REPRODUCTIVE PERFORMANCE OF DJALLONKÉ SHEEP IN THE NORTHERN REGION OF GHANA

BY

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, IN FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF

MASTER OF PHILOSOPHY (REPRODUCTIVE PHYSIOLOGY) DEGREE

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES
FACULTY OF AGRICULTURE
DEPARTMENT OF ANIMAL SCIENCE

NOVEMBER, 2014

CERTIFICATION

I hereby certify that the work herein submitted as a thesis for Master of Philosophy (Animal Reproductive Physiology) Degree has neither been presented nor is being concurrently submitted for any other degree elsewhere. However, work of other researchers and authors which served as sources of information are duly acknowledged

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Head of Department	Signature	Date

DEDICATION

This work is dedicated to my family, and especially to my daughter, Saha Salifu.

ACKNOWLEDGEMENTS

This work could not have been done without the generous help received from many individuals and institutions. I hereby acknowledge them.

I wish to thank Professor Stephen A. Osei, my supervisor, for supervising this work; for bringing his trademark thoroughness to bear on this thesis, and for his patience with me. It was an honour to work under him. I also appreciate the advice and criticisms of Mr. P.K. Karikari and Professor Daniel B. Okai of the Animal Science Department of KNUST and Dr. F. Y. Obese of the University of Ghana Animal Science Department in the preparatory stages of this work.

I am indebted to the Farm Manager of the Pong Tamale Livestock Breeding Station, Mr. Ibrahim Shahadu and his assistant Mr. Lawrence Dartey, for granting me access to the animals and facilities of the Breeding Station for this project. I also wish to thank the stockmen at the sheep section who assisted me in sample collection for over a year. I especially wish to thank Mr. Ben Bodi who was a great help in all the work I did on the farm.

The laboratory space, reagents and technical expertise were provided by the Pong Tamale Central Veterinary Laboratory (PTCVL) during analysis for progesterone. I am indebted to the following individuals at the laboratory who were generous with their time and expertise: Dr. Edward Harunah, the former head of the PTCVL; Dr. Emmanuel Alegye Kudjo, the Head of the laboratory and Head of the vaccine unit for granting access to the laboratory and its resources and for supplying all the equipment I needed for sample collection and storage. I also wish to thank Mr. Patrick Mbii of the Savelugu sheep farm and Dr. Franklin K. Avornyo of the CSIR-ARI, who introduced me to the personnel of the laboratory. Mr. Mbii also provided some

secondary data, equipment and technical advice. I am truly grateful to Alhaji Ibrahim Seidu, Head of the Serology laboratory and Mr. Reindolf Danso of the same unit who collected the samples and performed the analysis.

The ELISA kits and other materials used for this project were purchased on my behalf by Mr. Faisal Musah of New Jersey, USA and Mr. Gershon Y. Banini of CSIR-Animal Research Institute cleared the materials at the ports. I am grateful to both individuals. I also appreciate the help of the Director of CSIR-Animal Research Institute, Dr. Naaminong Karbo, who sent out the order letter for the materials. The ram harnesses and crayons which greatly aided oestrus detection were supplied by Dr. Razak Alhassan of Manchester University and my mother, Fati Lansah, in Saudi Arabia. I am grateful for their help.

I also appreciate the help of Mr. A. Bawa of the UDS Spanish laboratory and the staff of the World Vision water quality laboratory in Savelugu for supplying the deionized water used for the ELISA tests.

Finally, I wish to thank Mr. Abdulai Nabrizini, owner of Akana Farms, who freely shared his data and hosted me in his own home while I was collecting data in Gushiegu.

My ultimate thanks go to God Almighty for making all this possible.

ABSTRACT

This study was undertaken to assess the reproductive performance of Djallonké ewes in the Northern Region of Ghana. The study was in two parts. In the first part, blood progesterone levels of 20 Djallonké gimmers and 20 postpartum Djallonké ewes at the Pong Tamale Livestock Breeding Station in the Savelugu district of the Northern Region, were monitored to determine the age at puberty of the gimmers and the length of postpartum return to oestrus of the postpartum ewes (as evidenced by progesterone rises above 1ng/ml). The mean age and weight of the experimental gimmers was 136±3.38 days and 9.94±0.33kg, respectively at the beginning of the experiment. The postpartum ewes weighed 22.57±0.68kg at the start of sampling. Data on weight changes, body condition scores, blood glucose levels and packed cell volume (PCV) were also taken. Reproductive parameters such as age at first oestrus, age at first parturition of gimmers, lambing intervals of postpartum ewes, prolificacy and birth weights of lambs were also determined. The effect of season on all parameters was assessed.

In the second part of the study, data from production records of two government sheep farms (Savelugu Sheep farm and CSIR-ARI sheep farm) and one private farm (Akana Farms) were analyzed to determine fertility rate, age at first parturition, lambing intervals, birth weight of lambs, prolificacy, pre-weaning mortality rates and the effect of season, parity of dam and location on these parameters.

The results of the progesterone monitoring study showed that Djallonké gimmers reached puberty at a mean age of 220.6 days, with rainy season born gimmers reaching puberty at a significantly younger age (202.4 days vs. 238.7 days) ($P<0.05$). The gimmers of both seasons however showed their first progesterone rise at a similar weight (13.05kg for rainy season and 12.65kg for dry season gimmers) ($P>0.05$).

Mean age and mean weight at first oestrus were 289.3 days and 15.65kg respectively. There were no differences in mean age and mean weight at first oestrus between seasons (P>0.05). Gimmers in the progesterone-monitoring study gave birth to their first lambs at the mean age of 460 days, with rainy season born gimmers lambing significantly earlier than the dry season born gimmers (424.6 vs. 495.8) (P<0.05). The progesterone patterns of gimmers showed a brief first rise of progesterone followed by a few irregular cycles before conception. Fifty-eight percent of the gimmers conceived when mated at the first display of overt oestrus, 95% conceived at the second and 100% conceived at the third oestrus.

The postpartum ewes experienced first progesterone rise 69 days postpartum and came into overt oestrus 108 days postpartum. There was no significant difference between seasons for days to first rise of progesterone postpartum and days to first oestrus (P>0.05). The mean number of days from parturition to first oestrus was 101 days for rainy season ewes and 114 days for dry season ewes. The lambing intervals averaged 266.7 days for both seasons, with rainy season ewes having a mean lambing interval of 264.2 days while dry season ewes had a mean lambing interval of 268.7 days. There was no statistically significant difference between seasons for the lambing interval (P>0.05). Mean birth weight of lambs was 2.04kg, with the lambs of the rainy season ewes being significantly heavier (2.32kg vs. 1.83kg) and having higher placenta weights (175.2g vs. 132.7g) compared to the dry season ewes (P<0.05).

The analyzed data from the 3 sheep farms, in the second part of this study, showed that average fertility rate was 85% for Akana Farms and 52% for Savelugu Sheep farm. The mean age at first parturition was 595 days. There was no significant difference in age at first parturition for rainy season and dry season born ewes (566 vs. 614 days) (P>0.05). The CSIR-ARI sheep had their first lambs at a significantly

younger age (496 days) compared to the Akana Farms and Savelugu farm sheep (600 and 671 days respectively)($P<0.05$).

The overall mean lambing interval for sheep at the three stations was 267.4 days. Lambing intervals declined significantly with increasing parity ($P<0.05$). Mean lambing intervals were lowest for CSIR-ARI farm, followed by Akana farms and Savelugu farm ($P<0.05$). Mean birth weight for all stations was 2.57kg. Birth weight increased significantly with increasing parity ($P<0.05$) and rainy season born lambs were significantly heavier than dry season born lambs. Litter size and location also had a significant effect on the birth weight of lambs. Lambs born as twins had lower birth weights compared to lambs born as singles (2.25kg vs. 2.53kg) ($P<0.05$). Lambs born on Akana farms had the highest mean weights (2.67kg) followed by Savelugu farm (2.03kg) and lastly CSIR-ARI farm (1.59kg). The sex of the lamb did not significantly influence the birth weight of lambs.

Overall pre-weaning lamb mortality was 28%. More of the dry season born lambs died before weaning compared to rainy season born lambs (36.3% vs. 16.7%) ($P<0.01$). Type of birth and sex of lamb did not significantly influence the pre-weaning mortality rate. The annual reproductive rate was 1.03 lambs per ewe of reproductive age.

Based on this study, it was concluded that Djallonké gimmers reach puberty when they are 7 months old and are first mated when they are 8 months old. Gimmers born in the rainy season reach puberty earlier than the dry season born gimmers. Postpartum ewes resume cycling about 2 months postpartum and come into overt oestrus almost 4 months after parturition. Reproductive parameters for Djallonké females lambing in the rainy season are generally better than for those that lamb in the dry season.

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CHAPTER ONE

1.0 INTRODUCTION

Small ruminants constitute an important sub-division of the animal production industry in Ghana, representing 17% of the traditional livestock population in Ghana and contributing 49% of all ruminant meat in the country (FAOSTAT, 2009). According to Adjorlolo (2007) small ruminant meat production and consumption in Ghana increased between 85 and 100% from 1995 to 2005.

Sheep and goats are particularly valuable in developing countries, where they are generally considered to be a form of savings, in addition to the meat and milk they provide. Small ruminants are resilient and well adapted to environments where conditions such as inadequate feed and unfavourable climates are pervasive. Such adaptability to the prevailing environment usually brings small ruminant rearing within the ability of resource-poor farmers since only bare minimum deliberate interventions are made to keep production going. The nutritional and socio-economic impacts small ruminants make in the lives of their owners have received considerable attention in several publications (Devendra, 1988; Tuah, 1990; Abassa, 1995; Gatenby, 2002; Baiden, 2009).

Reproduction determines the rate of expansion of a population; reproductive performance is therefore a good measure of the productivity of small ruminants. In Sub-Saharan Africa, where small ruminant production is typically a low input venture, reproductive failure is usually the first sign of decreased productivity (Abassa, 1995). In spite of increases in small ruminant numbers, it is unclear whether a corresponding increase in productivity of small ruminants has taken place (Abassa, 1995; Adjorlolo, 2007).

