexual quiescence between September and December (spring - early summer). The libido of these Angora rams was significantly higher from March to June (autumn), compared to the other months of the year (Loubser & Van Niekerk, 1983a).

Differences in libido between sheep breeds were recorded by Mandiki *et al.* (1997), who found that Texel rams produced more spermatozoa during autumn compared to the Suffolk and Ill-de-France breeds. Studies showed that a reduction in fertility caused by elevated ambient temperatures to be sustained during the late stages of spermatogenesis but to have little or no effect on semen volume or libido (Howarth, 1969).

Mating behavior is an important aspect of the male reproductive function as it has a direct bearing on the number of females mated and eventually fertilized. In general, a common sign of a severe energy or protein deficiency in the male is the suppression of its endocrine functions, rather than exocrine functions. Testicular function is coupled with diminished libido and arrest of growth and secretory activity of the accessory sex glands (Mann & Lutwak-Mann, 1981). Overfeeding and obesity may result in diminished sexual activity and less willingness and ability to mate and inseminate a female (Walkden-Brown *et al.*, 1992).

There is a paucity of information concerning the effects of trace mineral deficiencies upon male reproductive functions. Iodine deficiency is suspected to be a cause of poor libido and semen characteristics in bulls. Improvement in sperm production and fertility have been noted following supplementary feeding of copper, cobalt, zinc and manganese (Jainudeen & Hafez 2000).

2.2.12 Serum testosterone concentration

The effect of photoperiod on plasma testosterone levels was monitored in studies conducted by Perez and Mateos (1995). Higher testicular steroidogenic activity was recorded during the time of decreasing photoperiod for Verata and Malaguena bucks. In agreement with previous reports, this study showed marked seasonal variation in plasma testosterone levels.

Similar serum testosterone level patterns were observed in bucks and rams by several authors, whether in an isolated blood sample collected weekly or monthly (Degen *et al.*, 1981; Miyamoto *et al.*, 1987) or when frequent sampling were done, (Pelletier *et al.*, 1982; Howland *et al.*, 1985; Walkden-Brown *et al.*, 1992). Higher testosterone secretion was recorded in summer and autumn – with higher peak amplitudes and

frequencies, basal and mean levels being recorded, compared to these recorded in the winter and spring seasons.

The mean monthly plasma testosterone levels from weekly samples in bucks were closely correlated to samples taken at the basal levels, peak values, and general mean concentration patterns. Therefore, it would seem as if a single weekly blood sample for testosterone determination reflects the secretory activity of the testis in bucks in different seasons of the year, and is an accurate guideline for the study of seasonal variation in secretory activity of testosterone (Perez & Mateos 1995).

Pelletier and Almeida (1987) hypothesised that latitude affects testosterone secretory patterns, in Barbarine rams. These animals show slight seasonal variations in plasma testosterone concentrations. Latitude could be the reason why Malagueña bucks, originating from a lower latitude (37°N), recorded a seasonal plasma testosterone concentration increase which is less marked than in Verata bucks. In previous studies it was observed that both semen production and quality were more affected by season and photoperiod in Verata than in Malagueña bucks (Pérez et al., 1991; Pérez & Mateos, 1993a).

Similar to the findings of Munduli *et al.* (1979) in pygmy goat rams, plasma testosterone and LH concentrations of the Angora ram also shows a seasonal secretory pattern (Loubser et al., 1983a). A maximum serum testosterone concentration of 15.86 ng/ml in April (autumn) and a minimum level of 1.17ng/ml in September (onset of spring) were recorded. The serum LH concentration reached a peak of 8.18 ng/ml in May (end of autumn) and a minimum of 1.86 and 1.75 ng/ml in February (end of summer) and December (summer) respectively. As both the serum testosterone and LH concentrations varied seasonally, little or no relationship was found between these two parameters (Loubser *et al.* 1983a).

Certain hormones like melatonin and GnRH can stimulate the central nervous system and the pituitary gland to secrete gonadotrophins (SSH and ICSH) and testosterone. Melatonin is an important component and plays an important role in the seasonal reproductive activities of small ruminants (Adam & Robinson, 1994). This hormone has an effect on both LH and testosterone production, as well as on testes activity in

the buck when administered via exogenous pathways (Asher *et al.*, 1993). Melatonin also has an effect in seasonal semen production on the buck (Chemineau, 1993). Other roles of melatonin include the induction of puberty in small ruminants (Mukasa-Mugerwa & Lahlou-Kassi, 1995). The mechanism by which melatonin acts on the reproduction patterns is not well known, but there is evidence that it stimulates GnRH secretion by acting in the hypothalamus (Trejo et al., 2000).

GnRH is a hormone involved in both LH and FSH secretions and is part of the mechanism that regulates spermatogenesis by testosterone and androgen binding protein secretion (Cunningham, 1997). GnRH is also the principal hypothalamic component for semen production and acts in young males to establish good quality and larger quantities semen from young to adulthood (Trejo *et al.*, 2000).

The mechanisms involved in under- or overfeeding on the reproductive functions of males are not well documented. As in the female, the influence of energy intake appears to be exerted via the hypothalamic-pituitary-gonadal axis (Hunter, 1980). Patterns of LH secretion may be altered and serum concentrations decreased by reduced energy intake. Circulating plasma testosterone concentrations are often decreased by reduced feed intake. These low testosterone concentrations may be due to reduced gonadotropin secretion and/or reduced testicular response to gonadotropins. These effects are often coupled to reduced sensitivity of the accessory sex glands to testosterone (Mann & Lutwak-Mann, 1981).

Prolonged, severe malnutrition, particularly energy or protein deficiencies or water insufficiency, leads to a depression or cessation of spermatogenesis and a decrease in semen quality in most species. These effects are accompanied by a decrease in the size of the testes and accessory sex glands. Atrophy of the interstitial and Sertoli cell populations may accompany these changes (Hunter, 1980). These changes are then also accompanied by a reduced plasma concentration of testosterone and LH. It has been suggested that underfeeding, protein malnutrition, and certain hypovitaminoses somehow interfere with the regulation of the hypothalamic-pituitary axis, thereby altering gonadal steroid production. In addition, responses of accessory sex glands to testosterone stimulation are reduced (Mann & Lutwak-Mann, 1981).

2.2.13 Body weight

Body weight, as a reflection of inter alia the health condition of bucks, is mainly controlled by age and nutrition.

It has been shown that nutritional management may influence testicular growth and the onset of puberty in rams (Mukasa-Mugerwa & Ezaz, 1992), and that undernutrition causes reduced testicular volume (Thwaites, 1995). Mandiki *et al.* (1997) found that testicular mass was significantly related to body weight and Schwalbach *et al.* (2000), concluded that undernutrition has a significant detrimental effect on testicular development and semen quality in young Boer goat bucks. It was suggested that winter supplementation can be beneficial to young Boer goat bucks that are intended to be used during the subsequent spring mating season.

Delgadillo *et al.* (1991) observed seasonal variation in the body weight of Alpine and Saanen bucks. During the natural breeding season the body weight decreased with approximately 7 kg. To explain these seasonal body weight variations in bucks, Solomon & Thwaites, (1997) observed that due to the intense sexual activity during the breeding season, animals spend less time grazing. However, in a study reported by Delgadillo *et al.* (1991), animals exposed to light regime alternations of either 1 month of 16L:8D and 1 month of 8L:16D, bucks constantly gained in body weight over a two year period, in spite of the maintenance of high sexual activity. In this group of animals the ADG was high and similar between long and short day treatments. This last observation suggests that the loss of body weight observed during the sexual season in animals left outdoors is probably not due to sexual activity, but also due to the decreasing daylight length. In fact it was demonstrated that exposure of sheep to short days resulted in slower body weight gain, compared to exposure to long days (Forbes *et al,* 1979; Barenton *et al,* 1987; Gettys *et al,* 1989). The slow growth during short days may, in part, be explained by both decreased feed intake and feed efficiency, but also by lower growth hormone secretion during this period, compared to long days (Terqui, *et al.,* 1984; Barenton *et al.,* 1988).

2.2.14 Other factors

Presence of sexually active females

Sexual activity of the male increases as females in the flock become sexually receptive. When 4 receptive ewes were available, rams mated 3 times more than when only one ewe was in oestrus. The enhanced stimulating effect of a new oestrous animal should be borne in mind under modern husbandry conditions. For instance, the changing of a teaser doe is an effective way to increase sexual behavior in a sluggish male (Hafez & Hafez, 2000).

Presence of other males

The presence of other males while teasing a female or copulating improves the sexual libido of the male. Social hierarchy, however may interfere with sexual activity when several males compete for a single receptive female (Hafez & Hafez, 2000).

Effect of age/experience

The efficiency or ability of copulation of males and females is improved by age and experience (Hafez & Hafez, 2000).

CHAPTER 3

MATERIALS AND METHODS

3.1 LOCATION OF THE STUDY

This study was conducted at the University of the Free State campus in Bloemfontein. The study site is located at a latitude of 29° 06' 30"South, longitude of 26 °11'10" East and an altitude of 1410 m above sea level, in a area where the annual rainfall varies between 500 and 550 mm and occurs predominantly during the summer months (December to April).

The mean maximum monthly ambient temperature during the observation period varied between 16.6 °C and 27.1 °C respectively. The mean minimum monthly ambient temperature varied between 0.2°C and 11.7°C.The corresponding relative humidity varied between 40% and 90%.

3.2 ANIMALS

Initially 16 twelve month old Boer goat bucks were selected to be used in this trial. These bucks were divided into two experimental groups (n=8 per group) in such way to obtain two homogeneous groups, with regard to body weight (BW). During the trial period two rams from each group were removed from the trial due to reasons unrelated to the treatments (injury, lack of adaptation to a confined environment or reluctance to ejaculate in an artificial vagina). Their data were eliminated from the study. In the end, 6 rams (n=6) data from each group was used. The mean body weight of the bucks at the onset of the trial was 42.4 ± 5.3kg. A high plane diet was randomly allocated to one group (Group H) and a low plane diet was allocated to the other group (Group L).

Four young Boer goat does (12 to 14 months old) were used as teasers for the artificial collection of semen and to test the libido of the bucks. The does were

regularly alternated during the semen collection process to maximize the sexual interest of the bucks.

3.3 TRIAL PERIOD

This trial started at the beginning of June 2000 (onset of winter), lasted for a period of 26 weeks and ended at the end of November 2000 (end of spring).

3.4 FEEDING REGIME

A total mixed diet (TMD) based on *Themeda triandra* (Red grass) hay harvested in summer, supplemented with maize meal, molasses, HPK 40, HPK 60 and lucerne at two nutritional levels, namely, a high plane (H) and low plane (L) were given *ad lib* to the two respective experimental groups (Table 3.1). Each group received its respective diet throughout the observation period of 6 months (winter and spring). Sufficient red grass was harvested and bailed during the previous summer season to last for the entire trial period. During the entire period, clean fresh water was always available to the animals *ad lib.*

3.5 THE ADAPTATION PERIOD

The experimental animals were purchased from a Boer goat stud farm near Bloemfontein, where they were maintained extensively on the veld. All the bucks were therefore subjected to a prescribed diet for adaptation for a period of 4 weeks. Initially all bucks were fed a mixture of lucerne and red grass (*Themeda trianda*) ad lib (50 :50) to adapt them to the new environment (feed and facilities). Additionally to the roughage all animals were supplemented with 200g of yellow maize (coarse) per day. Then 2 weeks prior to the onset of the observation period of this trial, each group received their respective diets – a high plane (H) and low plane (L) diet respectively (Table 3.1).

Table 3.1 The composition of the High and Low Plane Diets

	GROUP H (High plane diet)	GROUP L (Low plane diet)
	%	%
Themeda triandra	45	75
Lucerne	10	10
Yellow maize meal (coarse)	30	5.0
HPK 60	5.0	2.5
HPK 40	5.0	2.5
Molasses meal (cal 3000)	5.0	5.0
ME (MJ/kg DM)	7.15	4.67
CP (%)	13	10

The animals were trained during the 6 weeks of adaptation prior to the observation period to use the artificial vagina for semen collection, using oestrogen treated does (2 mg/doe ECP – Estradiol cypionate 2mg/ml) injected 36 hours before collection to induce oestrus. Once the bucks were trained, there was no more need to induce oestrus. It was during this period that the 4 animals (2 from each group) were removed from the trial.

3.6 HOUSING AND HEALTH MANAGEMENT

Animals from both Group H (high plane diet) and Group L (low plane diet) were housed in the same facilities only separated by poldenvale kraals i.e. equal size kraals, same feed and water troughs and were exposed to the same duration of daylight. The two groups were fed *ad lib* at the same time, with the same frequency (8:00 AM and 17:00PM). Both groups were dosed for round- and tapeworms and vaccinated against Pasteurellosis at the beginning of the trial and their hoofs were trimmed when needed during the trial.

3.7 SEMEN COLLECTION

Semen samples from each buck was collected by means of an artificial vagina (AV). Semen was collected twice weekly (between 8:00AM and 10:00AM) throughout the 26-week observation period (winter and spring). In order to have a more realistic and accurate measurement, an average of the two measurements taken in a week (i.e. semen volume, mass motility etc.) was used as the specific measurement for the respective week. Semen collection was performed using one of the four teaser does used during the training period, restrained in the same neck clamp. These females were alternated to maximize the sexual interest of the bucks during the entire observation period.

Preparation of the artificial vagina (AV) entailed the following: The initial temperature of the water used in the AV varied between 40-45°C. The semen collection tubes were maintained in an incubator at 35°C prior to use. Prior to the collection the AV was lubricated with a sterile lubricant. Caution was taken to keep the semen collection tube warm during the semen collection and evaluation processes. Care was taken to have adequate pressure in the AV. A cloth insulator was made especially for temperature control and also served to protect the semen from exposure to light.

A laboratory to perform the semen evaluation was set up adjacent to the semen collection area in the same experimental building. This made it easier and ideal for accurate semen evaluation as most tests were done immediately after semen collection. As soon as the semen samples were collected, all were evaluated for volume, colour and mass motility. A semen smear stained with nigrosine/eosine was immediately prepared for later evaluation. The remaining sample was placed in a water bath (32°C) for about 1-2 hours to be evaluated for sperm concentration.

3.8 MACROSCOPIC EVALUATION OF THE SEMEN (Greyling & Grobbelaar, 1988)

(i) The volume of the ejaculate was measured immediately after collection in the calibrated collection test-tube.

(ii) The colour of the ejaculate was noted as an indication of the semen density and the possibility of semen contamination.

3.9 MICROSCOPIC EVALUATION OF THE SEMEN (Greyling & Grobbelaar, 1988)

(i) The mass motility of the ejaculate was assessed microscopically (x100 magnification) and a value (on a subjective scale of 0-stationary to 5-fast movement) awarded according to the mass motility of the semen sample.

Scale for motility evaluation:

5- Very strong progressive, dark waves (90% plus live cells)

4- Strong progressive undulations (70 to 85% live cells)

3- Weak undulations (50 to 65% live cells)

2- Very few, weak, non-progressive undulations (30 to 45% alive)

1- No undulations (5 to 25% live cells)

0- No movement (all cells dead)

(ii) Sperm concentration determinations were done using a hemocytometer (dilution rate of 1:200) to calculate the density or concentration of the ejaculate ($x10^6$/ml).

(iii) The percentage of the live sperm per ejaculate was determined by microscopic observation (x1000 magnification) of a semen smear stained with nigrosine / eosine. This slide was also used for determining the percentage of abnormalities (x1000 magnification). All sperm cells that stained pink/red were classified as dead. A 100 sperm on each smear from randomly selected areas were counted to determine the percentage live as well as for the determination of the percentage abnormal sperm and expressed as a percentage. Sperm cell abnormalities were expressed as total percentage of abnormalities and included head, mid piece and tail abnormalities.

3.10 BLOOD SAMPLING

Blood samples for serum testosterone determination, were collected every fortnight, early in the morning (8:00) from all the bucks (Group H and Group L) for the entire 26-week observation period. These samples were taken by jugular veni puncture using an 18-gaunge needle attached to a 7 ml vacutainer, plain (red top) blood collection tube. Blood was allowed to clot in the vacutainer tubes for 30-45 minutes at room temperature. Serum was recovered from each blood sample after centrifuging the blood for 15 minutes at 2500 r.p.m. The serum was then separated and stored in a vial at –20°C until assayed for serum testosterone concentration.

3.11 SERUM TESTOSTERONE CONCENTRATION ASSAY

The serum testosterone concentrations were determined using the Automated Chemiluminescence System (Chiron Diagnostic ACS: 180, USA). The Chiron Diagnostic ACS: 180 testosterone assay is based on a competitive immunoassay using direct chemiluminescent technology. Testosterone in the samples binds to an acridinium ester-labeled mouse monoclonal anti-testosterone antibody in the light reagent. Unbound antibody binds to a testosterone derivative convalently coupled to paramagnetic particles in the solid phase. The amount of relative light units is detected by the system. The ACS: 180 testosterone assay sensitivity was 0.11ng/ml. The analytical sensitivity is defined as the concentration of serum testosterone that corresponds to the relative light units (RLUs) of 20 replicate determinations of the testosterone zero standards.

3.12 SCROTAL CIRCUMFERENCE (AS AN INDICATOR OF TESTICULAR SIZE)

Scrotal circumference (cm) of each ram was measured with the aid of a measuring tape placed around the broadest part of the scrotum, as an indication of testis size (Knight, 1977; Greyling & Grobbelaar, 1983). These measurements were recorded every second week, at a specific time (8:00AM to 10:00AM).

3.13 TESTICULAR VOLUME

The testicular volume (scrotal volume) was determined by submerging the entire scrotum containing the testes in a calibrated flask filled with water up to the neck of the scrotum. The quantity of water displaced by the scrotum and testes was recovered and measured as an estimate of the testes volume (Knight, 1977; Greyling *et al,* 1993). The testicular volume was measured from the rear, between the buck's legs, while standing. The scrotum was initially soaked in a bucket full of water (25°C) prior to measuring in order to saturate the skin with water. These measurements were taken at the same time every second week, (8;00AM to 10:00AM), to eliminate the possible effect of environmental temperature.

3.14 SCROTAL SKIN THICKNESS

The scrotal skin thickness was measured with the aid of a caliper. The skin fold thickness was divided by two, to get the scrotal skin thickness. Again the bucks were approached from behind when measuring this parameter. The skin thickness was measured in the middle of the scrotum, on the same spot at the right side of the scrotum for all the animals.

3.15 LIBIDO

Libido or sex drive of the bucks was measured concurrent (twice a week) with semen collection by evaluating their sexual interest and urge to mate when introduced to the doe. Libido was determined using a score (Scale of 0-5) on the reaction time (the time taken by the buck from exposure to the female to mounting and ejaculation). The scoring system used was adapted from (Bothma, 1991) and entailed the following:

5- Mounting and ejaculating in less than 30 seconds
4- Mounting and ejaculating in more than 30 seconds and less than 60 seconds
3- Mounting and ejaculating in more than 60 seconds and less than 90 seconds
2- Mounting and ejaculating in more than 90 seconds and less than 120 seconds
1- Mounting and ejaculating in more than 120 seconds and less than 150 seconds
0- Mounting and ejaculating in more than 150 seconds

3.16 RECTAL TEMPERATURE

Rectal temperatures (°C) in all the bucks were recorded weekly (between 8:00AM and 10:00AM) with the aid of a clinical thermometer. Temperatures were noted after insertion of the clinical thermometer for a period of 1 minute.

3.17 BODY WEIGHT

The body weight (kg) of all bucks was recorded weekly (7:00AM) with the aid of a mobile scale. Body weight was used as an indicator of nutritional status and health of the animals.

3.18 ENVIRONMENTAL FACTORS

The ambient temperature, daylight length and humidity data for the 26 week observation period was obtained from the Weather Bureau in Bloemfontein.

3.19 STATISTICAL ANALYSIS

PROC GLM (General Linear Model) of PC SAS 6.04 was used to analise the data. The repeated measures options of Proc GLM, with weeks as the repeated measure and nutritional groups as the fixed effect, were used (SAS, 1991).

CHAPTER 4

RESULTS

4.1 BODY WEIGHT

The mean body weight of bucks from Group H and Group L recorded during the trial period are set out in Table 4.1 and Figure 4.1. The body weights of both treatment groups increased significantly ($P<0.05$) from the onset of winter (beginning of the trial) to the end of spring. Although the mean body weights in both groups stayed relatively constant during the first 4 weeks, Group H's (high plane of nutrition) mean body weight remained higher than Group L for the rest of the trial period. The mean body weight of Group L increased from 43.8 ± 5.41kg at week 4 (winter), to 48.2 ± 1.54kg in week 26 (end of spring) – an overall increase of 4.4kg. Concurrently in the high plane group, animals gained 21kg during the same period - starting at 42.7 ± 2.53kg at week 4 (winter) to 63.7 ± 1.47kg in week 26. Significant ($P<0.05$) differences in mean body weight between the low and high plane groups were recorded at week 3, 17, 23 and 26 respectively, with animals in Group H being heavier.

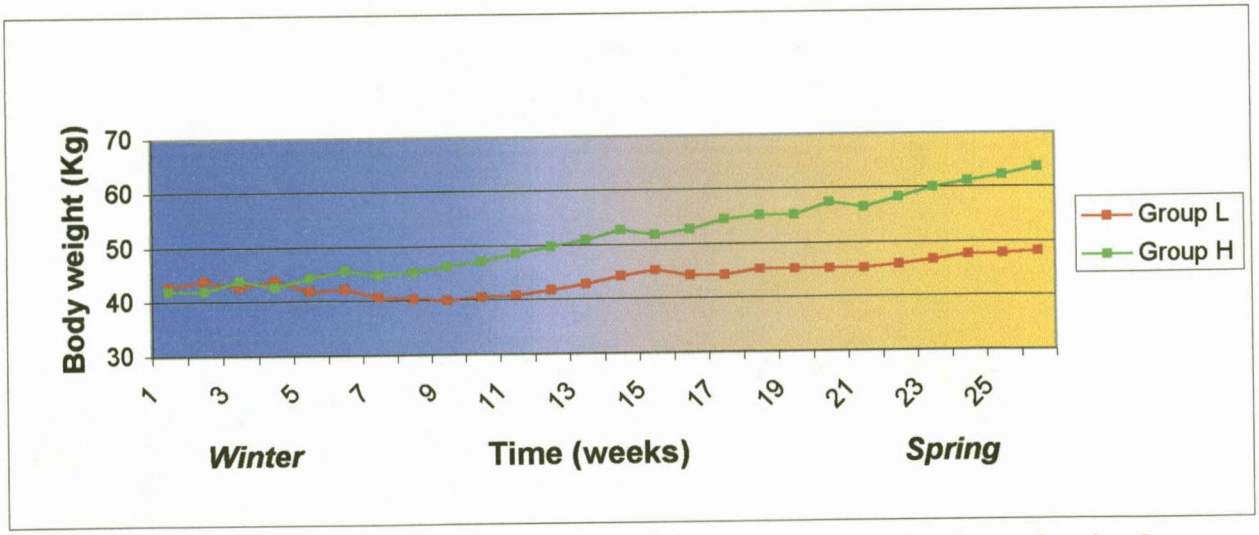

Figure 4.1 The mean body weight (kg) of young Boer goat bucks maintained on a low (Group L) and high (Group H) plane diet

Table 4.1 **The mean (±SD) body weight (kg) of young Boer goat bucks maintained on a low (Group L) and high (Group H) plane diet**

	Group L		Group H	
Week	Mean (kg)	SD	Mean (kg)	SD
1	42.8	±5.32	42.0	±5.28
2	43.8	±5.49	42.0	±5.05
3	42.7[a]	±3.50	43.8[b]	±2.73
4	43.8	±5.41	42.7	±2.53
5	41.8	±4.99	44.3	±4.59
6	42.2	±4.29	45.7	±2.04
7	40.7	±2.61	44.8	±1.72
8	40.3	±3.9	45.3	±1.23
9	40.0	±1.87	46.3	±1.63
10	40.5	±4.45	47.3	±0.84
11	40.8	±4.35	48.7	±1.47
12	41.7	±2.07	49.8	±2.32
13	42.8	±3.06	51.0	±1.16
14	44.2	±1.86	52.7	±0.82
15	45.3	±2.71	51.8	±1.72
16	44.2	±2.99	52.8	±2.64
17	44.2[c]	±3.78	54.5[d]	±1.47
18	45.3	±2.94	55.2	±2.14
19	45.3	±4.45	55.2	±1.87
20	45.2	±2.14	57.5	±2.64
21	45.3	±3.39	56.5	±1.96
22	46.0	±3.27	58.3	±1.86
23	46.8[a]	±3.16	60.0[b]	±2.73
24	47.7	±1.87	61.2	±2.16
25	47.8	±1.84	62.3	±2.34
26	48.2[a]	±1.54	63.7[b]	±1.47

[a,b] Means in the same row with different superscripts differ significantly (P<0.05).
[c,d] Means in the same row with different superscripts differ significantly (P<0.01).

4.2 EVALUATION OF SEMEN

4.2.1 Semen volume

The semen volume recorded during the observation period in both groups (H and L) is set out in Table 4.2 and Figure 4.2. The semen volume stayed fairly constant, ranging between 0.86 ml and 0.47 ml for both treatment groups, with the initial value (onset of winter) being slightly lower than the end value (end of spring) (0.66 vs. 0.7ml respectively). The week on which the semen samples were collected had a significant (P<0.05) effect on the semen volume, however no clear trend was observed. There

was a general tendency for animals from Group H to have a higher volume of ejaculate compared to Group L, throughout the observation period. Significant differences ($P<0.01$) between the two groups were only recorded during week 11 and 12 (end of winter). No significant interaction between time (weeks) and nutritional level of the bucks was recorded for the trait of semen volume.

Table 4.2 The mean (±SD) sperm production (ml) of young Boer goat bucks maintained on a low and high plane diet

	Group L		Group H	
Week	Mean (ml)	SD	Mean (ml)	SD
1	0.64	±0.14	0.68	±0.28
2	0.76	±0.23	0.80	±0.16
3	0.74	±0.21	0.86	±0.32
4	0.69	±0.21	0.60	±0.31
5	0.68	±0.30	0.75	±0.31
6	0.68	±0.17	0.86	±0.21
7	0.63	±0.09	0.66	±0.17
8	0.61	±0.29	0.66	±0.20
9	0.63	±0.21	0.85	±0.25
10	0.59	±0.11	0.71	±0.10
11	0.43^{a}	±0.20	1.03^{b}	±0.23
12	0.38^{a}	±0.12	0.76^{b}	±0.19
13	0.50	±0.17	0.74	±0.24
14	0.53	±0.12	0.67	±0.32
15	0.47	±0.34	0.63	±0.13
16	0.57	±0.10	0.62	±0.21
17	0.73	±0.39	0.69	±0.18
18	0.61	±0.19	0.60	±0.18
19	0.54	±0.16	0.67	±0.23
20	0.50	±0.21	0.52	±0.26
21	0.62	±0.26	0.65	±0.11
22	0.54	±0.13	0.68	±0.20
23	0.48	±0.26	0.60	±0.12
24	0.56	±0.23	0.83	±0.30
25	0.58	±0.24	0.83	±0.21
26	0.57	±0.18	0.82	±0.33

[a,b] Means in the same row with different superscripts differ significantly ($P<0.01$)

4.2.2 Semen colour

No specific trend regarding the subjective evaluation of semen colour was observed during the observation period. Almost every single semen sample was of a milky to cream colour. No contamination (urine or blood) was observed throughout the trial

period. Being a subjective and qualitative measurement of the ejaculate, no additional statistical analyses were carried out.

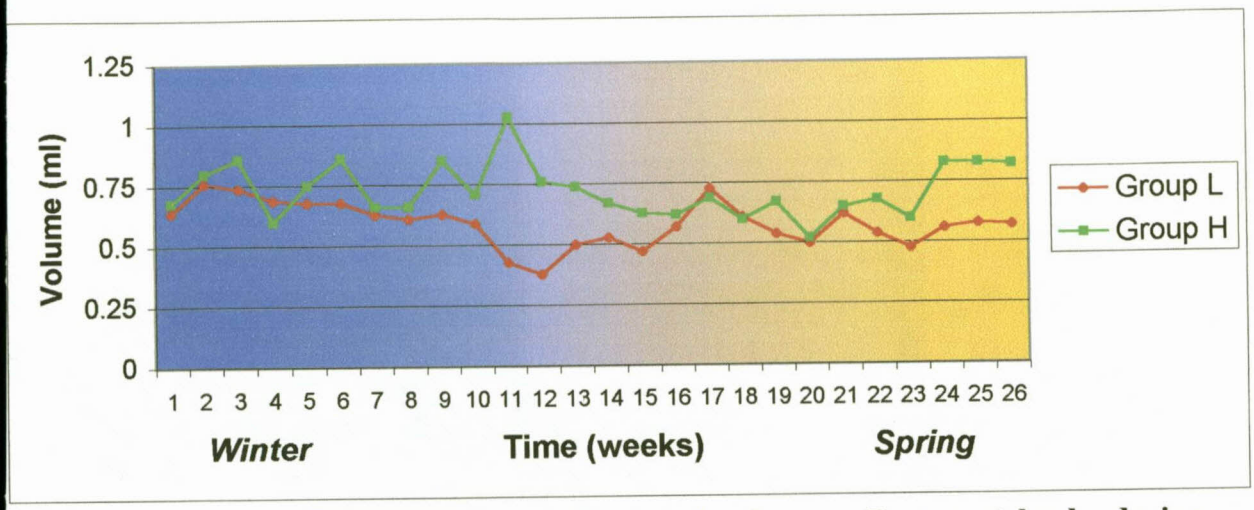

Figure 4.2 The mean semen volume (ml) of young Boer goat bucks during winter and spring on a high and low plane diet

4.2.3 Sperm mass motility

The sperm mass motility results recorded from the onset of winter to the end of spring (26-week period) are set out in Table 4.3 and Figure 4.3. A significant ($P<0.05$) difference in the week for motility during which semen collection was performed (Group H and Group L values), as well as a significant ($P<0.01$) interaction between time (weeks) and nutritional management (treatment) was recorded.