In Ghana, published literature on the reproductive performance of small ruminants has often taken the form of analysis of on-station data obtained from government farms (Tuah and Baah, 1985; Baffour-Awuah *et al*, 2007). Awotwi *et al* (1992), conducted a similar study, but under on-farm conditions.

Measurement of progesterone has been used as a tool to monitor reproductive performance and to diagnose reproductive dysfunction in pigs, cattle, sheep and goats (Stabenfeldt *et al*, 1968; Mukasa-Mugerwa and Esaz, 1990; Osei *et al* 1997; Blaszczyk *et al*, 2009). Obese (1994) used progesterone measurements to monitor the reproductive performance of Djallonké gimmers in the humid forest belt of Ghana. Monitoring the hormones that modulate reproductive activity makes it possible to detect optimum times of breeding even in the absence of overt signs of oestrus since patterns associated with normal and abnormal oestrous cycles can be established using the levels of those hormones (Vercoe, 1978).

Obese (1994) and Osei *et al* (1997) used progesterone measurements to study the reproductive performance of Djallonké sheep and N'dama cattle in the humid southern zone of Ghana. No similar work has been done in the drier, Guinea Savannah zone of Ghana where the Northern Region is located. An assessment of reproductive performance in the Guinea Savannah is however imperative given the estimation by Abassa (1995), that small ruminants occur in larger numbers in drier regions of Africa than in humid regions. Gatenby (2002) in fact estimated that out of 200 million sheep in Africa, only 20 million (10%) were found in humid and sub-humid areas. There is also a possibility that variations in climatic conditions across the country could result in differences in reproductive performance in the different agro-ecological zones owing to factors like differences in feed quality and

availability. This study was therefore undertaken to document the reproductive performance of Djallonké sheep in the dry Savannah of Northern Ghana.

The specific objectives of this study were to:

A. Determine age at puberty of gimmers and length of post-partum return to oestrus among ewes using serum progesterone measurements.
B. Obtain baseline data on the reproductive performance of Djallonké sheep in the Northern Region of Ghana with regard to their fertility, age at first lambing, prolificacy and parturition intervals.
C. Examine the effect of parity of dam, sex of offspring, season of birth and location on reproductive performance.
D. Assess the reproductive losses that occur prior to weaning.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Importance of Sheep

Sheep are a typical feature of smallholder farms in Northern Ghana (Tuah, 1990; GLSS, 2008). Avornyo *et al* (2007) estimated that households in the Northern Region keep on the average between 10 and 20 small ruminants. Sheep rearing comes with manifold benefits for the resource-poor farmers (Devendra, 1988; Ibrahim, 1998; Adogla-Bessa, *et al* 2007) and this has made them popular in the Northern Region of Ghana.

Sheep are well integrated into the crop-livestock farming system where crops and livestock complement each other and reduce the risk farmers could face by focusing exclusively on crop or animal agriculture. Crop-livestock integration presents opportunities for nutrient cycling, enhanced income per unit of land and sustainable agriculture (Winrock International, 1992). Osei (2012) stated that some of the benefits derived from crop-livestock integration include the manure derived from livestock that improves soil fertility and contributes towards sustainable agriculture under smallholder conditions. Small ruminants in turn convert crop residues generated from cereals and legumes into valuable and high quality food in the form of meat and milk for humans (Oltjen and Beckett, 1996; Ibrahim, 1998).

Sheep also supply food and generate income for the direct benefit of resource-poor people. In the subsistence sector, farmers depend on them for much of their livelihood, often to a greater extent than on cattle because sheep are generally owned by the poorer strata of society. Adogla-Bessa (2007) argued that any intervention that improves the productivity of sheep is an important route to creating wealth and

improving the standard of living of the resource-poor farmer. Sheep and goats are offered for sale at the beginning of the rainy season and the proceeds of the sales are invested in the purchase of fertilizer, seed, labour and other inputs. Due to their rapid reproductive turnover (early puberty, short gestation) and, in some breeds, high incidence of multiple births, a farmer can quickly build up a flock of sheep as a major capital asset. With increased production, the farmer has a surplus for sale, and with the cash income, can buy inputs for cultivation of crops.

Like goats, sheep represent an important "emergency" capital asset that can be sold for household needs, school fees, medical bills and other emergencies (Annor, 2002).

In developing countries, ownership of sheep also confers social status. This is particularly important in sub-Saharan Africa where livestock occupy an important place in many cultures. The social function of small ruminants may be as important as food and cash, although it is difficult to place monetary value on the personal satisfaction and social prestige derived from sheep rearing by their owners (Adogla Bessa, 2007). In spite of this difficulty in placing value on the intangible benefits derived from sheep, Kosgey *et al* (2004) established that it is only when intangible benefits are considered, along with tangible benefits, that a more accurate estimation of gains derived from small ruminant production by the resource-poor farmer can be made.

Small ruminant meat contributes on the average 18% of all meat consumed in Sub-Saharan Africa; their production therefore plays an essential role towards achieving food security (Ibrahim, 1998). Consumption of even small amounts of their meat helps in ameliorating amino acid deficiencies in areas where diets are primarily cereal and legume-based ones (Winrock, 1992; Ibrahim, 1998).

Small ruminants are widely used for religious and cultural purposes. Small ruminants are often presented as gifts and dowries in some cultures. They are also sacrificed during religious festivals.

2.2 Sheep Production in Ghana

According to the GLSS (2008), the total value of sheep in Ghana stood at US$ 75,485,000.00 or 14.2% of the total livestock output. A large population of these sheep can be found in the northern regions of Ghana (Savannah zone) where an estimated 60% of the sheep are being reared by rural households. The rest are distributed between rural forest areas (22%), urban centres (12%) and the coastal savannah (6%).

The low input, extensive system is pervasive and to a large extent small ruminant farming is a rural enterprise, although rearing small flocks of sheep and goats is a known pastime in some urban centres (GLSS, 2008).

The Djallonké breed is the predominant sheep breed in Ghana (Annor, 2002; Koney, 2004) although Sahelian crosses exist, accounting for less than 10% of the sheep population (Koney, 2004).

2.3 West African Dwarf Sheep/ Djallonké Breed of Sheep

The Djallonké breed is widely distributed across West and Central Africa and is adapted to both the dry Savannah and humid, tsetsefly-infested areas (Epstein, 1971). The Djallonké are thin-tailed sheep belonging to the larger West Africa Dwarf breed (Traore *et al*, 2008). The breed has been described by Gbangboche *et al* (2008) and Koney (2004) as a compact breed that reaches a height of 40 to 60cm at the withers and weighs 20 to 30kg (females) or 25 to 35kg (males). The rams have horns while the females are polled. The typical colours of this breed are white, black, brown or a motley mixture of white and black, where the black colour is confined to the

headquarters and hindquarters, with the white colour dominating the middle portion (Wilson, 1991; Payne and Wilson, 1999).

2.4 Overview of the Physiology of Reproduction in Sheep

Reproduction in farm animals involves complex interlinked biological processes with characteristic patterns. In female farm animals, the main processes of reproduction are the initiation or resumption of cyclical ovarian activity in the female leading to display of oestrus behaviour and the release of a healthy ovum (i.e. oocyte) at ovulation. Oestrus and ovulation, when accompanied by mating or artificial insemination (AI) of the female sheep at the most opportune time, results in fertilization, pregnancy and implantation of the fertilized embryo in the uterus, which various hormones would have made functionally and structurally competent to carry the embryo (Vetheraniam *et al*, 2010). The developing embryo(s) and foetus(es) are then nurtured in an appropriate environment to ensure that pregnancy is maintained to parturition (Gatenby, 2002; Vetheraniam *et al*, 2010). Reproductive processes are helped along by numerous hormones and involve multiple metabolic and hormonal pathways (Hess *et al*, 2005; Garnsworthy *et al*, 2008). Reproductive events in sheep, as in other non-primate mammals, revolve around the oestrous cycle, which provides multiple opportunities for an animal to become pregnant (Senger, 2003).

2.4.1. Oestrous Cycles of Sheep

The oestrous cycle is a sequence of physiological events with species-specific duration that involves morphological changes in the reproductive system and behavioural changes in the animal (Pineda, 2003). In the healthy non-pregnant animal, the cycle repeats itself at defined intervals. In domestic sheep this interval, known as the ovarian cycle or oestrous cycle, occurs several times during the year in the tropics

(non-seasonal breeders), but only occurs in the breeding season for sheep in temperate regions (seasonal breeders). Sheep are therefore described as polyoestrous animals (Pineda, 2003).

The average length of the ovarian cycle in sheep has been variously reported as 16 or 17 days (Pineda, 2003). Breeds that develop in the temperate regions experience a seasonal pattern of oestrous cycles that involves an extended period of anoestrus during which ovarian cyclicity ceases. The breeds found in the tropics follow no such pattern, and could continue to cycle all-year-round if the conditions permit (Ibrahim, 1998; Hafez *et al*, 2000, Adogla-Bessa *et al*, 2005).

The oestrous cycle is dated from the first day of oestrus. The ovarian cycle of sheep has two recognized/distinct stages;

i.) The stage associated with the growth of the follicle, called the follicular phase; and

ii.) The stage characterized by the formation of the corpus luteum and secretion of progesterone, called the luteal phase.

Figure 1 shows the stages of the oestrous cycles and the number of days associated with each stage in sheep.