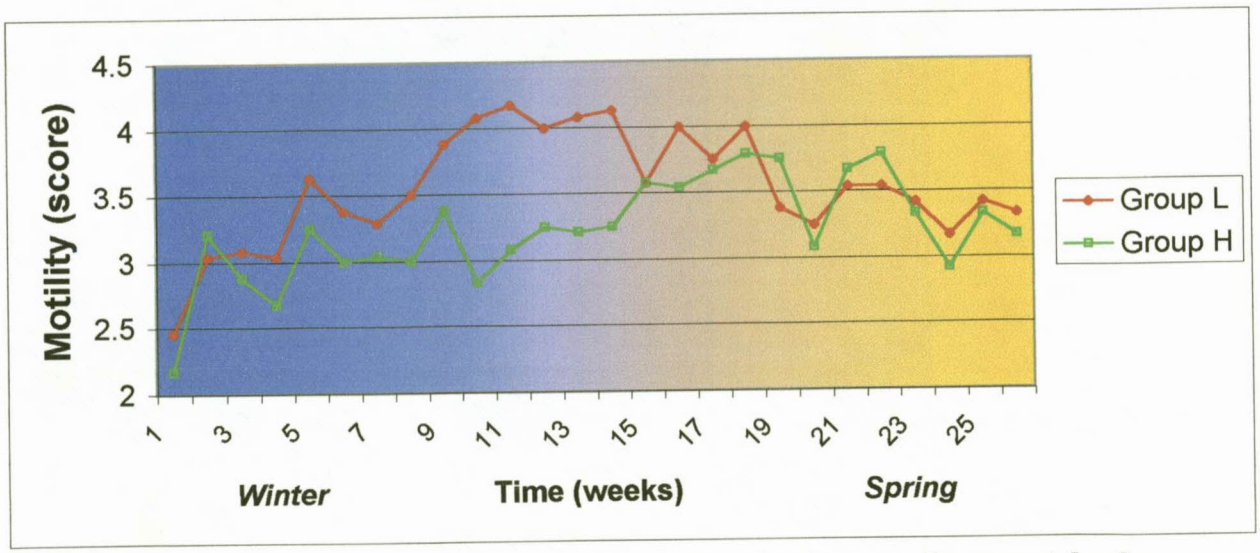

Figure 4.3 The mean sperm mass motility (score) of young Boer goat bucks over a period of time maintained on a low and high plane diet

Table 4.3 **The mean (±SD) sperm mass motility (score) of young Boer goat bucks maintained on a low and high plane diet**

	Group L		Group H	
Week	Mean (score)	SD	Mean (score)	SD
1	2.46	±0.84	2.17	±0.68
2	3.04	±0.62	3.21	±0.62
3	3.08	±0.40	2.88	±0.49
4	3.04	±1.07	2.67	±0.75
5	3.63	±0.90	3.25	±0.80
6	3.38	±0.94	3.00	±0.65
7	3.29	±1.01	3.04	±0.64
8	3.50	±0.70	3.00	±0.70
9	3.88	±0.51	3.38	±0.26
10	4.08^{a}	±0.37	2.83^{b}	±0.68
11	4.17^{a}	±0.60	3.08^{b}	±0.37
12	4.00^{a}	±0.77	3.25^{b}	±0.27
13	4.08^{a}	±0.37	3.21^{b}	±0.48
14	4.13^{a}	±0.30	3.25^{b}	±0.27
15	3.58	±0.58	3.58	±0.58
16	4.00^{a}	±0.38	3.54^{b}	±0.24
17	3.75	±0.82	3.67	±0.68
18	4.00	±0.31	3.79	±0.60
19	3.38	±0.68	3.75	±0.44
20	3.25	±0.61	3.08	±0.37
21	3.54	±0.60	3.67	±0.40
22	3.54	±0.67	3.79	±0.24
23	3.42	±0.49	3.33	±0.40
24	3.17	±0.25	2.92	±0.37
25	3.42	±0.37	3.33	±0.45
26	3.33	±0.40	3.17	±0.40

[a,b] Means in the same row with different superscripts differ significantly ($P<0.05$)

There was a general tendency for the bucks from Group L to maintain a higher sperm motility score for the latter part of the winter and early part of spring. It is also evident that between week 10 and 16 (end of winter to onset of spring), excluding week 15, the sperm motility of bucks in Group L was significantly ($P<0.05$) higher, compared to that of bucks in Group H. For the rest of the observation period values recorded for the two treatment groups were very similar, ranging between 2.46 ±0.84 and 4.0 ±0.32 (on a scale of 0 to 5) for the low plane group (Group L) and 2.17 ±0.68 and 3.9 ±0.6 for the high plane group (Group H).

4.2.4 Sperm concentration

The sperm concentration recorded during the observation period (onset of winter to the end of spring), is set out in Table 4.4 and Figure 4.4. In general, the week during which the semen was collected had a significant ($P<0.05$) effect on sperm concentration for both treatment groups. However there was not a clear pattern throughout the trial. The sperm concentration of the bucks in Group L (mean of 3212 X 10^6 sperm/ml) remained higher than the sperm concentration of the bucks in Group H (mean 2381 X 10^6ml) throughout the observation period. These differences were significant from week 5 onwards.

Table 4.4 The mean (±SD) sperm concentration (x10^6/ml) of young Boer goat bucks maintained on a low and high plane diet.

	Group L		Group H	
Week	Mean (x10^6/ml)	SD	Mean (x10^6/ml)	SD
1	2587	±693.41	2095	±609.02
2	2668	±585.02	2073	±516.55
3	2500	±561.35	2055	±480.61
4	2490	±612.01	1985	±549.64
5	2693[a]	±528.04	2145[b]	±265.46
6	2770[a]	±542.32	2030[b]	±238.66
7	3140[c]	±304.82	2047[d]	±189.70
8	3088[c]	±392.04	2082[d]	±440.33
9	3177[c]	±305.46	2137[d]	±410.54
10	2857[c]	±279.47	1792[d]	±507.91
11	2930[c]	±310.61	1977[d]	±635.53
12	2888[c]	±397.06	1777[d]	±511.53
13	3213[c]	±283.52	2093[d]	±543.34
14	3302[a]	±517.70	2402[b]	±672.41
15	3493[c]	±322.90	2560[d]	±241.16
16	3402[a]	±463.18	2690[b]	±353.10
17	3595[c]	±131.56	2623[d]	±468.85
18	3473[c]	±311.87	2657[d]	±293.77
19	3462[c]	±286.24	2683[d]	±247.92
20	3448[c]	±254.43	2600[d]	±428.85
21	3502[c]	±289.16	2615[d]	±268.38
22	3973[c]	±426.08	3117[d]	±324.57
23	3818[c]	±234.89	2023[d]	±238.46
24	3748[c]	±122.21	2832[d]	±263.39
25	3647[a]	±256.33	3005[b]	±474.96
26	3645[c]	±176.60	2820[d]	±294.61

[a,b] Means in the same row with different superscripts differ significantly ($P<0.05$)

[c,d] Means in the same row with different superscripts differ significantly ($P<0.01$)

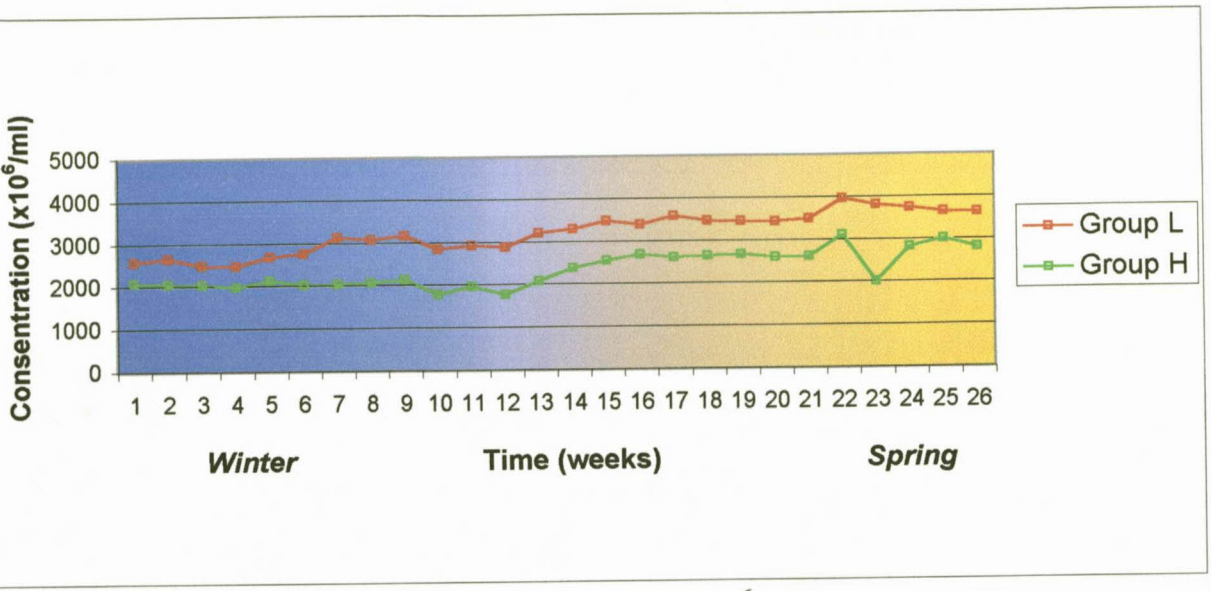

Figure 4.4 The mean sperm concentration (X10^6/ml) for young Boer goat bucks maintained on a low and high plane diet

4.2.5 Percentage live sperm

The percentage of live sperm in the ejaculate recorded during the observation period (onset of winter to the end of spring), is set out in Table 4.5 and Figure 4.5. Both treatment groups seemed to follow the same trend, starting with a low percentage live in winter and ending with a significantly ($P<0.05$) higher percentage live sperm in spring. The week during which the semen was collected had a significant effect ($P<0.05$) in the mean percentage of live sperm cells in the ejaculate for all animals. The most prominent difference in percentage live sperm between the two treatment groups occurred during the first two weeks of winter, when the mean percentage of live sperm for Group L (65.2 ± 17.06%) was significantly ($P<0.05$) higher than that in Group H (28.9 ± 9.85%). A significant difference was only recorded during this period, thereafter the differences in percentage live sperm between treatment groups were minimal and not significant.

4.2.6 Percentage abnormal sperm

The percentage of sperm abnormalities observed in nigrosine/eosine stained semen smears is set out in Table 4.6 and Figure 4.6. The week during which the semen samples were collected had a significant effect ($P<0.05$) on the percentage of abnormal sperm cells for both groups. There was however not a clear seasonal pattern. It is of interest to note that the mean sperm abnormalities for Group L remained

higher than Group H for most of the observation period. However, these differences were only significant ($P<0.05$) for a few weeks of the trial. During the first 3 weeks of winter the mean sperm abnormalities in both treatment groups increased sharply (Group L peaked at 27.5 ± 3.5%) and Group H showed a maximum of 23.3 ± 2.7% abnormal sperm cells. The sperm cell abnormalities thereafter declined rapidly to a mean of 5.5 ± 2.07% for the L Group and 5.17 ± 2.13% for the H Group in week 12 respectively and remained relatively low throughout the rest of the observation period. There were also significant differences recorded between Groups H and L at week 17 ($P<0.01$), 23 ($P<0.05$) and 26 ($P<0.05$). The most common sperm abnormalities recorded in these microscopic evaluations were deviations regarding the tail.

Table 4.5 The mean (±SD) percentage live sperm (%) in Boer goat bucks maintained on a low and high plane diet

	Group L		Group H	
Week	Mean (%)	SD	Mean (%)	SD
1	14.3[a]	±4.41	5.7[b]	±5.12
2	65.2[a]	±17.05	28.7[b]	±9.85
3	44.2	±15.10	40.8	±9.47
4	61.8	±12.27	65.8	±16.46
5	63.0	±12.79	64.0	±4.19
6	64.7	±7.86	68.5	±11.02
7	59.2	±6.17	56.8	±7.80
8	54.7	±18.73	59.0	±7.50
9	57.0	±9.63	60.5	±8.31
10	64.5	±17.09	62.0	±13.19
11	61.0	±3.89	67.2	±14.04
12	63.3	±17.14	60.8	±10.72
13	54.3	±21.39	62.7	±6.53
14	59.0	±15.44	52.7	±8.28
15	59.2	±15.26	46.0	±10.41
16	69.3	±8.52	64.3	±12.87
17	73.0	±4.93	65.5	±6.86
18	71.2	±3.92	66.5	±12.66
19	69.7	±8.04	71.8	±6.96
20	69.7	±9.13	62.7	±14.19
21	64.8	±6.43	70.3	±3.32
22	64.5	±4.32	66.2	±11.75
23	58.3	±13.04	60.2	±7.08
24	58.2	±7.35	57.7	±3.55
25	61.0	±5.65	58.7	±5.68
26	64.5	±17.96	56.7	±10.11

[a,b] Means in the same row with different superscripts differ significantly ($P<0.05$)

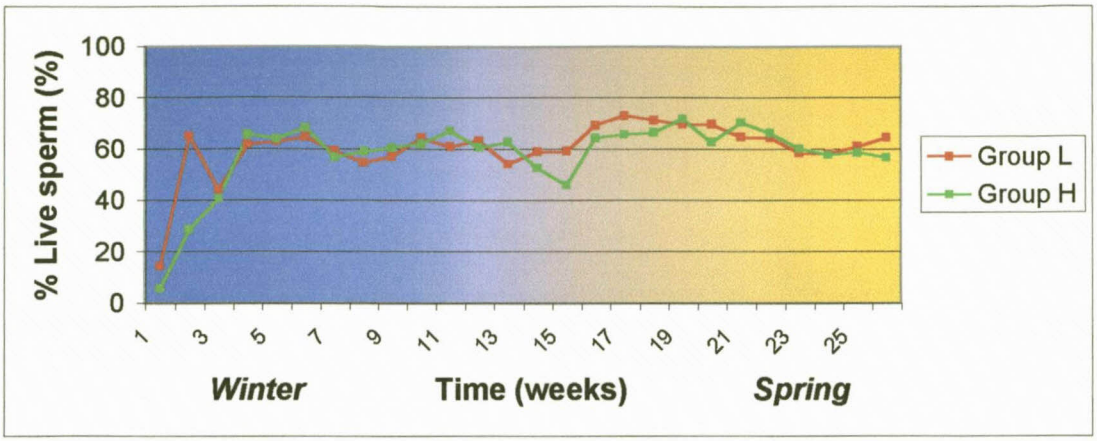

Figure 4.5 **The mean percentage (%) of live sperm cells observed in the ejaculate of young Boer goat bucks maintained on a low and high plane diet**

Table 4.6 **The mean (±SD) percentage abnormal sperm (%) in young Boer goat bucks maintained on a low and high plane diet**