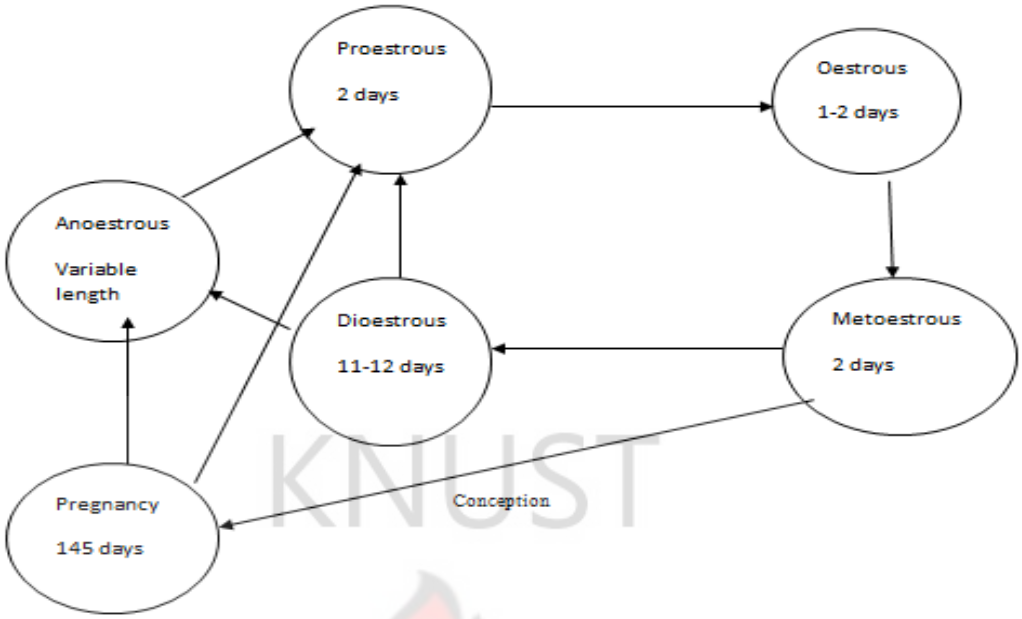


Figure 1: Number of days associated with each stage of the sheep oestrous cycle. Source: Pineda (2003).

2.4.1.1 The Follicular Phase

Two events typify the follicular phase; pro-oestrus and oestrus. Pro-oestrus involves the growth of ovarian follicles and production of estradiol, under stimulation by the gonadotropins follicle stimulating hormone (FSH) and luteinizing (LH). Under the influence of oestradiol the tubular genital tract of the female becomes engorged with blood and the cervix and vagina begin to secrete a serous fluid during pro-oestrus. In sheep, vaginal and cervical secretions are much less evident (Gatenby, 2002) than in cattle. Oestradiol also elicits oestrus behaviour in sheep to facilitate mating. It is during the pro-oestrous phase that the corpus luteum of the previous cycle undergoes regression (Pineda, 2003).

Oestrus immediately succeeds pro-oestrus and is the period of acceptance of the male by the female. Oestrus supplies the most reliable evidence of the stage of ovarian cyclic activity and it is the baseline for determining the oestrous cycle length. In

sheep, oestrus lasts for 30 to 40 hours with ovulation occurring towards the end of oestrus. Pro-oestrous and oestrus occur over 2-3 days (Pineda, 2003).

2.4.1.2 The Luteal Phase

Metoestrus and dioestrus collectively form the luteal phase. Metoestrus succeeds oestrus, and marks the formative stage of the corpus luteum (Senger, 2003). The granulosa and theca cells from the ovulated follicle form lutein cells which develop into the corpus luteum, a temporary endocrine gland which secretes the hormone progesterone. The metoestrus stage in sheep is virtually indistinguishable from the dioestrus, unlike in cattle where the metoestrus is distinguished by the fact that ovulation actually occurs during that stage (Hopkins, 2003). The period in which the corpus luteum is fully formed and begins to secrete large amounts of progesterone (more than 1ng/ml) is known as the dioestrus phase. In sheep the luteal phase lasts 12 to 14 days, with dioestrus alone accounting for 11-12 days. (Senger, 2003) (Fig 1).

2.4.1.3 Neuroendocrine Regulation of the Oestrous Cycle

The oestrous cycle operates under the control of the hypothalamo-pituitary-ovarian axis (Noakes *et al*, 2001). The principal hormones involved in regulating the precisely-timed events of the oestrous cycle are gonadotropin releasing hormone (GnRH) of hypothalamic origin; Follicle stimulating hormone (FSH) and Luteinizing hormone (LH), from the anterior pituitary gland; and the ovarian sex steroids oestradiol and progesterone. Ovarian-derived peptides like inhibin, activin and follistatin, respectively, inhibit FSH activity, stimulate FSH activity and play permissive roles in gonadotropin secretion (Noakes *et al*, 2001; Bartlewski, 2011).

The follicle stimulating hormone (FSH) is responsible for the development of ovarian follicles from the time they have become antral and have reached a size of 2-3mm.

FSH stimulation of the follicle results in the secretion of oestradiol by the theca cells. FSH action is curtailed by oestradiol and inhibin via a negative feedback mechanism (Hunter, 2004). In spontaneously ovulating species, once a threshold level of oestradiol is attained, a massive burst of LH is released from the anterior pituitary which triggers ovulation. The collapsed theca and granulosa cells left behind as a result of the freshly ovulated follicle rapidly luteinize to form the corpus luteum. The developed corpus luteum then starts to secrete progesterone (Senger, 2003). In the non-pregnant polyoestrous female, the functional and morphologic life of the corpus luteum is terminated by the luteolysin prostaglandin F2alpha, produced by the uterus. As the corpus luteum regresses and progesterone declines, the block on follicle development is removed and a new wave of follicles develops, which completes the oestrous cycle (Aiello, 1998). Figure 2 shows the various hormones and their characteristic patterns during the normal oestrous cycle of sheep.

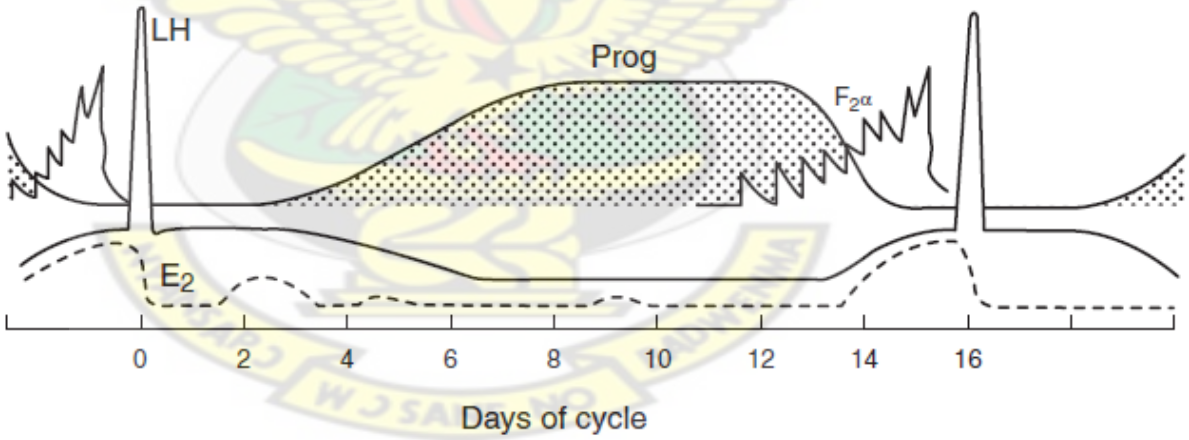


Figure 2: A sixteen-day ovine oestrous cycle showing patterns of luteinizing hormone (LH), oestradiol (E2), progesterone (Prog) and prostaglandin F2α (F2α).

Source: Goodman and Inskeep (2006).

2.4.2 Pregnancy

Pregnancy is the period of intrauterine development of the mammalian young following fertile mating, until parturition. It follows the non-return of the animal to oestrus after successful mating or insemination. The intervening period between fertile mating and parturition is also known as gestation period (Jainudeen and Hafez *et al*, 2000). In sheep, the gestation period spans a period of 148 days (Hafez *et al* 2000, Pineda, 2003) but may range between 140 and 159 days. Gestation is concerned with the nourishment of the foetus until parturition and the dam usually undergoes metabolic, hormonal and immunologic changes to accommodate the growing foetus (Warning *et al*, 2011). Some major hormonal changes associated with pregnancy in the ewe are illustrated in Figure 3.

Gestation is conveniently broken down into three main stages. The first stage is the period of the zygote, which lasts until the initial tenuous attachment of the blastocyst to the uterus (nidation) is established. The second stage, the embryonic stage, starts from day 12 post conception and ends around day 34. The third stage, the period of the foetus, starts from around day 34 until parturition (Jainudeen and Hafez *et al*, 2000).

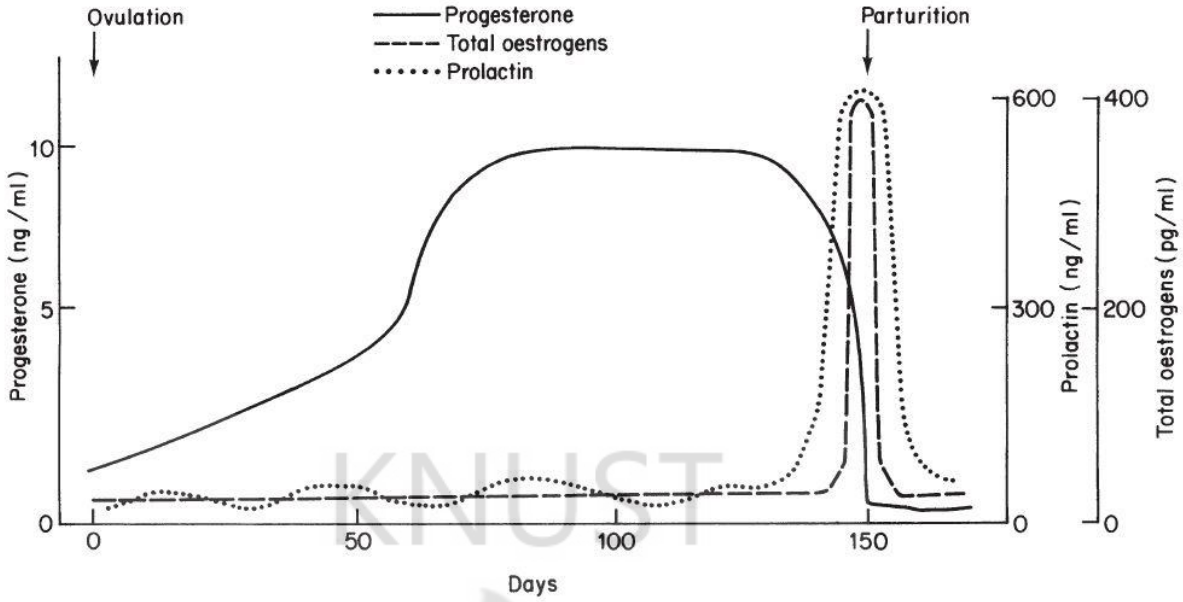


Figure 3: Trends in peripheral concentrations of progesterone, oestrogen and prolactin in the ewe during pregnancy and at parturition

Source: Noakes *et al* 2001

Progesterone is the main pregnancy hormone. It maintains pregnancy by stalling myometrial contractions throughout pregnancy, thus preventing the expulsion of the foetus prematurely (Senger, 2003). It is also believed to temporarily suppress maternal immunity (Lewis, 2003; Hunt *et al*, 2006) to facilitate the attachment of the embryo (which is essentially a foreign body) to the maternal endometrium.