	Group L		Group H	
Week	Mean (%)	SD	Mean (%)	SD
1	13	±5.32	15.7	±5.27
2	20.2	±5.49	22.7	±5.04
3	27.5[a]	±3.50	23.3[b]	±2.73
4	18.8	±5.41	17	±2.52
5	15.8	±4.99	14.7	±4.58
6	13	±4.28	12.2	±2.04
7	8	±2.60	6.83	±1.72
8	9.33	±3.93	7.5	±1.22
9	5.5	±1.87	6.33	±1.63
10	6.83	±4.44	4.5	±0.83
11	5.83	±4.35	5.17	±1.47
12	5.5	±2.07	5.17	±2.31
13	7.17	±3.06	5.83	±1.16
14	6.33	±1.86	5.33	±0.81
15	6.17	±2.71	5.17	±1.72
16	8.83	±2.99	7.17	±2.63
17	10.5[c]	±3.78	5.17[d]	±1.47
18	6.67	±2.96	5.83	±2.13
19	5.67	±4.45	5.5	±1.87
20	6.17	±2.13	6.83	±2.63
21	8.5	±3.39	5.83	±1.94
22	8.5	±3.27	6.67	±1.86
23	10[a]	±3.16	5.33[b]	±2.73
24	7.5	±1.87	5.67	±2.16
25	7.17	±1.83	6.5	±2.34
26	6[a]	±1.54	8.17[b]	±1.47

[a,b] Means in the same row with different superscripts differ significantly ($P<0.05$)
[c,d] Means in the same row with different superscripts differ significantly ($P<0.01$)

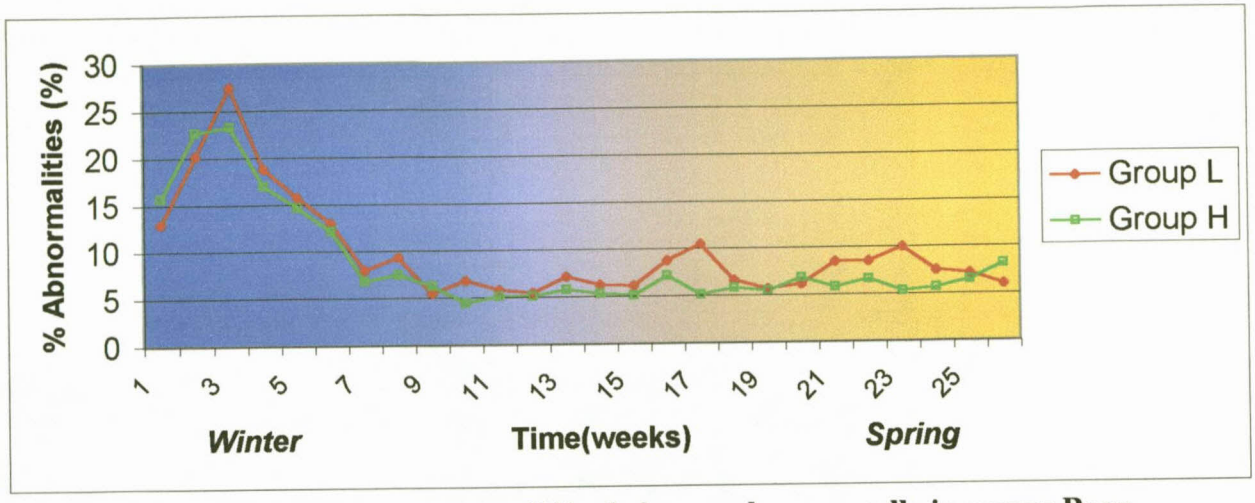

Figure 4.6 The mean percentage (%) of abnormal sperm cells in young Boer goat bucks maintained on a low and high plane diet

4.3 SCROTAL CIRCUMFERENCE

The mean scrotal circumference recorded during the observation period is set out in Table 4.7 and Figure 4.7. The time at which scrotal circumference was measured had a significant ($P<0.05$) effect in this parameter as a whole. The mean scrotal circumference of the bucks in Group H remained generally higher, compared to the scrotal circumference of those in Group L throughout most of the trial period (from week 3). However these differences were only significant ($P<0.05$) in most weeks from the end of winter/onset of spring. The mean scrotal circumference of the bucks in the high plane group (Group H) increased significantly ($P<0.05$) during the latter part of the observation period (spring), while the mean scrotal circumference of the bucks in the low plane group (Group L) stayed relatively constant (Figure 4.7).

The high plane group's mean scrotal circumference increased on average 31mm, from the onset of winter (248 ± 14.03mm) to the end of spring (279 ±12.9mm), while the mean scrotal circumference of the low energy group stayed relatively constant at 248 ± 14.7mm. The scrotal circumference differences for Group H and Group L were significant ($P<0.05$) at the end of winter period (week 11), with a mean scrotal circumference of 259 ± 151.6mm and 237 ± 136.6mm respectively. Other significant differences in scrotal circumference ($P<0.05$ and $P<0.01$) occurred during the spring in weeks 19, 23 and 25 of the observation period.

Table 4.7 **The mean (±SD) scrotal circumference (mm) of young Boer goat bucks maintained on a low and high plane diet**

	Group L		Group H	
Week	Mean (mm)	SD	Mean (mm)	SD
1	248	±14.72	248	±14.02
3	245	±14.22	251	±20.11
5	245	±15.17	252	±12.80
7	244	±14.29	252	±9.31
9	241	±13.85	252	±10.30
11	237[a]	±13.66	259[b]	±15.16
13	240	±10.99	255	±11.69
15	240[a]	±13.93	257[b]	±15.19
17	250	±13.95	263	±12.52
19	248[a]	±14.63	266[b]	±13.64
21	251	±18.48	265	±13.41
23	246[a]	±15.58	268[b]	±11.91
25	247[c]	±17.79	279[d]	±12.09

[a,b] Means in the same row with different superscripts differ significantly ($P<0.05$)
[c,d] Means in the same row with different superscripts differ significantly ($P<0.01$)

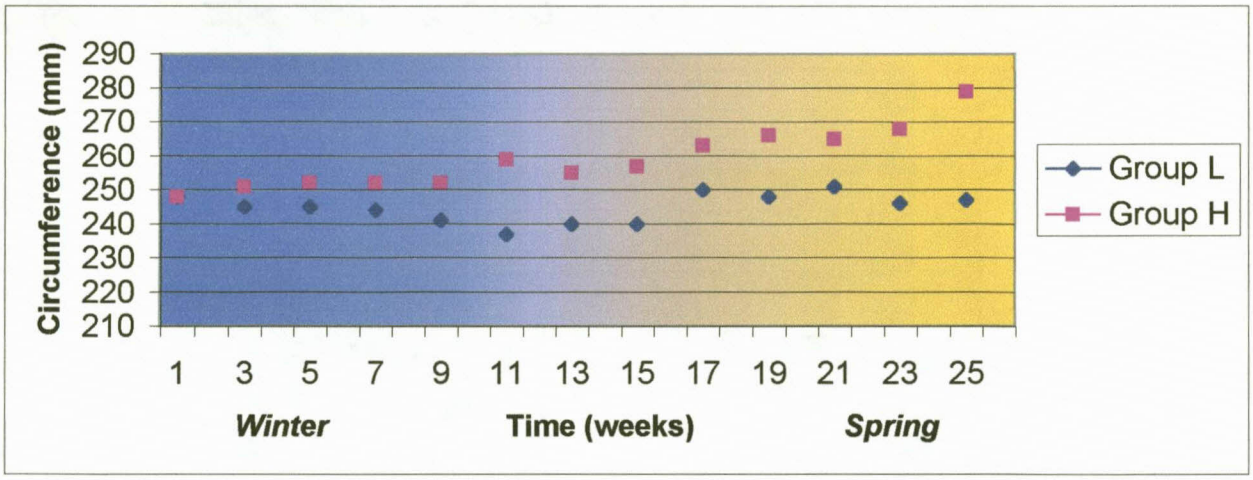

Figure 4.7 **The mean scrotal circumference (mm) of young Boer goat bucks maintained on a low and high plane diet**

4.4 TESTICULAR VOLUME

The testicular volume estimated during the observation period (winter and spring) in animals from Group H (high plane) and Group L (low plane) is set out in Table 4.8 and Figure 4.8. The week at which the testicular volume of all animals was determined had a significant ($P<0.05$) effect on the result. The scrotal circumference from animals in both groups (Group H and Group L) were relatively similar until the end of the winter season. Thereafter the testicular volume of bucks from Group H became greater and remained higher for the rest of the trial period (spring) (Figure 4.8). The high plane group increased on average 158ml in testicular volume during this trial, from the onset of winter (365 ± 54.29ml) to the end of spring (523 ± 36.56ml). 70% of the testicular volume gained by the high plane fed males was recorded in spring. The low plane fed males only gained on average 29ml in scrotal volume during the same period from the onset of winter (385 ± 37.45ml) to the end of spring (414 ± 61.43ml).

Table 4.8 The mean (±SD) testicular volume (ml) in young Boer goat bucks maintained on a low and high plane diet

	Group L		Group H	
Week	Mean (ml)	SD	Mean (ml)	SD
1	385	±37.45	365	±54.29
3	378	±25.43	374	±52.95
5	403	±26.74	389	±63.11
7	378	±26.58	385	±42.54
9	369	±28.58	395	±35.77
11	338[a]	±40.45	406[b]	±55.94
13	351	±44.88	412	±50.99
15	363	±44.75	401	±29.40
17	389	±34.26	443	±58.71
19	410	±51.38	473	±60.63
21	409[a]	±48.50	494[b]	±74.66
23	411[a]	±53.42	499[b]	±61.76
25	414[a]	±61.43	523[b]	±36.56

a,b Means in the same row with different superscripts differ significantly ($P<0.05$)

4.5 SCROTAL SKIN THICKNESS

The mean scrotal skin thickness recorded in bucks during the observation period (winter and spring) is set out in Table 4.9 and Figure 4.9. The week during which

scrotal skin thickness was measured for all animals had a significant ($P<0.01$) effect on the measurement.

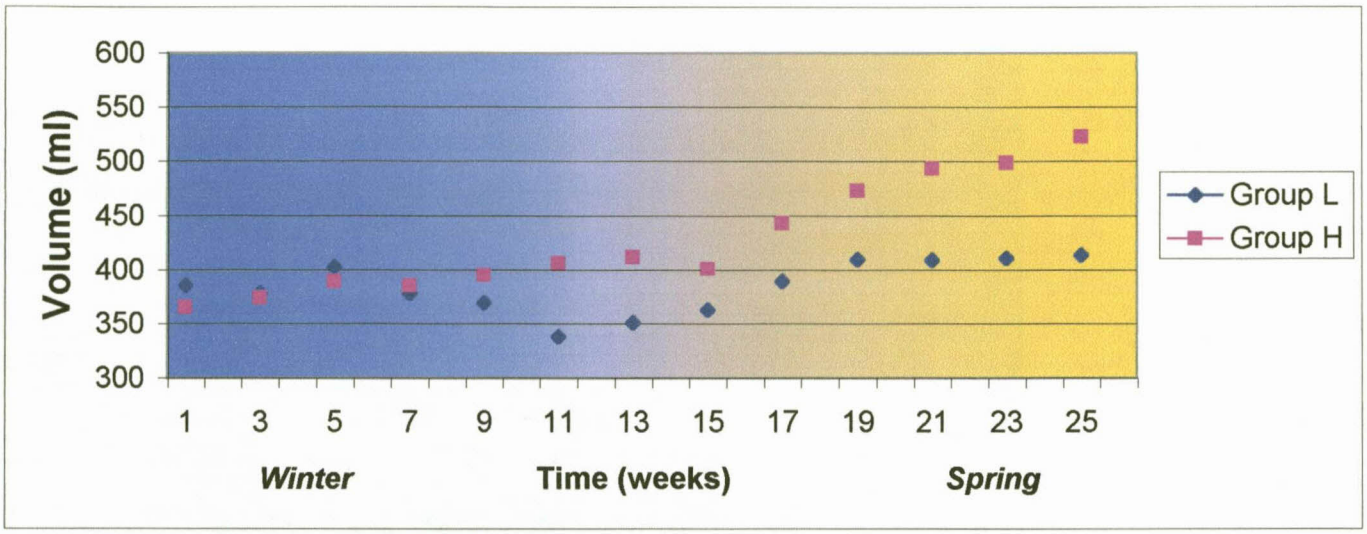

Figure 4.8 **The mean testicular volume (ml) for young Boer goat bucks maintained on a low and high plane diet**

Table 4.9 **The mean (±SD) scrotal skin thickness (mm) of young Boer goat bucks maintained on a low and a high plane diet**

	Group L		Group H	
Week	Mean (mm)	SD	Mean (mm)	SD
1	1.83	±0.34	1.88	±0.41
3	1.64	±0.30	1.77	±0.13
5	1.48	±0.11	1.56	±0.05
7	1.75	±0.27	1.73	±0.17
9	1.89	±0.28	1.88	±0.14
11	1.98	±0.34	2.04	±0.29
13	2.02	±0.21	2.19	±0.25
15	1.90	±0.26	2.07	±0.98
17	1.71^{a}	±0.25	2.06^{b}	±0.11
19	1.77	±0.37	1.96	±0.10
21	1.65^{a}	±0.20	2.02^{b}	±0.05
23	1.68^{a}	±0.19	2.42^{b}	±0.20
25	1.68^{a}	±0.02	2.42^{b}	±0.20

^{a,b} Means in the same row with different superscripts differ significantly ($P<0.05$)

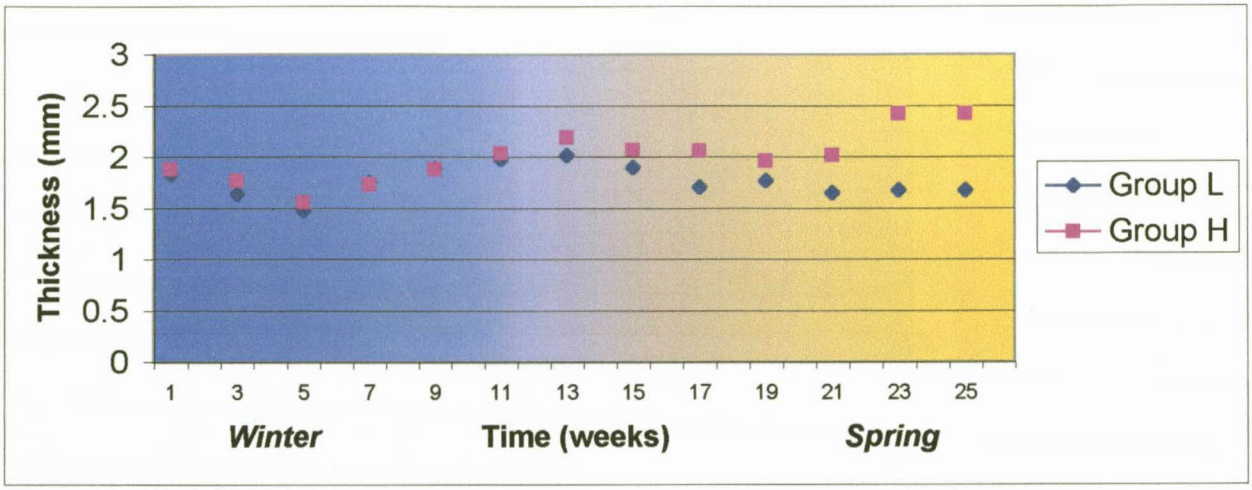

Figure 4.9 The mean scrotal skin thickness (mm) of young Boer goat bucks maintained on a low and a high plane diet

It is of interest to note the pattern for both the high (H) and low (L) energy groups regarding scrotal skin thickness throughout the observation period. The mean scrotal skin thickness of Group H and Group L decreased slightly during early winter, reaching a minimum thickness (week 5) of 1.56 ± 0.04mm and 148 ± 0.11mm respectively. The overall mean scrotal skin thickness for both treatment groups increased towards the end of winter, onset of spring (week 13) when the scrotal skin thickness of Group L reached a maximum of 2.02 ± 0.21mm. From this period in time, the animal's scrotal skin thickness on a low plane of nutrition stayed relatively constant (1.68 ± 0.25mm) for the rest of the observation period. The scrotal skin thickness of animals from Group H also increased until the end of winter (week 13), reaching a value of 2.19 ± 0.25mm. At the onset of spring the mean scrotal skin thickness of the Group H bucks declined slightly, before increasing again until reaching a maximum value of 2.42 ± 0.2mm. This value was significantly ($P<0.05$) higher, compared to that of the Group L bucks, (1.68 ± 0.02mm) at the end of spring (week 26). Throughout the entire spring season, scrotal skin thickness of animals from group H, was higher than that for of Group L males. These significant differences however were only significant ($P<0.05$) in week 17, 21 and 23 of the observation

period. This increase in scrotal skin thickness reflects fat deposition under the scrotal skin.