2.5.0 Reproductive Performance of Djallonké Sheep

In farm animals, production performance is the combined outcome of reproductive efficiency, growth rate and quality of the final product (Mukasa-Mugerwa and Lahlou-Kassi, 1995; Ibrahim, 1998; Gbangboche *et al* 2006). Martin *et al* (2004) stated that excellent reproductive results consist of maximizing the number of animals born, minimizing post—fertilization wastage by ensuring successful embryonic foetal

development, and ensuring the survival of the newborn until they become productive animals themselves.

The reproductive rate of sheep has been described by Mukasa-Mugerwa and Lahlou-Kassi, (1995); Ibrahim, (1998); Gbangboche *et al* (2006) and Martin *et al* (2004) as the most important factor affecting productivity and economic success in sheep production. Munoz (2009) reported that poor reproductive performance in young ewes is a major loss to the sheep industry. Annor *et al* (2007) identified low survival rate, slow growth rate and low reproductive rates as the main challenges to small-scale production of Djallonké sheep in Ghana and argued that improvement in reproductive output is more rewarding, economically, than improving growth performance.

2.5.1 Measures of Reproductive Performance

Reproductive performance is determined by a combination of factors. These factors include: age at puberty (Dyrmundsson, 1981); age at first lambing (Fall *et al*, 1982; Armbruster *et al*, 1991), lambing intervals (Fall *et al*, 1982), ovulation rates (Schoenian and Burfening, 1990), embryo survival (Schoenian and Burfening, 1990; Abassa, 1995), prolificacy (Tuah and Baah, 1985; Abassa, *et al* 1995) and reproductive rate (Gatenby, 2002).

These measures of reproductive performance are adopted by most workers when assessing reproductive performance of sheep. Other important parameters usually considered are fecundity (Baffuour-Awuah, 2002), weaning rate and the annual reproductive rate (Wilson, 1989; Ibrahim, 1998). In assessing reproductive performance, the measures used should be appropriate and data used must be suitable (Peacock, 1987).

2.5.1.1 Puberty

Puberty is the time when the reproductive organs first become functional. In the female, it is defined as the time when the first functional oestrus takes place and the earliest age at which reproduction can occur (Ibrahim, 1998). Some workers (Dyrmundsson, 1981; Lawrence and Fowler, 1997, Senger, 2003, Osei, unpublished) however point out that the advent of puberty does not suggest full sexual maturity or the ability of the animal to carry a pregnancy to term, since the reproductive organs of the female may not be fully mature at the time of puberty.

Some domestic species such as the heifer and the ewe lamb undergo one or more "quiet oestruses" and ovulations before they display full oestrus behaviour and establish the characteristic pattern of cyclic activity of the female (Pineda, 2003; Senger, 2003). The cyclic periods that characterize assumption of puberty are marked by two events: oestrus (periods of sexual receptivity) and ovulation (release of mature ovum/ova).

The principal requirement for the attainment of puberty is the pulsatile production of GnRH from the GnRH surge centre of the hypothalamus. The pre pubertal female animal shows no sign of recurring or cyclic periods of sexual receptivity prior to the advent of puberty (Noakes *et al,* 2001), and even though the hypothalamic-pituitary-ovarian system is functional, ovulation does not occur because tonic LH secretion is insufficient and the frequency and amplitude of GnRH and LH are still too low to drive the production of sufficient oestradiol, which stimulates the gonadotropin surge and ovulation (Foster *et al*, 1985; Senger 2003). The low oestradiol production at this stage is the result of a highly sensitive hypothalamo-pituitary unit which responds by negative feedback to prevent further production of oestradiol (Noakes *et al* 2001; Senger 2003). The sensitivity of the hypothalamo-pituitary unit however decreases as

puberty approaches, permitting increasing levels of oestradiol to be produced. Eventually, the decreasing sensitivity of the hypothalamus permits a high enough concentration of oestradiol to be reached which stimulates the GnRH surge centre (which responds to positive feedback of oestradiol) to produce GnRH pulses which stimulates the pituitary to produce the LH pulses that trigger ovulation. This process is called the "Gonadostat" hypothesis of puberty (Noakes *et al* 2001, Ball and Peters, 2004; Foster and Jackson, 2006; Ojeda and Skinner, 2006).

The age of puberty is an important parameter to consider because of its influence on the lifetime productivity of the animal; the earlier an animal attains puberty, the higher the potential number of offspring it can produce over its lifetime, environmental factors permitting. The age at which puberty is attained is influenced by both genetic and environmental factors and also by interactions between the two (Dyrmundsson, 1981). These factors have been identified as species, breed, body weight, heterosis, proximity of a male animal, season and other environmental factors such as temperature (Dyrmundsson, 1981; Koney, 2004; Noakes *et al*, 2001).

Species differences in age at puberty are considerable and the general trend indicates that smaller animals attain puberty earlier than larger animals. For example mice attain puberty at an average age of just 35 to 45 days while ewes reach puberty at 6-15 months, heifers at 7-18 months, mares at 12-24 months and elephant cows at 12 to 23 years.

Various workers (Foster and Nagatani, 1999; Jainudeen *et al*, 2000; Noakes *et al*, 2001; Pineda, 2003) have concluded that the weight of a female animal is more important than its chronologic age in predicting the age of puberty. Dyrmundsson (1973) observed that ewe lambs of high body weight generally reach puberty earlier and have more oestrous cycles and fewer subsequent silent ovulations than lighter

animals. Such fast-growing animals also have higher conception and lambing rates when mated (Dyrmundsson, 1981). Various authors have reported that sheep attain puberty when they have achieved a certain percentage of their mature body weight. Foster and Ryan (1981) reported that this threshold was between 60 and 65% of mature body weight while Ibrahim (1998) reported it to be 45 to 60% of mature body weight. However, there are considerable breed variations according to Hafez *et al* (2000) who observed that Romney ewes, Suffolk and Scottish Blackface, respectively, reached puberty at 30, 40 and 63% of their mature body weight. Mukasa-Mugerwa and Lahlou-Kassi (1995) reported this weight to be 56% of mature body weight for Menz ewe lambs while Obese (1994) reported that Djallonké sheep attain puberty when they are about 11kg or have achieved 55% of their mature body weight.

Nutrition levels modulate age at puberty because of its impact on body weight (Hafez *et al*, 2000). Animals that are fed a higher plane of nutrition generally have a faster growth rate and reach puberty earlier than animals that are underfed. However, underfed animals eventually attain puberty, albeit at an older age, provided the malnourishment previously suffered was not severe (Noakes *et al*, 2001).

Unlike what pertains in temperate regions, season has a much less important influence on the age at puberty in the tropics (Ibrahim, 1998).

In flocks where the rams are allowed to run with the ewes, age at parturition is a good indicator of the age at which conception occurred. An estimate of the age of puberty can usually be made for such flocks by subtracting the gestation length for the breed from the age at first parturition, although it must be borne in mind that the female may fail to conceive at the first oestrus(es) or the ram may not have detected that the female is in heat.

In Ghana, Tuah and Baah (1985) reported 638 days as the age at first parturition of Djallonké ewes in the humid zone of Ghana; making the age at puberty earlier than 448 days or 14 months). Other breeds such as the Menz are reported to attain puberty at 15 months of age (Mukasa-Mugerwa, 1994), which falls within the range of 212 days to 615 days reported by Gatenby (1986) and Foote (1991) for tropical and sub-tropical sheep. A major limitation of using the age at first parturition to compute age at puberty is the tendency of nulliparous ewes to ovulate without displaying oestrus (Foote *et al* 1970; Obese, 1994) or to display oestrus without ovulating (anovulatory oestrus) (Edey *et al*, 1977; Ibrahim, 1998). It is therefore likely that Djallonké ewes attain puberty much earlier than these observations seem to imply. This may be investigated by observing patterns of progesterone released into peripheral circulation and by observing the ovaries using the techniques like ultrasonography and laparoscopies.

2.5.2 Fertility and Pregnancy Rate

Fertility is a measure of the successful establishment of pregnancy (Robinson, 2006). A number of definitions and methods of estimating the fertility rate of sheep have been reported. Ibrahim (1998) defined it as the proportion of ewes that become pregnant out of the number of ewes available for mating. Due to the difficulty of diagnosing pregnancy, it is sometimes defined as the number of lambs born per ewes put to the ram (Hafez *et al*, 2000) or the number of matings required per conception. Abegaz *et al* (2002) identified ewe weight at mating, ewe parity before mating and ewe age at mating as some of the factors that influence the fertility of sheep. Their results showed an increase in fertility from a low of 56% among nulliparous ewes to 84% among ewes in their fourth parity. When the ewes were grouped by weight in

that study, it was found that ewes in the weight class <23.2kg had a lower conception rate (65%) than ewes in the 23.2 to 29.4kg weight class (83% conception rate) and the 29.4 to 35.6kg weight class (85% conception rate). Conception rate tended to decline when the ewes were heavier than 35.6 kg (71% conception rate). Dove and Dzakuma (1986) and Baffuor-Awuah (2007) reported fertility rates of 62% and 73%, respectively, for Djallonké sheep managed at the Ejura farm in Ghana. Obese (1994) reported 100% conception rate in ewes in reproductive performance studies in the humid southern zone of Ghana. Baffuour-Awuah (2007) reported a fertility rate of 79.1% for Djallonké sheep in the humid Southern zones of Ghana while fertility rates of 76% and 67% have been reported for Menz and Horro sheep respectively (Mukasa-Mugerwa *et al*, 2002).

Factors that are known to affect fertility are breed, age and environmental conditions (Gordon, 1957).

2.5.3 Gestation Length

Gestation is the period from fertilization to delivery of the foetus (Ibrahim, 1998). Gestation length is species-specific and varies within a narrow range (5-10%) for the different breeds of a species (Stewart, 1991). Terril and Hazel (1947) reported that 40% of the variance in gestation length in flocks was due to genetic differences. Clegg (1959) and Jainudeen and Hafez (2000) grouped the factors that influence gestation length under the broad headings of genetic factors, foetal factors, environmental factors and the maternal internal environment.

Age of the animal and parity, according to Jainudeen and Hafez (2000), exerts some influence on the gestation length. The authors reported that sheep of eight years or older have their gestation length, which is 148 days on the average, extended by two

(2) days. Forbes (1967) found that gestation length decreased from the third parity to the fifth parity (146.8 to 145.9 days) and then increased from the fifth parity to the eighth parity (145.9 to 149.7 days).

Foetal factors which appear to influence the gestation length are the sex of the foetus and the number of foetuses being carried simultaneously by the dam. Endocrine studies of the foetal pituitary-adrenal axis (Liggins *et al* 1967) and interbreed egg transfer by Dickinson *et al* (1962) showed that the duration of gestation is influenced by the foetus. Further interbreed egg transfer work by Bradford *et al* (1972) using different breeds of sheep with a range of one week difference in average gestation length clearly showed that gestation length was consistent for lambs of a given breed, regardless of the breed of the ewe carrying the pregnancy. Based on these results, Bradford *et al* (1972) concluded that two-thirds of the genetic variation in gestation length in sheep is due to the influence of the foetus.

Forbes (1967) reported that single lambs were carried for a longer period than twin lambs (147.3 vs. 146.7 days), and twins longer than triplets (146.7 vs. 145.6). Forbes (1967) proposed that the shorter gestation length of twin pregnancies compared to singleton pregnancies has basis in the fact that there is a higher nutritional demand in twin pregnancies compared to singleton pregnancies and that it is this relative under nutrition that triggers parturition. Obese (1994) and Addah and Karikari (2008) reported gestation lengths of 152 and 148 days, respectively, for Djallonké sheep in Ghana.

2.5.4 Age at First Parturition (AFP)

The age at first parturition is the number of years between birth and the first time the female animal lambs. The age at first parturition, ultimately influences the lifetime

productivity of the animal since, according to Abassa (1995), an early parturition results in much faster population turnover and genetic progress within the flock.

According to Wilson (1989), the age at first parturition is influenced by a number of environmental variables including the year and season of the ewe's own birth and also whether the ewe was born as a single or a twin. Management, with regard to whether breeding is controlled or uncontrolled also tends to affect the age at first parturition (Wilson, 1989; Abassa, 1995). Wilson (1989) observed delayed first parturitions in sheep that were bred in controlled breeding systems compared with sheep reared under uncontrolled systems where rams are free to run with females and serve them at the earliest possible display of oestrus (Table 1).

Fall *et al* (1982) reported the age at first lambing for station-managed Djallonké sheep in Senegal as 573.4 days. For the same breed, Tuah and Baah (1985) reported the length as 638 days for ewes in the humid zone of Ghana, which was the longest age at first parturition recorded for the breed. The lowest age at first parturition for the breed was reported as 350.75 by Rombaut and Vlaenderen (1976) for ewes in Cote d'Ivoire. Other work by Oppong-Anane (1971) (Ghana), Dettmers and Loosli (1974) (Nigeria), Armbruster (1988) (Cote d'Ivoire) and Gbangboche *et al* (2006) (Benin) showed the age at first parturition to be 431.3 days, 610 days, 408 days and 622.4 ± 55.6 days respectively.

Gbangboche *et al* (2006) found this parameter to be significantly influenced by season of birth and year of birth ($P<0.0001$), but Fall *et al* (1982) found no such effect. While Wilson (1989) acknowledged the contribution of some environmental effects to the age at first parturition, he concluded that environmental effects do not constitute a very important influence on the age at first parturition.

The data (Table 1) indicate that where controlled mating is employed as a management tool, the age at first parturition is usually significantly higher ($P<0.05$) than where the rams are allowed to run with the females, as happens under village conditions. Table 1 shows the age at first parturition for sheep raised under systems of controlled and uncontrolled mating. The average age at first parturition for sheep raised under controlled mating conditions is higher (531 days) compared to those raised under a system of uncontrolled mating (430 days).

Table 1: Ages at first parturition of WAD Sheep with controlled and uncontrolled mating

Breeding Management	**Age at first Parturition(days)**	**Source of data**
Controlled	408	Oppong Anane, 1971
Controlled	610	Dettmers and Loosli, 1974
Controlled	625.25	Dettmers *et al*., 1976
Controlled	573.4	Fall *et al*., 1982
Controlled	480	Armbruster *et al*., 1991
Uncontrolled	350.75	Rombaut & Vlaenderen, 1976
Uncontrolled	431	Armbruster *et al*., 1991
Uncontrolled	411	Ginistry, 1977
Uncontrolled	492	Sumberg and Mack, 1985
Uncontrolled	464	Faugere *et al*., 1988
Uncontrolled	431.3	Armbruster *et al*., 1988

Source: Wilson (1989)

Wilson (1989) argued that controlled mating does not increase lifetime productivity of sheep and may in fact reduce it by one full lambing.

2.5.5 Birth Weight

Birth weight is the weight of the lamb taken immediately after lambing. Koney (2004) has defined it as the weight of the newly born animal before it takes in milk. The importance of aiming at an optimum birth weight in lambs is based on evidence that high birth weights correlate negatively with lamb mortality; heavier lambs record

higher survival rates than lighter ones (Yapi *et al*, 1990; Mukasa-Mugerwa *et al*, 1994). Higher birth weights are associated with vigour and vitality in the lamb (Abassa, 1995). The chances of lamb survival tend to reduce considerably when the lamb is 1kg or less (Mukasa-Mugerwa *et al* 1994). Development is also altered in low-birth-weight lambs, which is manifested in slower growth, a lower accretion of fat and nitrogen, and decreased bone development (Greenwood *et al* 2000). Low birth weights are reported to impact on the health of the animal, including negative consequences for the reproductive ability of the animal which persist throughout its life (Steinheim *et al*, 2002; Gardner *et al* 2007). Steinheim *et al* (2002) and Gardner *et al* (2007) also found that low birth weight of female lambs subsequently affected the birth weights and number of lambs they produced later in life.

Variations in lamb birth weights are attributable to the type of breed, nutrition, season of lambing, parity of dam, type of birth (litter size) and sex (Fall *et al* 1982; Hafez *et al*, 2000; Koney, 2004; Gardner, 2007).

Differences in birth weights between species, breeds and strains are a result of genetically determined differences in the rate of cell division (Jainudeen and Hafez, 2000).

The influence of nutrition on birth weight starts *in utero*, where the foetus has to rely on the dam's supply of nutrients to grow and develop. How severely under-nutrition impacts birth weights depends on the stage of gestation at which the dam experiences nutritional deficit (Addah and Karikari, 2008). Poor nutrition during the first two trimesters of pregnancy interferes with proper "programming" of the foetus and the development of the placenta and accumulation of foetal fluids. A moderate restriction in nutrition in mid-pregnancy for animals already in good body condition is actually advantageous to the developing foetus in that the placenta expands in a bid to extract

more nutrients from the mother, leading to a larger sized lamb. This knowledge has been exploited for years by sheep farmers (Eriksson *et al*, 2012). However, a poor nutritional state in the third trimester of pregnancy is especially debilitating since most growth of the foetus is restricted to the third trimester. Improving dam nutrition during the third trimester of gestation has the effect of increasing the size of the foetus, although this can also be disadvantageous, to the extent that a larger foetus may require the intervention of a veterinarian during delivery (Koney, 2004).

Lambs born in the rainy season are generally heavier than those born in the dry season. Tuah and Baah (1985), Kabugah and Akowuah (1991) and Tibbo (2006) who all reported higher birth weights for rainy season-born lambs, attributed this to better nutrition (better quality and quantity of pasture) for the pregnant dam in the rainy season compared to the dry season.

Generally, the lambs born to pluriparous ewes are heavier than the lambs born to primiparous ewes (Tuah and Baah, 1985; Benyi *et al*, 2006). Tuah and Baah (1985) argued that the larger uteri and placentas of older ewes could, respectively, accommodate larger foetuses and ensure the supply of more nutrients to the foetus than the relatively smaller uteri and placentas of younger ewes. Furthermore, younger ewes, which are still growing, tend to partition nutrients to favour the dam at the expense of the foetus resulting in smaller birth weights (Addah, 2008).

Carrying multiple fetuses leads to a decline in lamb birth weight (Gootwine, 2005; Gardner, 2007). This is a result of the decline in the number and weight of placentomes per foetus and in placental weight (Rhind *et al*., 1980; Greenwood *et al*., 2000). A smaller placenta tends to limit foetal growth as it leads to a diminished supply of nutrients to the growing foetus and to slower removal of waste material from the foetus to the maternal circulation. Dickinson (1968) estimated the birth

weights of twins and triplets to be proportionately reduced by factors of 0.70 and 0.63 of the birth weight of singles.

Tuah and Baah, (1985) and Obese (1994) reported mean birth weights of 1.77kg and 1.7 ± 0.24kg respectively for WAD sheep in the humid zone of Ghana. Fall *et al* (1982), working in Senegal, reported an overall mean birth weight of 1.59kg for the same breed. Djallonké X Sahelian crossbreeds produce lambs with an average birth weight of 2.44kg (Kabugah and Akowuah, 1991). Mukasa-Mugerwa (1994) reported a mean birth weight of 2.0kg for Menz lambs in Ethiopia.

2.5.6 Prolificacy/Litter Size

Prolificacy is defined as the average litter size or the number of young produced per parturition. Sheep are reported to have the largest differences between breeds for this trait (Land, 1978). It is a function of the ovulation rate, which sets the upper limit for the number of offspring per birth. Prolificacy is relatively consistent within breeds (Evans, 2003).

The average litter size reported for tropical sheep is 1.14 (Ibrahim, 1998). The Djallonké breed has the reputation of being highly prolific (Adeleye, 1982; Ibrahim, 1998) even though various authors report prolificacies hinting at a less than 50% twinning rate both under station and traditional management systems. Fall *et al* (1982), Tuah and Baah (1985), and Gbangboche *et al* (2006) reported litter sizes of 1.31, 1.30 and 1.4, respectively for Djallonké sheep in Senegal, Ghana and Cote d' Ivoire.