4.6 SERUM TESTOSTERONE CONCENTRATION

The mean serum testosterone concentrations recorded for young Boer goat bucks from both nutritional treatment groups (H and L) during the observation period are set out in Table 4.10 and Figure 4.10. From these results it is clearly evident that the serum testosterone levels of both groups varied considerably throughout the trial. The week during which blood samples were collected, significantly ($P<0.05$) affected serum testosterone levels. There was a clear trend in both groups. Testosterone levels in both groups decreased during the winter reaching a minimum value at the end of winter and thereafter increasing gradually during spring. Testosterone levels of animals in Group H always tended to be higher than those for Group L animals. These differences however were only significant ($P<0.05$) during the second week of the observation period (onset of winter) as well as at week 24 (end of spring). At these two respective times, the mean serum testosterone concentrations for Group H were 12.50 ± 9.64 ng/ml and 13.25 ± 12.10 ng/ml respectively, which was significantly ($P<0.05$) higher than the concentration recorded at the same time in Group L bucks of 1.19 ± 0.78 ng/ml and 1.89 ± 1.96 ng/ml respectively.

Table 4.10 The mean (±SD) serum testosterone concentration (ng/ml) of young Boer goat bucks maintained on a low and a high plane diet

	Group L		Group H	
Week	Mean (ng/ml)	SD	Mean (ng/ml)	SD
2	1.19[a]	±0.78	12.50[b]	±9.64
4	5.51	±9.61	8.00	±10.90
6	0.82	±0.43	4.96	±7.63
8	2.39	±2.71	6.98	±6.16
10	2.64	±1.86	1.50	±1.14
12	1.05	±0.84	2.27	±2.31
14	2.40	±1.71	4.25	±5.59
16	5.60	±5.10	9.43	±8.05
18	3.62	±5.94	3.85	±4.73
20	2.58	±2.60	5.39	±5.86
22	4.38	±7.85	7.54	±10.60
24	1.89[a]	±1.96	13.25[b]	±12.10

[a,b] Means in the same row with different superscripts differ significantly ($P<0.05$)

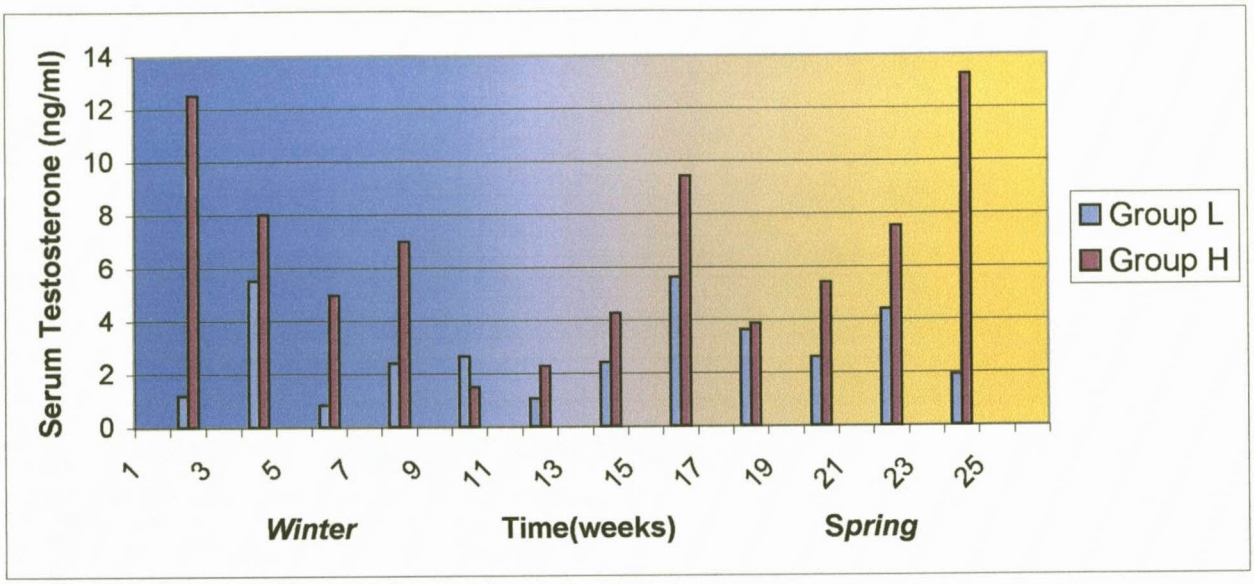

Figure 4.10 The mean serum testosterone concentration (ng/ml) of young Boer goat bucks during winter and spring maintained on a high and low plane diet

Although not significant, it is evident that the serum testosterone concentrations of Group H bucks stayed relatively higher than in Group L animals throughout the trial period – except for week 10, when Group H animals recorded a serum testosterone concentration of 1.50 ± 1.14 ng/ml, compared to Group L (2.64 ± 1.86 ng/ml). It is of interest to note the decrease in serum testosterone concentration of Group H bucks as winter progressed and in the increase in serum testosterone concentrations during the spring. The mean serum testosterone concentration for Group H in winter was 6.04 and 7.09 ng/ml for the winter (week 2 to 12) and spring (week 14 to 24) respectively and 2.27 and 3.41 ng/ml for Group L during the winter and the spring respectively. The overall mean serum testosterone concentration for the entire observation period was 6.66 ng/ml for Group H, compared to 2.84ng/ml in Group L.

4.7 LIBIDO

In this trial the reaction time of all the bucks was very short (less than 20 seconds), which resulted in all bucks receiving a libido score of 5, without any exception. Thus libido data was not analysed further statistically.

4.8 RECTAL TEMPERATURE

The mean rectal temperatures of bucks from Group H and Group L are set out in Table 4.11 and Figure 4.11. The week at which the rectal temperature was measured had a significant (P,0.05) effect on body (rectal) temperature of all the bucks. The rectal temperatures of both treatment groups rose during the trial period (winter to spring). The mean rectal temperature of Group H was generally higher, compared to that of Group L for the greater part of the trial. These differences for nutritional treatment however, were only significant ($P<0.05$) during certain weeks of the trial. Significant ($P<0.05$) interactions for this parameter between weeks and nutrition were recorded during the trial. Figure 4.11 clearly shows that during spring, when the ambient temperature rises, bucks from Group H generally tended to have increase body temperatures to a higher level than that for Group L.

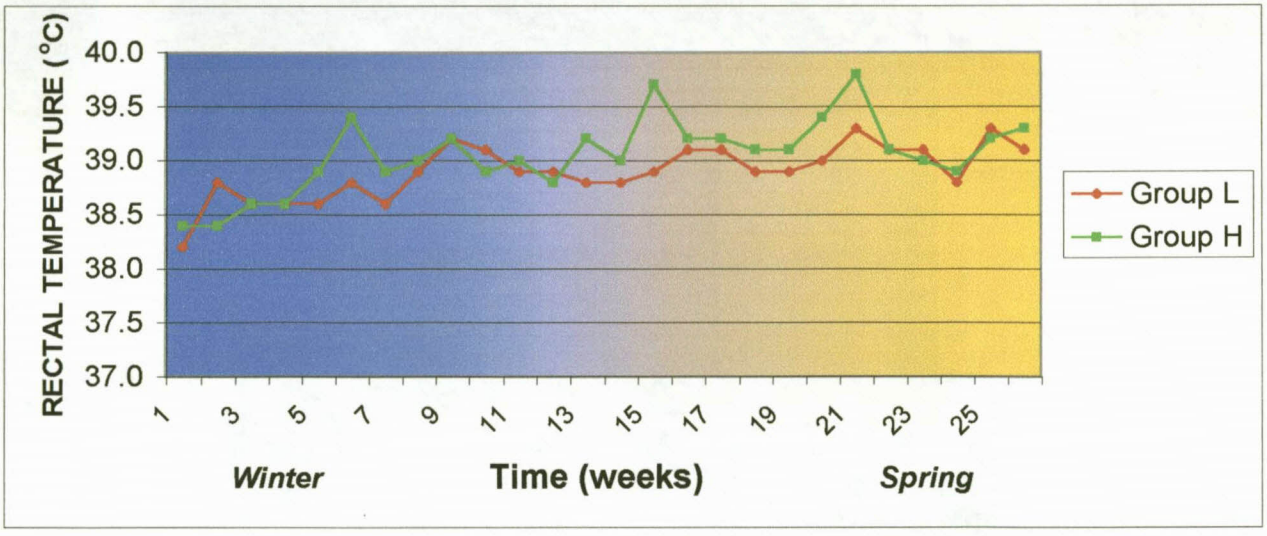

Figure 4.11 The mean rectal temperature (°C) for young Boer goat bucks maintained on a low and a high plane diet

Table 4.11 The mean (±SD) rectal temperatures (°C) for young Boer goat bucks on a low and a high plane diet

	Group L		Group H	
Week	Mean (°C)	*SD*	Mean (°C)	SD
1	38.2[a]	±0.11	38.4[b]	±0.05
2	38.8	±0.37	38.4	±0.30
3	38.6	±0.15	38.6	±0.19
4	38.6	±0.21	38.6	±0.33
5	38.6	±0.39	38.9	±0.36
6	38.8[a]	±0.15	39.4[b]	±0.36
7	38.6[a]	±0.26	38.9[b]	±0.24
8	38.9	±0.10	39.0	±0.44
9	39.2	±0.23	39.2	±0.42
10	39.1	±0.20	38.9	±0.17
11	38.9	±0.42	39.0	±0.48
12	38.9	±0.42	38.8	±0.17
13	38.8	±0.34	39.2	±0.38
14	38.8	±0.26	39.0	±0.13
15	38.9[a]	±0.30	39.7[b]	±0.21
16	39.1	±0.18	39.2	±0.16
17	39.1	±0.18	39.2	±0.16
18	38.9	±0.22	39.1	±0.39
19	38.9	±0.22	39.1	±0.39
20	39.0[a]	±0.21	39.4[b]	±0.30
21	39.3[a]	±0.36	39.8[b]	±0.16
22	39.1	±0.25	39.1	±0.57
23	39.1	±0.25	39.0	±0.53
24	38.8	±0.39	38.9	±0.34
25	39.3	±0.23	39.2	±0.28
26	39.1[a]	±0.19	39.3[b]	±0.22

[a,b] Means in the same row with different superscripts differ significantly ($P<0.05$)

4.9 AMBIENT TEMPERATURE, DAYLIGHT LENGTH AND RELATIVE HUMIDITY

From Figure 4.12 it can be seen that the maximum ambient temperature ranged between 7.6°C and 28.8°C during winter and 11.6°C to 32.9°C in spring. Similarly the minimum winter temperatures ranged between –6.7°C and 10.7°C and 0.3°C and 17.6°C for winter and spring respectively. The mean winter temperature (10.2°C) was significantly ($P<0.05$) lower than that of spring (17.4°C).

Daylight length (Figure 4.13) varied between 7 and 14 hours. From October/November (spring) daylight length was significantly ($P<0.05$) longer than that measured in June/July (winter) (12.11hours vs. 10.07 hours respectively). Relative humidity (Figure 4.14) varied over the entire observation period – being lowest in August (late winter) and highest in the early spring. The mean humidity for the entire observation period was 52.91%.

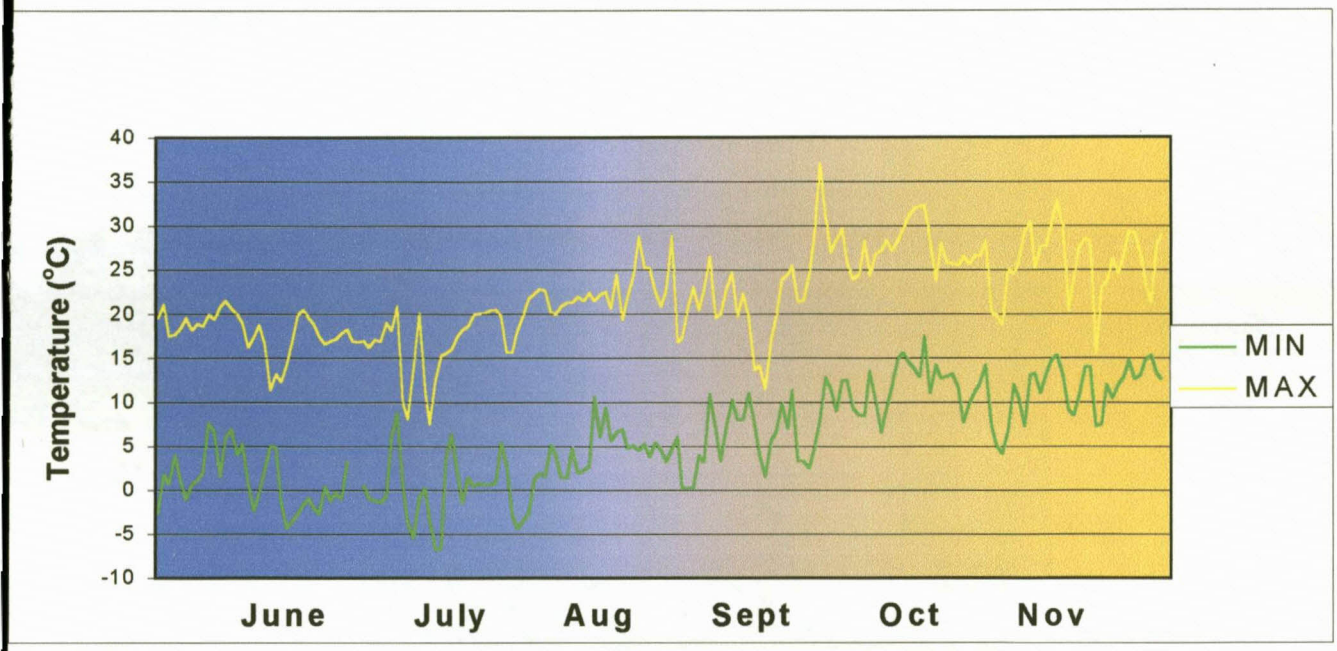

Figure 4.12 The ambient temperatures (°C) for the 26 week observation period

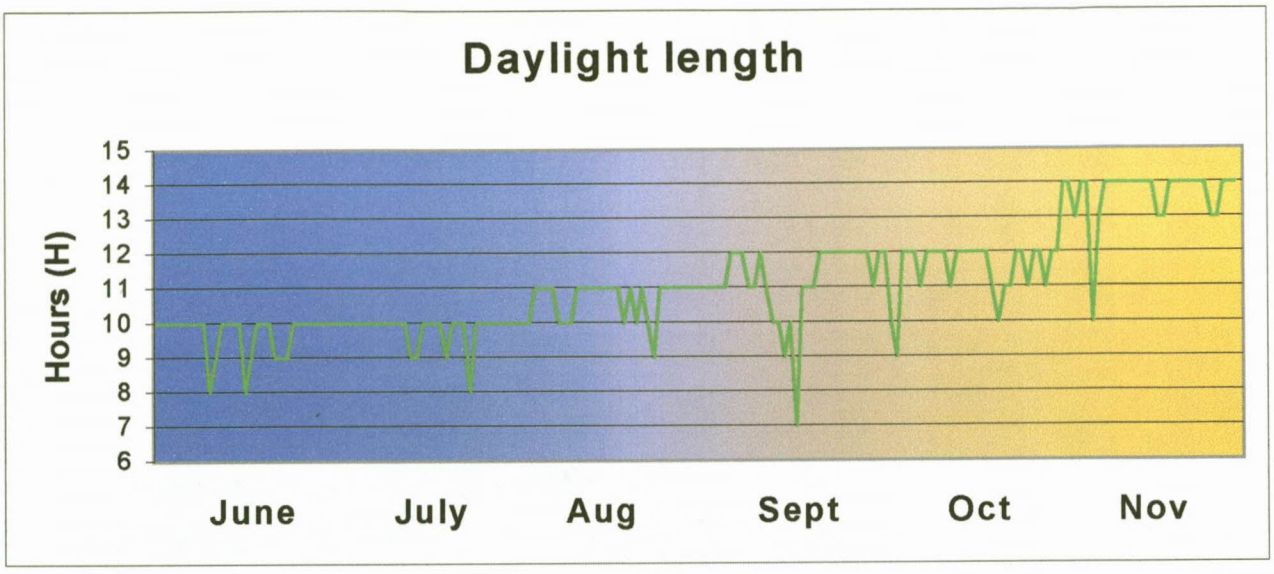

Figure 4.13 The daylight length (H) for the 26 week observation period

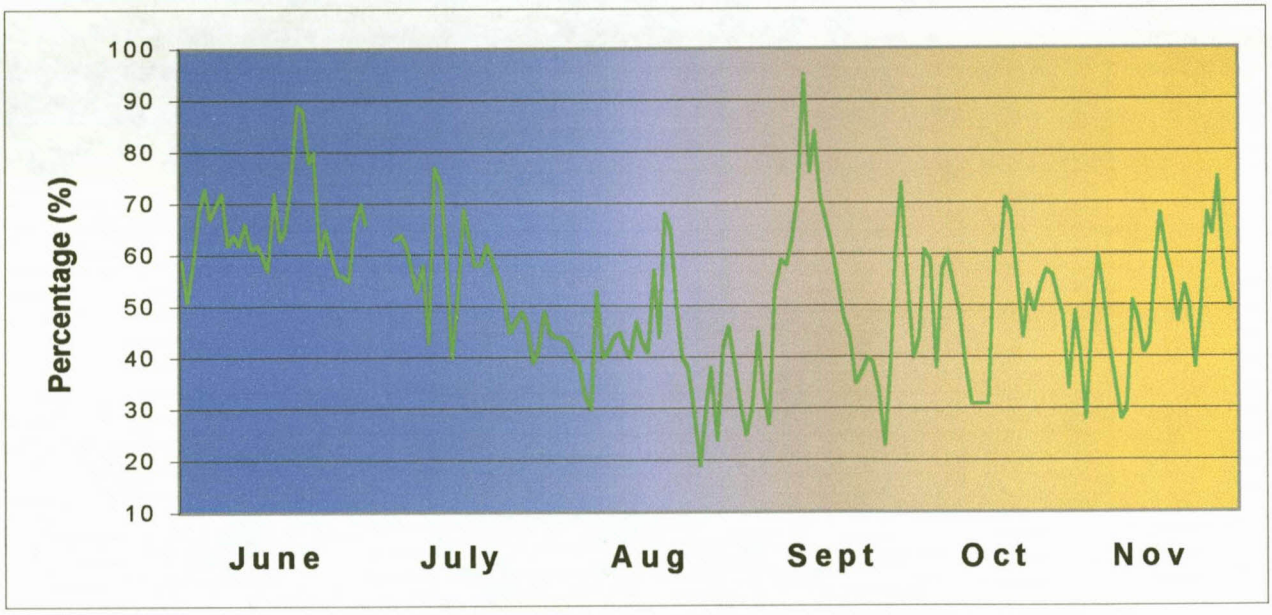

Figure 4.14 The relative humidity (%) for the 26 week observation period

CHAPTER 5

DISCUSSION

5.1 BODY WEIGHT

The mean body weight for both groups (Group H and Group L) of bucks (n=12) was 42.4 ± 5.3kg at the onset of the trial. During the first 4 weeks of the observation period, the mean body weight of the two treatment groups (Group H and Group L) stayed more or less in this range. From this time on the body weight of Group H increased and remained higher than in Group L, due to the different in plane of nutrition. These differences obtained between nutrition groups were however only significant ($P<0.05$) at certain weeks of the observation period. Similar results as a consequence of different nutrition levels, have been reported by Delgadillo *et al,* (1991) and Schwalbach *et al.,* (2000). The mean body weight for Group L (low energy group) increased on average 5.4kg, while Group H (high energy group) gained 21.7kg in mean bodyweight during the trial period. During the first 4 weeks, the bucks had to adapt to their newly fed diet and the mean body weight of both groups (Group H and Group L) stayed relatively constant. However if body weight had been regularly measured throughout the next two seasons (summer and autumn), the effect of season would have been more evident. Schwalbach *et al.,* (2000) stipulated that body weight, as a reflection of body condition of the bucks, is mainly affected by nutrition. A significant ($P<0.01$) difference in body weight changes in young Boer goat bucks fed different diets (sub-maintenance vs growing diet) for a 30 day period. The effect of nutrition was clearly visible in the treatment groups throughout the observation period (onset of winter to the end of spring). A factor that could confound the bodyweight changes in this trial, is the fact that these bucks were all young (12 months of age at the onset of the trial) and in an actively growing phase of their physiological cycle.

5.2 EVALUATION OF SEMEN

5.2.1 Semen volume

The mean semen volumes recorded in this trial are lower than those reported by Loubser and Van Niekerk, (1983b) for Angora goat bucks (1.56ml), but more in line with the values (0.48 to 1.01ml) observed by Perez and Mateos (1996) in Spanish bucks. These differences could be attributed not only to the season of the year when the semen was collected in this trial, but also to the young age (±12 months of age at the onset of the trial) of the bucks. In this trial it seemed as if the season (time of the year) played a minor role regarding the volume of semen obtained. The values remained relatively constant and no clear trend was observed throughout the year for both treatment groups. The difference in semen production could have been more evident had the trial been extended over all four seasons of the year. Even the lower ambient temperatures experienced during winter did not seem to have any effect on the semen production (in terms of volume).

In general, animals from the higher nutritional group tended to show higher semen volumes than those for Group L. These differences in semen volume were significant ($P<0.01$) at the end of the winter season (weeks 11 and 12). The patterns recorded for scrotal circumference and testicular volume also reflect a similar pattern as for semen production. The fact that semen volume for the two treatment groups did not differ significantly for a large part of the observation period could imply that the differences in nutritional level implemented in this trial were not big enough and/or that the observation period was not long enough to show a marked effect. Nutritional stress has been quoted as being responsible for decreased sperm production in some tropical goat breeds (Mukasa-Mugerwa, 1992).

5.2.2 Semen colour

Semen colour as an indicator of either semen density or possible semen contamination (Greyling & Grobbelaar, 1983), did not show a specific trend throughout this trial. This indicates that neither season nor nutritional management and its interaction had any significant effect on the semen color from the onset of winter to the end of spring. The use of the artificial vagina as a semen collection technique could have also played a role in this relatively stable trend. The voluntary mounting and ejaculation resulted

in a satisfactory natural semen sample every time. The artificial vagina has proved to be a desirable semen collection technique, compared to that of electrical stimulation in bucks. When semen is collected by means of electrical stimulation the sample obtained is often contaminated with urine (yellowish color) due to the accessory sex glands being over stimulated (Greyling & Grobbelaar, 1983).

5.2.3 Sperm mass motility

The week on which semen was collected had a significant ($P<0.05$) effect on mass motility over all the bucks collected. Meaning that there was weekly variation in the motility recorded. This can be attributed to the effect of season and/or the interaction between season and nutritional management. These results are in agreement with those reported by Greyling and Grobbelaar (1983), who also found season to have a significant effect on sperm mass motility in Boer goat bucks. The tendency of the low energy group (Group L) to show higher sperm mass motility for the latter part of winter and the early part of spring could possibly be attributed to the additional effect of the low plane of nutrition. As there were no significant differences in the percentage live sperm between the two treatment groups, these differences in mass motility can only be explained by the consistently higher sperm concentration observed in the ejaculates of animals from Group L. However these results are contrary to the findings of Walkden-Brown *et al,* (1992) who stated that malnutrition and in particular low energy intake, if severe enough is associated with a reduction in inter alia, sperm mass motility.

The sperm mass motility values recorded for the two treatment groups were not significantly different, except for the period between the end of winter to the onset of spring (weeks 10-16, except for week 15), when animals from Group L showed a significant ($P<0.05$) higher mass motility than those of Group H. The values ranged between 2.46 ±0.84 and 4.0 ±0.32 for the low plane group (Group L) and 2.17 ±0.68 and 3.9 ±0.6 for the high plane group (Group H). According to Hafez and Hafez (2000), these ranges of mass motility are normal for bucks. The lower sperm motility recorded at the end of winter is expected when compared to the onset of spring (higher ambient temperatures and complementary breeding season).

The effect of high ambient temperature on the semen motility in rams, however did not seem to have a significant effect on the sperm motility during the spring – when the ambient temperature rises. This is contrary to the findings of Delgadillo *et al.*, (1992) and Karagiannidis *et al.* (2000). This could be ascribed to the fact that in the spring the temperatures in South Africa are still moderate and not so high.

5.2.4 Sperm concentration

The mean sperm concentration for the two groups (Group H and Group L) followed the same trend (slow increase in concentration as the trial progressed). The sperm concentration of the bucks in Group L always remained higher compared to that of bucks in Group H throughout the trial period. The differences in sperm concentration were significant ($P<0.05$) from week 5 of the trial onwards. This difference could only be ascribe to individual (genetic) differences between treatment groups. The overall mean sperm concentration for all bucks (Group H and L) was significantly ($P<0.05$) affected by the week during which semen collection took place. In general sperm concentration increased from the onset of winter until the end of spring (co-inciting with an increase in in age). Unfortunately data for summer and autumn was not available which could have given a complete picture. These concentration ranges recorded are normal for bucks, according to Hafez and Hafez (2000), who quoted a normal sperm concentration range of 2.5×10^9ml to 5.0×10^9ml in bucks.

It is clearly evident that Group L had a higher sperm concentration and lower semen volume when compared to Group H for most of the trial period. This lower volume can be seen as a consequence of poorer nutritional status. Deficient nutrient intake can also be associated with a reduction in secretory output of the accessory sex glands and sperm concentration (Evans & Maxwell, 1987 ; Hafez & Hafez, 2000). This marked effect of nutrition on semen concentration is more evident from week 5 (mid-winter) to week 26 (end of spring), when a significant difference ($P<0.05$) in sperm concentration was recorded between the high plane (Group H) and low plane (Group L) groups. These results are in contrast with the findings of Schwalbach *et al.* (2000), who stated that extreme deficient nutrient intake in young Boer goat bucks is associated with a reduction in sperm concentration. The extremes in nutritional status of the two treatment groups in this trial were evidently not large enough to induce such a response.

The sperm concentration results confirm that the semen collection technique by means of an artificial vagina is satisfactorily, judged by the consistent values obtained. The increase in sperm concentration over time in both groups may be ascribed to the fact that they matured as the trial progressed and also gained experience in ejaculating in the artificial vagina.

5.2.5 Percentage live sperm

The mean percentage live sperm from both Group H and Group L bucks tended to follow the same trend – a slow increase in percentage live cells in the ejaculate over time. Significant differences ($P<0.05$) between these two groups in terms of percentage live sperm occurred during the first two weeks of the trial, (Group L 65.2 ± 17.06% vs Group H 28.9 ± 9.85%). These results obtained can possibly be attributed to the adaptation of the bucks to semen collection and the new environment. This initial significant difference was only recorded for this short period of time, thereafter the differences between groups were minimal and not significant. In general the technique used to determine the % live sperm was consistent and repeatable.

It would seem as if neither season nor nutrition or the interaction between these two factors had a major effect on the percentage of live sperm cells throughout the observation period.

5.2.6 Percentage abnormal sperm

The mean sperm abnormalities of Group L remained slightly higher than Group H for most of the trial period. These results are in agreement with the studies done by Schwalbach *et al.* (2000) and emphasize the effect of a low nutritional plane on sperm abnormalities. The overall mean percentage of abnormalities found in this study for Group H and Group L was 7.8% and 9.79% respectively – which are acceptable. These results indicate a very good semen quality and satisfactory semen handling procedures. During the first 3 weeks of winter the mean sperm abnormalities increased progressively and thereafter declined during the rest of the trial period and remained relatively low. These results are in agreement with those of Rocca *et al.* (1992) who also recorded the highest percentage of abnormal spermatozoa during the winter and the beginning of the spring season. It is of interest to note that the change

in sperm abnormalities during week 3 of the trial was concurrent with the period of the year in which the day light length started to increase (22nd June).

5.3 SCROTAL CIRCUMFERENCE

The mean scrotal circumference of both Group H and Group L bucks was very similar (248 ± 14.72mm and 248 ± 14.02mm respectively) at the onset of the trial period. The scrotal circumference of the animals in Group H increased progressively throughout the trial, while the scrotal circumference of animals from the group maintained on an inferior nutritional regime (Group L) remained relatively constant during the trial period. As the spring season progressed, scrotal circumference of animals in the high nutrition plane group increased noticeably. This could be an indication of the interaction between season and nutrition in testicular size. The observation of testicular volume followed the same trend as scrotal circumference. The significant ($P<0.05$) effect of season (weeks) on the scrotal circumference was consistent with the findings of Ahmed *et al.* (1996) who confirmed a significant seasonal variation in scrotal circumference. The scrotal circumference differences recorded between Group H and Group L increased significantly ($P<0.05$) at the end of winter (week 11) and recorded a mean scrotal circumference of 259 ± 15.16cm and 237 ± 13.66cm respectively. These results are in line with the findings of Ahmed *et al.* (1996), in Saanen bucks. The significant ($P<0.05$) effect of nutrition on the scrotal circumference was markedly visible, especially during the spring season. The high plane group's mean scrotal circumference increased with 31mm during this trial to 279mm, while the mean scrotal circumference of the low energy group stayed relatively constant at approximately 248 mm. These results are in line with the findings of Schwalbach, *et al.* (2000), who found a significant detrimental effect of undernutrition on the scrotal circumference in young Boer goat bucks. In general a seasonal variation in scrotal circumference (co-inciding with testicular activity) is experienced in Angora bucks (Loubser, 1983b).