The Booroola line of Merino sheep hold the distinction of being the most prolific sheep breed in the world because of its autosomal Fec B and is the subject of interest in crossbreeding programmes to improve litter size (Hua and Yang, 2009). A single

copy of the Fec B gene is estimated to increase ovulation rate by 150% and litter size by one extra lamb (Montgomery *et al*, 1995).

Since prolificacy is largely genetically influenced, it is quite possible to improve upon the trait in a flock by selection (Ibrahim, 1998). Although the same author reported that some environmental factors could be manipulated to increase litter size. For example, litter size of sheep can be increased by 10 to 40% by improving nutrition or by treatment with hormones.

Sheep have the ability to increase their litter size, by ovulating more ova in response to short term increases in feed allowance a few weeks before mating (Coop, 1966; Noakes *et al* 2001). This practice is known as flushing, and has been defined by Nix (2004) as the practice of putting the animal on a higher plane of nutrition 30 days prior to and 30 days after breeding.

Within breeds, age has been found to exert some influence on prolificacy. Tuah and Baah (1985) established a significant positive correlation between age and prolificacy in Djallonké sheep. Prolificacy increased significantly from 1.04 among ewes lambing for the first time, to 1.6 by their sixth year of lambing. The prolificacy declined from the sixth year onwards. Hoque *et al* (2002) and Hanford *et al* (2006) observed a similar trend. In the first study (Hoque *et al*, 2002) the prolificacy of ewes increased significantly from 1.64 to 2.20 between the first and fourth parity. In the study by Hanford *et al* (2006) litter size increased from 1.23 in the first parturition to 2.15 in the sixth parturition, after which litter size began to decline.

Wilson (1989) and Tuah and Baah (1985) found the trait to be significantly influenced by season of birth. While Tuah and Baah (1985) associated higher prolificacies with the major rainy season in Ghana, Wilson (1989) observed that Rwandan sheep recorded the highest prolificacies during the minor rainy season and dry season.

While it is clear that the sheep in Ghana were responding to availability of good quality feed by the observed increase in prolificacy in the major rainy season, the tendency for prolificacy to reduce in Rwandan sheep during the same period remains obscure.

2.5.7 Lambing Intervals

The lambing interval is defined as the period of time between two successive parturitions. Tuah and Baah (1985) reported 264 days as the mean lambing interval for Djallonké sheep in the humid forest zone of Ghana. The mean intervals of 256 and 279.5 days reported by Oppong-Annane (1971) for Djallonkés, and Kabugah and Akowuah (1991) for Djallonké-sahelian crosses did not differ remarkably. There however appears to be great variability in lambing intervals for the same breed even under similar management. For example, the data of Tuah and Baah (1985) show lambing intervals as low as 134 days for the Djallonké breed, indicating that some of the ewes delivered preterm lambs and resumed ovarian cyclicity within a short period of time. Within the same flock, however, Tuah and Baah (1985), observed lambing intervals greater than 700 days (23 months). Lambing intervals exceeding 243 days preclude the option of producing three lamb crops in two years, which, it is suggested, may be the optimum production level for sheep (Jainudeen *et al,* 2000). Wilson (1989), has attributed long lambing intervals among African small ruminants under station management to the practice of delaying mating of animals until certain body weights are achieved or until certain perceived desired conditions are met. He argued that by controlling mating of females under station management, reproductive potential is reduced since tropical small ruminants do not undergo the seasonal

anoestrous common to temperate sheep. However this loss in reproductive potential may be offset by the larger litter sizes of station-managed sheep.

2.5.8 Pre-weaning Mortality

This is the mean mortality from birth to weaning. It includes neonatal mortality (Abassa, 1995). The ability to control pre weaning losses undergirds any successful livestock enterprise. Annor *et al* (2007) reported that survival is an economic trait of utmost importance in sheep production. A World Bank Report (1992) implicated pre-weaning mortality as a major obstacle to the productivity of small ruminants in Ghana.

The conditions that have been found to affect this trait are birth weight, litter size, ewe nutrition, dam age (Ibrahim, 1998). The type of birth (Jollans, 1960, Fall *et al*, 1982, Tuah and Baah, 1985), sex of lamb, season of birth and maternal and neonatal behaviour (Haughey, 1993; Addae, 2000) were also found to influence the pre-weaning mortality.

The data published by Fall *et al* (1982) and Tuah and Baah (1985) for Djallonké sheep showed the pre-weaning mortality to be 33.09% and 20.95%, respectively, which fell within the range of 10 to 50% reported by Ibrahim (1998) for African small ruminants in general.

2.5.9 Annual Reproductive Rate

The annual reproductive rate (ARR) is an index which estimates the number of lambs born per ewe of reproductive age per year (Ibrahim, 1998). It is a composite parameter that combines key influences on small ruminant productivity i. e., litter size, pre-weaning mortality and lambing intervals and it is described by the following relationship:

$$\text{ARR} = \frac{s(1-M)}{L}$$

Where S is the litter size, M is the rate of pre weaning mortality and L the lambing interval in years (Ibrahim, 1998).

Wilson (1989) highly recommended the use of this parameter as it allows for easier comparison of sheep productivity between different systems and easily highlights changes in climate. A high annual reproductive rate is an indication of shorter lambing intervals, low mortality and a high litter size and therefore, high productivity. Using data from Tuah and Baah (1985) the ARR of sheep in the humid zone of Ghana was computed as 1.1 lambs per ewe per year. Kabugah and Akowuah (1991) reported 1.5 as the ARR for Sahelian x Djallonké crosses. The annual reproductive rates computed for various countries in Africa have ranged from 0.98 for Sudan Desert sheep (Suleiman and Wilson, 1988) to 1.97 (Armbruster, 1988).

2.6.0 Post-partum Return to Oestrus

The puerperium is the period between parturition and the return to the normal cycling state of the ovaries and uterus. It is a stage of reproductive repair during which the uterus reverts to its pre-pregnancy state (uterine involution). During puerperium, myometrial contractions expel lochia and bacteria that gained entry into the reproductive tract during the parturition process (Senger, 2003). Uterine involution is normally expected to be completed between 20 to 30 days in sheep (Senger, 2003). Following parturition, the ewe undergoes a period of acyclicity which varies with length of uterine involution, intensity of suckling, body condition score, health status of the animal, season and breed (Fray, 1995; Senger, 2003). This period of acyclicity is associated with low GnRH and LH secretion and a refractory anterior pituitary (Noakes *et al* 2001).

The length of time taken for sheep to resume ovarian cyclicity has major economic implications for sheep production. To obtain an optimum 6-month lambing interval the ewe must conceive within 35 d of parturition. However, following parturition the ewe undergoes a period of acyclicity which compromises reproductive efficiency. A prolonged postpartum return to oestrus results in reduced reproductive efficiency in sheep (Fray *et al*, 1995) and has been identified as a source of economic loss (Yavas, 2000; Obese *et al*, 2009).

In the ovaries, follicular development during postpartum anoestrus is common but ovulation is unusual and even when it occurs, it is silent. Failure of follicular maturation and ovulation has been attributed to inadequate production of LH, resulting from inadequate GnRH synthesis and secretion. As a result, basal LH levels and pulse frequency of episodic LH secretion are inadequate to stimulate normal ovarian function (Wright *et al*, 1981)

Anovulatory conditions may be induced by under nutrition and suckling (Wiltbank, 2002; Obese, 2009).

2.6.1 Effect of Nutritional Status on Postpartum return to Oestrus

Energy status is generally considered to be the major nutritional factor that influences reproductive processes, with prolonged low energy intake impairing fertility (Rhind *et al* 1989; Wade and Schneider, 1992). In sheep, poor nutrition, which results in lower ovulation rates, is associated with decreased LH pulse frequency, which is likely due to inadequate hypothalamic GnRH secretion (Rhind *et al* 1989).

2.6.2 Effect of Suckling on Postpartum return to Oestrus

In most mammals, suckling during the puerperium tends to delay the resumption of cyclic activity and the time when new gestation becomes possible (Hammond, 1961).

Suckling is reported to delay the resumption of ovarian activity by modifying the tonic release of GnRH and LH through the release of opioid peptides (Noakes, 2001). In non-suckled ewes, oestrous cycles resume within 3-5weeks postpartum (Shivah *et al* 1975; Kann *et al* 1979). The suckling stimulus in early lactation is by itself sufficient to maintain a block on the GnRH pulse generator limiting pulsatile LH secretion, regardless of the nutritional status of the dam. As lactation advances however, and the young demands more milk, the mechanism becomes more complex as the nutritional status of the dam starts to indirectly contribute to the block on LH secretion. This effect of the negative energy balance is more apparent in high-yielding milk animals and animals with large litters (McNeilly, 2006).

2.6.3 Effect of Pre-mating Body Condition of Dam on Postpartum return to Oestrus

Body condition score (BCS) is a subjective estimation of muscle and fat development of an animal. Body condition score reflects body reserves of lipids and is useful for assessing nutritional status (Morand-Fehr, 2005; Montiel and Ahuja, 2005). BCS therefore represents an indirect way of assessing the body reserves available for metabolism, growth, lactation and activity (Wright *et al*, 1987).

There are several reports associating BCS with reproductive function. Ovulation rate in small ruminants has been found to be strongly related to adiposity (Rhind *et al*, 1986; Boland *et al*., 1993; Rondon *et al*., 1996). Rhind and McNeilly (1986) found that high BCS's led to the development of greater numbers of large oestrogenic follicles compared to ewes with low BCS. Low BCS has also been found to negatively impact reproductive function by increasing neonatal and prenatal mortality (West *et al*, 1989; Nordby *et al* 1986; Noakes *et al*, 2001). Munoz (2009) reported

that low BCS at mating resulted in a decrease in litter size at birth. More recently, Abdel-Majeed and El-Maaty (2011) found that back fat significantly improved conception rate and prolificacy in Egyptian ewes.

2.7.0 Reproduction in an Environment of Seasonal Fluctuations in Feed Resources

The range of reproductive events, from ovulation and conception to pregnancy and lactation, is probably one of the most energy-taxing activities the female mammal will ever undertake (Wade and Schneider, 1992). Production stages such as gestation and lactation do not only come with an increased demand for nutrients but also changes the mode of nutrient partitioning and utilization due to numerous pregnancy-induced adaptations in maternal tissue metabolism (Robinson *et al*., 2006).

It is often the case that female animals would only produce offspring during particular seasons to coincide with the period when food is most abundant, so that lactation, which is critical to nurturing the young, is not compromised (Noakes *et al*, 2001; Senger, 2003). This restriction of breeding activities to particular seasons of the year is typical of temperate breeds of sheep and is not as decisively restricted in tropical breeds of sheep which can breed year-round. This natural advantage of Tropical sheep is however not always fully realized due, in large part, to the almost complete dependence of sheep on natural pastures, that undergo seasonal fluctuations in quality and quantity and can often result in serious nutrient deficits for ruminant livestock (Mukasa-Mugerwa *et al* 1994).

Supply of quality feed in good quantity is the perennial bane of animal agriculture in the northern regions of Ghana, and indeed in Sub Saharan Africa (Jutzi, 1993, Larbi *et al*, 1993). Where feed supply is seasonal, changes in body weight or body condition

tend to mirror the seasonal pattern of change in feed supply, usually with a lag period of three to six weeks (Thorne, 1999). This general seasonal pattern of changes in body weight and condition is then modified by varying demands of the animal for nutrients at various stages of its production cycle (Thorne, 1999). During the dry season, there is an acute shortage of feed and this is compounded by poor nutritive value of the little forage available (Alhassan and Karbo, 1993). The incidence of accidental and willful burning of vegetation further decimates the feed supply and exacerbates the shortage of quality feed.

Even where forage is available, it is usually low in crude protein and high in fibre resulting in low voluntary intake by ruminants and low digestibility (Pamo, 2007). Poor nutritional prospects for the animal translate into low production and poor reproductive performance.

During the rainy season, sheep are tethered to prevent them from grazing cultivated crop (Karbo and Agyare, 2002). Their days are therefore spent grazing within the limits of their tether; a situation which limits the quantity and choice of feed of the animal.

2.8.0 Blood Parameters

Examination of certain characteristics of blood such as packed cell volume (PCV) and blood glucose aids in the diagnosis of conditions such as anaemia in animals (Baker and Silverton, 1985).

2.8.1 Packed Cell Volume (PCV)

The Packed Cell Volume is a means of assessing the Red Blood Cell (RBC) or erythrocyte status of animals. It measures the percentage by volume of RBC's in whole blood after centrifugation (Rastogi, 2007). A low PCV is an indication of

anaemia while a very high PCV is most often a result of severe dehydration. The normal PCV for sheep falls within the range of 27-45% (Aiello, 1998). PCV correlates positively with haemoglobin (Best and Taylor, 1985); the PCV being three times the value of the haemoglobin value, expressed as a percentage. Packed cell volume is known to vary with season (Taabazuing, 1982) and pregnancy (Taabazuing, 1982; Tuah and Klusey, 1982; Obese, 1994). PCV values reported for the dry season and rainy season were 24% and 26% respectively (Taabazuing, 1982). Tuah and Klusey (1982) and Obese (1994) reported PCV values of 33.9% and 33.5% for pregnant sheep, respectively, compared to 27.62% and 32.25% for non-pregnant sheep.

2.8.2 Blood Glucose

Blood glucose is the main blood metabolite and is an indicator of the energy status in the animal. Homeostatic mechanisms endeavour to keep the blood glucose within a narrow range of limits, in spite of a continuous flux in the supply and demand for glucose. Hyperglycaemia and hypoglycaemia, respectively represent the conditions when the animal has high and low levels of blood sugar.

Blood glucose level is often used to investigate metabolic disorders in animals; fasting blood sugar determination being the key to diagnosis. The normal range for blood sugar for clinically healthy sheep is reported to be 2.44 to 4.49mmol/L (Aiello, 1998).

Factors that influence blood glucose levels are nutrition, hormones and pregnancy. Blood sugar levels decline during periods of fasting and rise during ingestion of carbohydrates or infusion of glucose (Cole, 1967). The metabolic hormones, insulin and glucagon, act in opposite directions to regulate blood sugar levels. Insulin promotes the uptake of glucose by cells and covert excess glucose into glycogen for storage in the liver and muscles. Glucagon on the other hand promotes the breakdown

of glycogen into glucose when there is a shortfall in blood glucose. Glucocorticoids, mainly cortisol, are known for their gluconeogenic action which elevates blood glucose (Marieb and Hoehn, 2007).

Taabazuing (1982) observed decreasing glucose levels as pregnancy advanced. The blood glucose of sheep in early pregnancy was 3.5mmol/L compared to 2.88mmol/L in advanced pregnancy.

2.9.0 Progesterone in reproduction

Progesterone is a steroid hormone secreted by the luteal cells of the corpus luteum and the adrenal gland (Hafez *et al*, 2000). During gestation, the placenta also produces large amounts of the hormone to supplement the output from the corpus luteum. Progesterone is required to prepare the endometrium for implantation and plays the role of inhibiting motility of the myometrium to maintain pregnancy. Progesterone is said to do this by producing a hyperpolarized myometrium which then develops a reduced ability to respond to oxytocin and oestrogen (Hafez *et al*, 2000).

Progesterone inhibits oestrus and the ovulatory surge of LH when in high amounts. It has found wide application in the artificial manipulations of reproductive events in animals due to its importance in oestrous cycle regulation.

It stimulates the growth and secretions of the endometrial glands, causes the cervix to close to variable degrees according to species and induces the sexual behaviour appropriate to the pregnancy. In the early part of pregnancy, the corpus luteum produces circulating levels of progesterone at least as high as the late dioestrus levels. In the pig, goat, and dog, functional corpora lutea are essential until very shortly before parturition; in the cow the corpus luteum is similarly active but is not essential after about days 200 of the 280 day gestation period. Sheep require luteal function for

at least two-thirds of the pregnancy, and the mare, after complex endocrine activity in the early pregnancy, does not rely on ovarian progesterone during the last third of the gestation. In these species, the progesterone is produced by the placenta or possibly by the foetus.

Blood progesterone levels directly reflect the activity of the corpus luteum; which means that monitoring levels of progesterone is a reliable means of keeping track of ovarian activity (Ball and Peters, 2004). As a result of this, progesterone measurements have been used as an aid to study the oestrous cycles, pregnancies (when combined with palpation) and post-partum ovarian activity of various animals (Stabenfeldt *et al*, 1968; Mugerwa and Esaz, 1990; Obese, 1994; Osei *et al* 1997; Mukasa-; and Blaszczyk, 2009)

2.9.1 Measurement of Progesterone

Most advances in quantitative determination of progesterone took place from the 1960s onwards. No method had sufficient sensitivity to measure progesterone in serum before then and endogenous progesterone production was assessed by measurement of its main metabolite, pregnanediol, in urine (Wood and Gower, 2010).

Before quantitative determination was possible, bioassays were found suitable for examining the effect of progesterone on the uterine endometrium or on the maintenance of pregnancy but bioassays lacked specificity and were influenced by varying concentrations of progesterone metabolites. They could not therefore be used for routine progesterone measurements though they could be used to assess the progestational effects of synthetic progestagens and antiprogestagens in the pharmaceutical industry (Wood and Gower, 2010).

Highly sensitive methods like the radioimmunassay (RIA) and enzyme-linked immunoassays (ELISA) are in use today. Both methods involve antigen/antibody

binding and can therefore detect progesterone with a high degree of specificity (Wood and Gower, 2010; Noakes *et al*, 2001).

RIAs were developed by Yalow and Berson for insulin in the 1960s. They are based on the principle of competitive binding, where a known amount of a labelled antigen and an unlabelled antigen compete for limited binding sites on a progesterone antibody. Following a period of incubation of labelled antigen, unlabelled test material and progesterone antibody, the unbound antigens are washed off and the radioactive "tracer" of the bound antigen are counted in a gamma counter. The radioactive label of choice for progesterone assays is usually the Iodine-123 isotope. A number of known concentrations of standards are usually tested and the results used to plot a standard curve, from which further tests of unknown samples are read off. The amount of bound radioactive antigen is usually reverse proportional to the unlabelled antigen whose concentration is being determined. The RIA procedure while highly sensitive and specific, has to be carried out with extreme caution and in a laboratory certified to work with radioactive material (Wood and Gower, 2010).

ELISAs use a similar principle to the RIA, but in their case, the label is an enzyme, conjugated to the antigen. ELISA kits allow the testing of large numbers of samples at once. In an ELISA test, the plastic wells of the microtiter plate are coated with a specific progesterone antibody. A sample (serum, plasma, milk, saliva or even faeces) containing unlabelled progesterone is added to each well, together with a fixed quantity of progesterone antigen conjugated to an enzyme (alkaline phosphatase or horse-radish peroxidase). After a period of incubation, the microtiter well is washed out, leaving the progesterone conjugate and any unlabelled progesterone bound to the progesterone antibody in the microtiter well. A substrate reagent is added to react with the enzyme-labelled progesterone to produce a colour reaction (Noakes *et al*, 2001;

Wood and Gower, 2010). The intensity of the colour is read by a microtiter plate reader as optical densities (OD's). The more intense the colour, the higher the quantity of labelled progesterone and therefore the smaller the number of unlabelled progesterone. In this procedure too, a standard curve is plotted using standard solutions supplied with the kit. The optical densities produced from the test are used to read off the concentrations of progesterone in the test solution.

2.10.0 Inferences from literature

Sheep are a valuable resource in the Northern Region of Ghana. Farming households keep sheep as a form of asset that can be readily sold for money to meet household needs, in addition to their use as a valuable protein source. Sheep are also widely used for many socio-cultural purposes such as sacrifice during festivals and presentation as dowry during marriage ceremonies.