5.4 TESTICULAR VOLUME

The testicular volume of the young Boer goat bucks increased significantly from the onset of winter to the end of spring (70% of this increase was recorded in spring) and

could in part be explained by the fact that these bucks were still in a growing phase. Shresta *et al.*, (1983) and Colas *et al.*, (1990) and Baril *et al.*, (1993) reported similar findings. The significant ($P<0.05$) effect of weeks on the testicular volume (Group H and Group L) recorded during the observation period (winter and spring) could imply a specific influence of changes in daylight length (season) on testicular activity. A better demonstration of the effect of daylight length on scrotal volume would have be more evident, had all four seasons been monitored in this trial.

The high plane group (Group H) gained on average, 158ml in testicular volume, from the onset of winter to the end of spring. In contrast Group L (low energy group) bucks only gained an average of 29ml in testicular volume during the same period. These results are in agreement with the findings of Mukasa-Mugerwa and Ezaz, (1992) and Thwaites, (1995), who have demonstrated the effect of nutritional management on testicular growth and the onset of puberty in rams and also that undernutrition reduced testicular volume in goats (Schwalbach et al., 2000).

5.5 SCROTAL SKIN THICKNESS

The significant ($P<0.05$) effect of time (weeks) on the scrotal skin thickness, for the combined values (Group H and Group L), as well as the clear trends observed throughout the observation period (onset of winter to the end of spring), gives a good indication of the effect of season and nutrition on the subcutaneous fat deposition in the scrotum. At the end of spring the mean scrotal skin thickness of bucks from Group H recorded a maximum value of 2.42mm ±0.2mm which differed significantly ($P<0.05$) from that of Group L bucks. These significant ($P<0.05$) differences emphasize the detrimental effect of under-nutrition on fat deposition, as observed by Schwalbach *et al.*, (2000) in young Boer goat bucks. These researchers recorded a reduction in scrotal skin thickness of 0.5mm in severely underfed young bucks following a 30 days period.

5.6 SERUM TESTOSTERONE CONCENTRATION

The great variation in serum testosterone levels in both treatment groups and the pattern of testosterone fluctuations, clearly indicate an influence of season on the

testicular activity. The effect of season (photoperiod) on serum testosterone levels would have possibly been more evident, had the other two seasons (summer and autumn) also been monitored or blood been sampled at more frequent intervals. The testosterone levels decreased in winter and increased during spring. Similar results have been reported by Loubser *et al,* (1983b) in the Angora goat, where minimum testosterone concentrations of 1.17ng/ml during September (onset of spring) were recorded. Although not always significantly higher, it is clearly visible that the serum testosterone concentration of Group H stayed relatively higher than Group L, throughout the trial period (except in week 10). This demonstrates the effect of nutrition on serum testosterone production and testicular activity. These findings are in agreement to those of Mann and Lutwak-Mann (1981) who found nutrition to play a role in the development and secretory ability of the testes.

5.7 LIBIDO

In this trial the reaction time recorded for the bucks was very short (less than 20 seconds). Thus, all bucks were always allocated a maximum score of 5 for every semen collection throughout the trial. These results could sever to demonstrate the high libido of the Boer goat buck experienced throughout the two seasons evaluated, even at such a relatively young age. Despite the fluctuations encountered in serum testosterone levels, libido remained high throughout the two seasons. No evident effect of low nutritional treatment on libido was observed in the young Boer goat bucks evaluated. With the infrequent sampling of blood and the pulsatile nature of testosterone it was difficult to determine any relationship between libido and serum testosterone concentration

5.8 RECTAL TEMPERATURE

Figure 4.10 clearly shows that in general bucks from Group H maintained a higher body temperature than those in Group L. This could possibly be explained by the differences in metabolic energy ingested by the two nutritional groups. Group L, ingested considerably less energy and therefore it could be expected that these animals generate less metabolic heat (body temperature). Mean rectal temperature as an indicator of body temperature, followed a similar pattern as that of the mean

ambient temperature. Figure 4.10 illustrates that during spring, when ambient temperature rises, the bucks from Group H tend to increase their body temperature to a higher level than those of the Group L animals. These differences also indicate differences in the energetic metabolism as a result of dietary energy restrictions. No research in this regard could be obtained for bucks.

5.9 AMBIENT TEMPERATURE, DAYLIGHT AND RELATIVE HUMIDITY

From Figure 4.13 it is evident that the mean winter temperature (10.24°C) was significantly ($P<0.05$) lower than that in the spring (17.43°C). These significant lower temperatures recorded during winter are characteristic of the region and can drop to very low temperatures as recorded in this trial. Few studies has been done to determine the effect of minimum (freezing) ambient temperatures on semen quality in goat bucks. Many studies, however have been carried out to determine the effect of high ambient temperature on semen characteristics and these effects would have been more evident during the summer when the mean temperatures are significantly higher (Folch, 1983).

Daylight length (Figure 4.14) for the observation period varied between 7 and 14 hours. During October/November (spring) daylight length was significantly ($P<0.05$) longer, compared to that measured in June/July (winter). Daylight length is synonymous with the change in seasons. The effect of the change in daylight length on the semen quality and sexual characteristics of small ruminants as reported in this trial, are confirmed by studies of Lincoln (1988).

Relative humidity varied over the entire observation period. The lowest percentage humidity recorded was in August (late winter), which is normal in this summer rainfall region with the highest percentage humidity measured in the early spring. Little work, if any has been done on the effect of humidity on the sexual performance of goat bucks and it would be difficult to isolate the specific effect of ambient temperature, daylight length, rainfall or humidity.

CHAPTER 6

GENERAL CONCLUSIONS

All the semen quality and quantity indicators/parameters observed during this trial (semen volume, sperm mass motility, sperm concentration, percentage live sperm and percentage abnormal sperm), were markedly influenced by the week in which semen was collected. This can be attributed to the effect of season (ambient temperature, daylight length and relative humidity), although no clear seasonal trend was observed. This effect of season was also markedly visible in other parameters recorded (e.g. scrotal circumference, testicular volume and scrotal skin thickness), serving as indicators of the sexual activity and fertility of the bucks – with the higher nutritional plane fed group of males recording better values. The serum testosterone levels of both groups however fluctuated considerably throughout the trial period and it was difficult to note any close relationship with the other parameters measured (e.g. libido, testicular volume, etc). The effect of season would probably have been more meaningful and significant if the parameters had been measured for all 4 seasons of the year – thus the observation period was too short. If a more seasonal breed had been used, the effect of season would have been more pronounced with greater variation being obtained.

In general the animals on a higher nutritional plane diet tended to record higher serum testosterone levels and show better testicular and semen characteristics compared to the group maintained on a lower plane of nutrition. These differences were however only significant at certain times of the observation period and there was not a strong or evident seasonal trend or pattern for all parameters measured. Even within each nutritional group there was considerable variation amongst animals regarding the parameters measured. It would seem that the difference in plane (quality) of nutrition would have to be more extreme to demonstrate differences in e.g. semen volume, testicular volume and semen quality. With a greater difference in energy intake between the two treatment groups, greater response could have been inducted.

Another possible factor that could have affected the response of the animals additional to season and nutritional status, was the age of the bucks during the trial period. Older animals could have responded differently to the environmental and nutritional cues. From these results, it can be concluded that the Boer goat buck is not seasonal or at least less seasonally bonded than other goat breeds. Boer goat bucks maintain their libido and satisfactory potential fertility at least during winter and spring. Breeds of bucks e.g. the Angora, with a higher degree of seasonality with regard to sexual activity and semen characteristics could possibly also have demonstrated greater differences than those obtained in the current study. Further research with regard to seasonal variation in the Boer goat buck is warranted to exploit the potential of this breed to the utmost. It is also necessary to evaluate the Boer goat buck throughout the year to get the complete picture regarding seasonality.

ABSTRACT

THE EFFECT OF SEASON AND NUTRITION ON THE REPRODUCTIVE POTENTIAL AND SEXUAL CHARACTERISTICS OF BOER GOAT BUCKS

by

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A study to evaluate the effect of season (ambient temperature, daylight length and relative humidity) and nutrition on the reproductive potential and sexual characteristics of young Boer goat bucks was carried out between June (winter) and November (spring), 2000. This study was carried out at the University of the Free State campus in Bloemfontein, South Africa.

Twelve Boer goat bucks with a mean initial age of 12 months were used in this study. These bucks were divided into two similar experimental groups, with regard to body weight. A high nutritional plane diet was randomly allocated to one group (Group H) and a low nutritional plane diet was allocated to the other group (Group L). The total mixed diet based on *Themeda triandra* (Red grass) summer hay, supplemented with maize meal, molasses, HPK 40, HPK 60 and lucerne at two different nutritional levels (High and Low) was given *ad lib* to the two respective experimental groups. Prior to the observation period, all the bucks were subjected to a prescribed diet for adaptation, for a period of 4 weeks. Then 2 weeks prior to the observation period of

this trial, each group received their respective treatment diets. During these 6 weeks, the experimental bucks were trained for semen collection with the aid of an artificial vagina. Apart from the different nutritional management, both groups were housed and managed under similar conditions.

Semen samples from each buck were collected by means of an artificial vagina. Semen was collected twice weekly throughout the observation period (winter and spring). In order to have a more realistic and accurate measurement an average of the two measurements taken per week (i.e. semen volume, mass motility etc.) was used as a measurement for the respective week. The following semen parameters were evaluated: semen volume, semen colour, mass motility, sperm concentration, percentage live sperm and percentage abnormal sperm. Other sexual characteristics (serum testosterone concentration, scrotal circumference, testes volume, scrotal skin thickness and libido) as well as rectal temperature and body weight was recorded every second week concurrently with semen collection. The environmental factors (ambient temperature, daylight length and relative humidity) were recorded daily.

From this study it can be concluded that the semen and sexual characteristics of young Boer goat bucks observed during this trial, were markedly influenced by the week (season) in which semen was collected, although no clear seasonal trend was observed. In general the animals on the higher nutritional plane diet tended to record higher serum testosterone levels and superior semen and testicular characteristics compared to those from the group maintained on a lower plane of nutrition. These differences however were only significant at certain times of the observation period. It can be also concluded that the Boer goat buck maintains its libido and satisfactory potential fertility (testicular characteristics and semen quality) during the winter (outside the natural breeding season). The effect of season and nutrition on the fertility of Boer goat bucks would have been better evaluated, had this study been carried out for all 4 seasons of the year and the nutritional differences been more extreme.

OPSOMMING

DIE EFFEK VAN SEISOEN EN VOEDING OP DIE REPRODUKSIE POTENSIAAL EN GESLAGSEIENSKAPPE VAN BOERBOKRAMME

deur

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'n Studie om die effek van seisoen (omgewingstemperatuur, dagliglengte en relatiewe humiditeit) en voeding op die reproduksie potensiaal en geslagseienskappe van jong Boerbokramme te evalueer, is uitgevoer op die kampus van die Universiteit van die Vrystaat in Bloemfontein, Suid Afrika.

Twaalf Boerbokramme met 'n aanvanklik gemiddelde ouderdom van 12 maande is in die studie gebruik. Die ramme is in twee eksperimentele groepe op grond van liggaamsgewig verdeel. 'n Dieet met hoë voedingswaarde is willekeurig aan een groep (Groep H) toegeken en 'n dieet met 'n laer voedingswaarde is aan die tweede groep toegeken (Groep L). Die totale diëet bestaande uit *Themeda triandra* (Rooigras) somerhooi, met aanvullende mieliemeel, molasse, HPK 40, HPK 60 en lusern (teen verskillende peile) is aan die ramme op 'n *ad lib* basis gevoer volgens die indeling. Al die ramme het vir 4 weke lank 'n aanpassingsdieet ontvang en 2 weke voor die aanvang van die eksperiment het elke groep sy respektiewelike dieet ontvang. Gedurende die 6 weke aanpassingsperiode is die diere geoefen om die kunsvagina vir semen kolleksie te gebruik. Beide groepe is onder dieselfde omstandighede gehuisves en bestuur, met die enigste verskil dié in die voedingsbestuurspraktyk.

Semenmonsters is m.b.v 'n kunsvagina gekollekteer. Semen is twee maal per week gedurende die observasie tydperk (winter tot lente) gekollekteer. Die gemiddelde waarde van twee monsters per week (bv. semenvolume, sperm motiliteit ens.) wat gebruik is as metings, is geneem om 'n meer realistiese en akkurate meting te verkry. Die volgende semenparameters is ge-evalueer: semenvolume, semenkleur, spermmotiliteit, spermkonsentrasie, persentasie lewendige en abnormale sperme). Ander geslagseienskappe (serumtestosteroon konsentrasie, skrotumomvang, testesvolume, skrotum veldikte en libido) sowel as rektale temperatuur en liggaamsgewig is elke tweede week tesame met semenkolleksie gemeet. Die omgewingsfaktore (omgewingstemperatuur, dagliglengte en relatiewe humiditeit) is daagliks gemonitor.

Vanuit die studie kan die gevolgtrekking gemaak word dat semen- en geslagseienskappe in jong Boerbokramme wat gedurende die studie genoteer is, beduidend beïnvloed is deur die week (seisoen) waartydens semen gekollekteer is, alhoewel geen seisonale tendens waargeneem is nie. Oor die algemeen was die tendens dat diere op 'n hoër vlak van voedingswaarde dieet, hoër testosteroonvlakke en semeneienskappe getoon het vergeleke met die groep wat 'n dieet op 'n laer energievlak ontvang het. Die verskille waargeneem was slegs betekenisvol tydens sekere tye in die observasieperiode. Die gevolgtrekking kan gemaak word dat die Boerbokramme 'n bevredigende vrugbaarheid potensiaal en libido gedurende die winter (buite die natuurlike teelseisoen) gehandhaaf het. Die effek van seisoen en voeding op die vrugbaarheid van Boerbokramme sou waarskynlik beter evalueer kon word, indien die studie oor al 4 seisoene van die jaar kon duur en die voedingswaarde verskille van die twee diëte ook meer prominent was.

REFERENCES

ADAM, C.L. and ROBINSON, J.J., 1994. The role of nutrition and photoperiod in the timing of puberty. *Proc. Nutr. Soc.* 53(1), 89-102.

AHMED, M.M.M., MAKAWI, S.A. and GADIR, A.A., 1996. Reproductive performance of Saanen bucks under tropical climate. *Small Rum. Res.* 26, 151-155

ASHER, G.W., FISHER, M.W., FENNESY, P.F., SUTTIE, J.M. and WEBSTER, J.R., 1993. Manipulation of reproductive seasonality of farmed red deer (*Cervus elaphus*) and follow deer (*Dama dama*) by strategic administration of exogenous melatonin. *Anim. Reprod. Sci.* 33(1-4), 267-287.

BARENTON, B., CHABANET, C. and PELLETIER, J., 1987. Influence of photoperiod and protein diet on growth hormone secretion in rams. *Proc. Soc. Exp. Biol. Med.* 185, 312-317.

BARENTON, B., RAVAULT, J.P., CHABANET, C., DAVEAU, A., PELLETIER, J. and ORTAVANT, R., 1988. Photoperiodic control of growth hormone secretion and body weight. *Dom. Anim. Endocrinol.* 5, 247-255.

BARIL, G., CHEMINEAU, P., COGNIÉ, Y., LEBOEUF, B., ORGEUR, P. and VALLET, J.C., 1993. Manuel de formation pour l'insémination artificielle chez les ovins et les caprins. FAO, Rome, 219-223.

BARTH, A.D. and OKO, R.J., 1989. Abnormal Morphology of Bovine Spermatozoa. Iowa State University Press, Ames, IA, 130-271.

BEARDEN, J. and FRUQUAY, J. 2000. Applied Animal Reproduction, Pergamon Press, Reston Publ. Comp. Inc. USA.

BOTHMA, J.N., 1991. 'n Studie van paringsgedrag by ramme. MSc. (Agric) Dissertation, University of the Orange Free State, South Africa.

BRADEN, A.W.H., and MATTNER, P.E., 1970. The effects of scrotal heating in the ram on semen characteristics, fecundity and embryonic mortality. *Aust. J. Agric. Res.* 21, 509-518.

BROOKS, J.R. and ROSS, C.V., 1962. Effect of ambient temperature and thyroxine therapy on semen quality of rams. *J. Anim. Sci.* 21, 700-705.

CAMERON, A.W.N., FAIRNIE, I.J., CURNOW, D.H., KEOGH, E.J. and LINDSAY, D.R., 1984. The output of spermatozoa of naturally mated rams. Proc. 10th Intern. Congr. Anim. Reprod. & Art. Insem., University of Illinois U-S, Vol. II, 266-271.

CAMPBELL, Q.P., 1994. Information regarding the improved Boer goat. Boer Goat News, 49-50.

CHEMINEAU, P., CAGNIE, Y., GUERIN, V., ORGEUR, P. and VALLET, J.C., 1991. Training Manual on Artificial Insemination in Sheep and Goats. FAO, Rome, 396-399.

CHEMINEAU, P., 1993. Environment and animal reproduction. *World Anim. Rev.* 77, 2–14.

COLAS, G., 1980. Variations saisonniéres de la qualité du sperme chez le bélier Ile-de-France : 1. Etude de la morphologie cellulaire et de la motilité massale. *Reprod. Nutr. Dev.* 28, 1789-1799.

COLAS, G., UÉRIN, Y., LEMAIRE, Y., MONTASSIER, Y., and DESPIERRES, 1986. Seasonal variations in the testicular diameter and sperm morphology of Vendean and Texel rams. *Reprod. Nutr. Dev.* 26, 863-875.

COLAS, G., LEFEBVRE, J. and GUÉRIN, J., 1990. Etude de la transmission éère-fils des variations saisonniéres du diamètre testiculaire et du pourcetage de spermatoïdes anormaux chez le bélier Ile-de-France : 1. Fils nés en février. *Reprod. Nutr. Dev.* 30, 589-603.

CORTEEL, J.M., 1978. Seasonal variations in motility and fertilising ability of goat spermatozoa. *Anim. Breed., Abstr.* 46, 41-43.

CORTEEL, J.M., 1981. Collection, processing and artificial insemination of goat semen. In: Goat Production. Ed. Gall, G. (Editor), Academic Press, London, UK, pp 171-191.

CUNNINGHAM, J.G., 1997. Reproduction and lactation. Textbook of Veterinary Physiology. W.B. Saunders Co. 2nd. De. U.S.A.: 446-448.

DEGEN, A.A., SOD-MORIAH, U.A., LEVY, Y. and RATTNER, D., 1981. Seasonal fluctuations in plasma testosterone levels and testes size in male goat *(Capra hircus)*-ibex (*Capra ibex Nubiana*) crosses. *Comp. Biochem. Physiol.* 69A, 713-716.

DELGADILLO, J.A., LEBOEUF, B. and CHEMINEAU, P., 1991. Abolition of seasonal variations in semen quality and maintenance of sperm fertilizing ability by photoperiodic cycles in goat bucks. *Small Rumin. Res.* 9, 47-59.

EVANS, G. and MAXWELL, W.M.C., 1987. Salamon's Artificial Insemination of Sheep and Goats. Butterworth, Publ. London, Boston, Durban, Singapore, 123-127.

FOLCH, J., 1983. Influence of age, photoperiodism and temperature on semen production of rams. In: The Male in Farm Animal Reproduction. Ed. Courot, M. Martinus Nijhoff Publ. Amsterdam, Netherland.

FORBES, J.M., ELSHABAT, A.A., JONES, R., DUNCAN, J.G.S. and BOAZ, T.G., 1979. The effect of daylight on the growth of lambs. *Anim. Prod.* 29, 33-42.

FRESNO, M., ALVAREZ, S., DARMANIN, N., DELGADO, J.V., LEBOEUF, B. and TERQUI, M., 2000. Testis volume and semen production in Canarian goats. *Proc. 7th Intern. Conf. on Goats*, France, May 15-21, pp 439-446.

GETTYS, T.W., SCHANBACHER, B.D. and TAYLOR, I.L., 1989. An assessment of the interaction between photoperiod and sex phenotype in relation to appetite development in the sheep. *Livest. Prod. Sci.* 22, 283-293.

GODFREY, S.I., WALKEN-BROWN, S.W., MARTIN, G.B. and SPEIJERS, E.J., 1996. Immunisation of goat bucks against GnRH to prevent seasonal reproductive and agonistic behaviour. *Anim. Reprod. Sci.* 44, 41-54.

GREYLING, J.P.C. and GROBBELAAR, J.A.N., 1983. Seasonal variation in semen quality of Boer and Angora goat rams using different collection techniques. *S. Afr. J. Anim. Sci.* 13(4), 250-252.

GREYLING, J.P.C. and GROBBELAAR, J.A.N., 1988. Artificial insemination in sheep. In: *Farming in South Africa – Mutton sheep*, B.7. Department of Agriculture, South Africa.

GREYLING, J.P.C., KOTZÈ, W.F., TAYLOR, G.J. and HAGENDIJK, W.J., 1993. Effect of an anabolic steroid on body measurements in ram lambs. *Small Rumin. Res.*, 11, 351-357.

GREYLING, J.P.C. and TAYLOR, G.J., 1999. The effect of the anabolic agent, nandrolone laurate, on certain production and reproduction parameters in ram lambs, under intensive and extensive feeding regimes. *S. Afr. J Anim. Sci.* 29(3): 179-188.

GREYLING, J.P.C., 2001. Personal communication.

HAFEZ, B. and HAFEZ, E.S.E., 2000. Reproduction in farm animals. *7th Ed. Lippincott Williams & Wilkins Publ.* Baltimore, USA.

HOWARTH, B. (Jr.), 1969. Fertility in the ram following exposure to elevated ambient temperature and humidity. *J. Reprod. Fert.* 19: 179-183.

HOWLAND, B.E., SANFORD, L.M. and PALMER, W.M., 1985. Changes in serum levels of LH, FSH, PRL, Testosterone and Cortisol associated with season and mating in male Pigmy goats. *J. Androl.* 6, 89-96.

HULET, C.V. and ERCANBRACK, S.K., 1962. A fetility index for rams. *J. Anim. Sci.* 21, 489-491.

HUNTER, R.H.F., 1980. Physiology and Technology of Reproduction in Female Domestic Animals. Academic Press, London.

JAINUDEEN, M.R. and HAFEZ, E.S.E., 2000. Sheep and goats. In: Reproduction in Farm Animals. Eds. HAFEZ, E.S.E. & HAFEZ, B., *Lippincott Williams & Wilkins Publ.* Baltimore, USA.

KARAGIANNIDIS, A., VARSAKELI, S., ALEXOPOULOS, C. and AMARANTIDIS, I., 2000. Seasonal variation in semen characteristics of Chios and Friesian rams in Greece. *Small Rumin. Res.*37, 125-130.

KNIGHT, T.W., 1977. Methods for the indirect estimation of testes weight and sperm numbers in Merino and Romney rams. *NZ J. Agric. Res.* 20, 291-296.

LANGFORD, G.A., SHRESTHA, J.N.B. and MARCUS, G.J., 1989. Repeatability of scrotal size and semen quality measurements in rams in a short daylight regime. *Anim. Reprod. Sci.* 19, 19-27.

LINCOLN, G.A., 1988. Regulation of LH and FSH secretion in the ram. *Proc. 11th Int. Congr. Anim. Reprod..& Artif. Insem.* 26-30 June, Dublin, Ireland, pp 10-17.

LOUBSER, P.G., 1981. Die seisonale veranderinge in die geslagsaktiwiteit en semenkwaliteit by die Angoraram en die diepvriesing van Angoraboksemen. MSc (Agric.) dissertation, University of Stellenbosch.

LOUBSER, P.C. and VAN NIEKERK, C.H., 1983a. Seasonal changes in sexual activity and semen quality in the Angora ram. 1. Libido an male hormone concentration. *S. Afr. J. Anim. Sci.* 19(2), 131-133.

LOUBSER, P.C. and VAN NIEKERK, C.H., 1983b. Seasonal changes in sexual activity and semen quality in the Angora ram.2.Semen volume, quality and freezability. *S. Afr. J. Anim. Sci.,* 13: 161-163.

MANDIKI, S.M.N., DERYCKE, G., BISTER, J.L. and PAQUAY, R., 1997. Influence of season and age on sexual maturation parameters of Texel, Suffolk and Ile-de-France rams. *Small Rum. Res.* 28 (1998), 67-79.

MANDIKI, S.N.M., DERYCKE, G., BISTER, J.L. and PAQUAY, R., 1998. Influence of season and age on sexual maturation parameters of Texel, Suffolk and Ild-de-France rams: 1. Testicular size, semen quality and reproductive capacity, semen quality and reproductive capacity. *Small Rumin. Res.* 28, 67-79.

MANN, T. and LUTWAK-MANN, C., 1981. Male Reproductive Function and Semen, , Springer Verlag, New York. p. 19-25.

MIYAMOTO, A., UMEZU, M., HAMANO, L. and MASAKI, J., 1987. Seasonal changes in inhibin activity in seminal plasma en serum concentrations of FSH, LH and Testosterone in the male goat (*Capra hircus*). *Theriogenology*, 28: 67-76.

MUKASA-MUGERWA, E. and EZAZ, Z., 1992. Relationship of testicular growth and size to age, body weight and onset of puberty in Menz ram lambs. *Theriogenology,* 38, 979-988.

MUKASA-MUGERWA, E. and LAHLOU-KASSI, A., 1995. Reproductive performance and productivity of Menz sheep in the Ehiopian highlands. *Small Rumin. Res.* 17(2), 167-177.

MUNDULI, D.S., SANFORD, L.M., PALMER, W.M., and HOWLAND, B.E., 1979. Secretory patterns and circadian and seasonal changes in LH, FSH, Prolactin and Testosterone in the male Pygmy goat. J. Anim. Sci. 49: 543-553.

PELLETIER, J. and ORTAVANT, R., 1975. Photoperiodic control of LH release in the ram. Acta Endocr. (Kbh.) 78, 435-439.

PELLETIER, J., GARNIER, D.H., DE REVIERS, M.M., TERQUI, M. and ORTAVANT, R., 1982. Seasonal variation in LH and testosterone release in rams of two breeds. *J. Reprod. Fert.* 64: 341-346.

PELLETIER, J. and ALMEIDA, G., 1987. Short light cycles induce persistent reproductive activity in the Ile-de-France rams. *J Reprod. Fert. Suppl.,* 34, 215-226.

PÉREZ, B., MATEOS, E. and PINTADO, B., 1991. Semen characteristics of Verata goat breed. *Información Técnica Económica Agraria,* Vol. Extra 11, 40-42.

PÉREZ, B. and MATEOS, E., 1993a. Study of semen characteristics in Malagueña goat breed. (Influence of season). *Información Técnica económica Agraria,* Vol. Extra 12, 471-473.

PÉREZ, B. and MATEOS, E., 1993b. Evolution of testicular size in bucks of Verata and Malagueña breeds. *Invest. Agric.: Prod. Sanid. Anim.* 8(3), 257-268.

PEREZ, B. and MATEOS, E., 1995. Seasonal variation in plasma testosterone levels in Verata and Malagueña bucks. *Small Rumin. Res.* 15, 155-162.

PÉREZ, B. and MATEOS, E., 1996. Effect of photoperiod on semen production and quality in bucks of Verata and Malagueña breeds. *Small Rumin. Res.* 23, 23-28.

RITAR, A.J., 1991. Seasonal changes in LH, androgen and testes in the male Angora goat. *Theriogenology* 36, 969-972.

ROCA. J., MARTINEZE, E., VAZUES, J.M. and COY, P., 1992. Characteristics and seasonal variation in the semen of Murciano-Grandina goats in the Mediterranean area. *Anim. Sci.* 29, 255-262.

SAS, 1991. SAS for P.C.6.04. SAS Institute Inc. SAS® Cary, North Carolina, USA.

SCHWALBACH, L.M.J., ALMEIDA, A.M., GREYLING, J.P.C., CARDOSO, L.A. and WILLIAMS, C., 2000. The effect of undernutrition on testes and semen characteristics in young Boer goats. *Proc.7th Int. Conf. on Goats*, France, pp 437-439.

SHRESTA, J.N.B., FISER, P.S., LANGFORD, G.A. and HEANEY, D.P., 1983. Influence of breed, birth date, age and body weight on testicular measurements of growing rams maintained in a controlled environment. *Can. J. Anim. Sci.* 63, 835-847.

SOLOMON, G. and THWAITES, C.J., 1997. Changes in liveweight, body condition and scrotal circumference and their relationships with sexual activity and flock fertility in Ethiopian Horro rams over a 3-cycle joining period. J. Agr. Sci., Cambridge, 128, 117-121.

TERQUI, M., DELOUIS, C. and ORTAVANT, R., 1984. Endocrine causes of seasonal anestrus in farm animals photoperiodism and hormones in sheep and

goats. Eds. Ellendorff, F. & Elsaessen, F. *Martinus Nijhoff*, Publ., Dordrecht, Netherland, pp 246-259.

THWAITES, C.J., 1995. The comparative effects of undernutrition, exercise and frequency of ejaculation on the size and tone of the testes and on semen quality in the ram. *Anim. Reprod. Sci.* 37, 299-309.

TOE, F., LAHLOU-KASSI and MUKASA-MUGERWA, E., 1994. Semen characteristics of Ile-de-France rams of different ages and physical conditions. *Theriogenology,* 42, 321-326.

TREJO, G.A., PONCE, L.C. and VIDAL, G.M.A., 2000. Effects of melatonin and GnRH treatments on semen quality in young male goats. *Proc. 7th Int. Conf. on Goats*, France, May 15-21, pp 444-449.

VAN DER NEST, M., 1997. Accelerated breeding techniques in Boer and indigenous goats: The evaluation of synchronization and MOET. MSc. (Agric) Dissertation, University of the Orange Free State, South Africa.

WALKDEN-BROWN, S.W., RESTALL, B.J. and SCARAMUZZI, R., 1992. Reproductive seasonality in Australian Cashmere bucks. *Proc. 5th Int. Conf. on Goats*, New Delhi, India, Abstr. 316-320.