Reproductive performance is an important means of assessing productivity, ranking higher than growth rate economically (Annor, 2007). The important indices of reproductive performance include the age of puberty, age at first lambing, prolificacy, birth weight, lambing intervals and pre-weaning lamb survival. Reproductive parameters are to a great extent under the control of environmental influences, making variation great across production systems, climatic zones and seasons. The study of how these factors impact reproduction and productivity should provide information on how to manipulate the environment, or the animal to achieve higher productivity. Along with analysing production data of animals, hormonal studies have been helpful in elucidating the inner workings of the reproductive system, and has offered options for manipulating the physiology of farm animals to enhance productivity.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Introduction

Two separate investigations were carried out in this study. In the first investigation, which took place at the Pong Tamale Livestock Breeding Station, the blood progesterone levels of 20 pre-pubertal gimmers and 20 postpartum ewes were monitored until the gimmers reached puberty and the postpartum ewes resumed ovarian activity, as evidenced by a rise in progesterone levels above 1ng/ml. Other data collected during the progesterone-monitoring study included live weight changes, body condition scores, blood glucose levels and packed cell volume (PCV). Reproductive parameters like the age at first parturition of gimmers, lambing intervals of ewes, prolificacy, birth weight of lambs and placenta weight and gestation length for the 20 gimmers and 20 postpartum ewes were also assessed.

In the second investigation, secondary data, sourced from two government farms and one private farm, were analyzed to obtain baseline information on lambing rate, age at first parturition, lambing intervals, prolificacy, lamb birth weights and lamb pre-weaning mortality rate. The effects of season, parity and location (farm) on those parameters were also estimated.

3.2 Study I: Progesterone Monitoring

The progesterone-monitoring experiment took place at the Pong Tamale Livestock Breeding Station in the Savelugu/Nanton district, about 32km North of Tamale, in the Northern Region of Ghana. The area experiences a unimodal rainfall pattern throughout the year; with mean annual rainfall of 1043mm. Peak rainfall is confined to the months of August and September. Rainfall for the peak period represents 40%

of rain for the entire rainy season. The rainy season covers the months of May to September, while the dry season begins in October and ends in April (District Agricultural Development Unit, 2010; Pong Tamale Meteorological Station, 2010).

3.2.1 Experimental Animals

Forty (40) Djallonké sheep at various physiological stages of development were purposively sampled for this experiment. The animals comprised 20 pluriparous ewes, 10 of which had lambed in the dry season and the other 10 being those that had lambed in the rainy season.

The other 20 animals were nulliparous gimmers, aged between 4 and 6 months. Ten of these gimmers were born in the dry season while the other 10 were born in the rainy season. The mean weights of the rainy season and dry season gimmers at the start of sampling were 10.13±0.48 kg and 9.75±0.45 kg respectively. The postpartum ewes weighed 23.25±0.63 kg and 21.90± kg for the rainy season lambing and dry season lambing respectively.

3.2.2 Management of Experimental Animals

The ewes were housed with their lambs and were suckled until the lambs were naturally weaned. Male lambs that had reached five months of age were isolated from the female flock and housed with other rams. The gimmers that had just been naturally weaned at about 5 months of age were housed with the rest of the ewes. Rams ran with the flock throughout the period of this study.

In the rainy season, the animals were alternately grazed on pastures in two separate paddocks between the hours of 8am and 5pm. The first paddock was predominantly composed of *Stylosanthes* and the second paddock was mainly *Cajanus cajan*. In the early dry season (early November), crop residues were offered to the sheep in the

morning before they were turned out on to the pasture, and in the evening, when they returned from the paddocks. The crop residues however became the primary diet of the animals as the dry season progressed. The crop residues commonly offered were groundnut haulms, corn husks, rice straw, pigeon pea waste and whole cotton seed. Cassava peels were also offered sparingly.

Water was offered daily and saltlick blocks were hung in the pens for the animals to have unrestricted access.

3.3.0 Blood Sampling

The animals were bled from 7am on each scheduled sampling day. Blood samples were drawn by jugular venipuncture into labelled 4ml silicone-coated vacutainers. The collected samples were stored on ice and allowed to clot after which they were spun in an Eppendorf 5702 centrifuge at 2500 revolutions per minute for 5 minutes to reveal a clear column of serum, which was then separated and stored in a deep freezer until they were assayed for progesterone.

Sampling of the pluriparous ewes began within one week of lambing for both the rainy season (May to September) and the dry season (October to April). Eight (8) of the ewes for each season were sampled once every week until they resumed ovarian activity, as evidenced by a rise in progesterone above 1ng/ml (Mukasa-Mugerwa and Esaz, 1991, Pineda, 2003). Two of the ewes for each season were however sampled every 2 days to closely monitor their oestrous cycles.

Blood samples were collected from a total of 20 gimmers (10 animals for each season) for progesterone analysis. Eight (8) dry season-born gimmers and 8 rainy season-born gimmers were sampled twice a week until they reached puberty, as

evidenced by a rise in peripheral blood progesterone concentration above 1ng/ml. In addition, 2 gimmers from each season were sampled every two days.

Blood glucose determinations were made on a monthly basis using a portable electronic Glucometer (Onetouch Ultra®2 Blood Glucose Monitoring System, LifeScan Inc., California, USA). Glucometer strips were dipped in freshly drawn blood samples and inserted into the Glucometer. The glucose reading appeared on the screen within 5 seconds of inserting the strip.

The packed cell volume (PCV) was also determined monthly for all animals. This was done by collecting blood samples into capillary tubes, sealing the tubes and spinning them in a haematocrit centrifuge until red blood cells were packed at one end of the capillary tube. The haematocrit value was then read using a Hawksley haematocrit reader.

3.3.1 Progesterone Assay

The sera obtained from the animals were assayed for progesterone using ELISA kits supplied by DRG-International, New Jersey, USA. Sera collection and sample analysis were done in accordance with instruction manual supplied with the kit.

3.3.2 Assay Procedure

The progesterone ELISA kit used in this study was a solid phase enzyme linked immunosorbent assay. The technique works on the principle of competitive binding where progesterone molecules in a test sample and labelled progesterone-enzyme conjugates compete for binding sites on progesterone antibodies attached to microtiter wells. The microtiter wells were coated with a polyclonal antibody, which binds specifically to sites on the progesterone molecule. Endogenous progesterone of a sample competes with a progesterone-enzyme conjugate for binding to the coated antibody. After incubation the unbound conjugate is washed off. The amount of

bound peroxidase conjugate is reverse proportional to the concentration of progesterone in the sample. After addition of the substrate solution, the intensity of colour developed is reverse proportional to the concentration of progesterone in the sample

The assay protocol was as follows:

1. Twenty five microlitres (25 microL) of each of the 7 standards (0, 0.3, 1.25, 5, 15 and 40ng/ml) were dispensed into the wells in duplicate and the samples to be assayed were dispensed similarly until all 96 wells were filled.
2. The microtiter plate was sealed and allowed to incubate for 5 minutes at room temperature.
3. Two hundred microlitres (200 microL) of the enzyme conjugate was dispensed into each well and shaken to ensure complete mixing.
4. The mixture was allowed to incubate for 60 minutes at room temperature.
5. The contents of the wells were then emptied by shaking the microtiter plates briskly.
6. The wells were rinsed 3 times with diluted Wash solution (400 microL per well). Residual droplets from the wells were removed by striking the wells sharply against a pad of absorbent paper towels.
7. Two hundred microlitres (200 microL) of substrate solution was added to each well and left to incubate for 15 minutes.
8. One hundred microlitres (100microL) of stop solution was added to each well to stop the enzymatic reaction.
9. The microtiter plate was loaded into a plate reader, within 10 minutes of adding the stop solution, to read the absorbance (optical density) values through a 450nm microtiter plate reader.

10. The optical density values were plotted against known concentrations to generate a standard curve (Figure 4).

The samples were tested in duplicate and the within and between coefficients of variation were 3.81% and 7.04% (average for 6 plates) respectively.

The ELISA test plates were read with a BioTek® Instruments ELISA plate reader (ELx800 model) through a 450nm filter. The absorbance/optical density (OD) values obtained from the reader were used to compute the concentration of progesterone in the samples. This was done by plotting a standard curve for each assay using 7 standards (in duplicate) with known concentrations. The concentrations of the samples collected were then interpolated from the standard curve using the OD's generated (Figure 4).

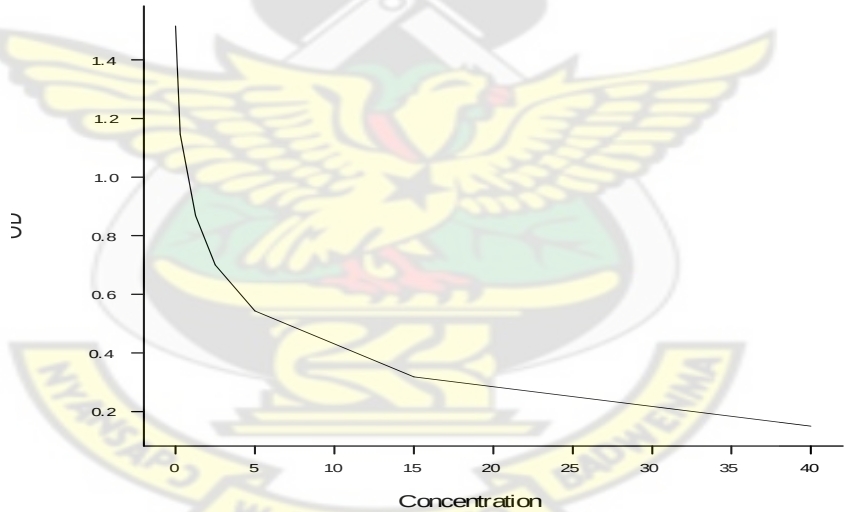


Figure 4: Standard curve for progesterone standards

3.3.3 Observation of Oestrus

The two rams running with the flock were each fitted with a ram harness containing crayons. The presence of streaks of crayon on the rumps of females was taken to indicate mating. The color of the crayon was changed every 14 days so that animals that were re-mated after failing to conceive could be easily detected. Sera of mated

animals were tested on days 21 and 35 after mating to diagnose pregnancy (Obese, 1994).

3.3.4 Other Parameters Measured

The following data were collected on the animals:

- **Live Weight**: The weights of the experimental animals were taken using a spring balance at the start of blood sampling and they were weighed on a monthly basis afterwards. Average daily weight change was calculated by subtracting the live weight at the beginning of the month from the live weight at the end of the month and dividing by the number of days in the month.
- **Age of the Animals**: The ages of all the gimmers were obtained from the farm records. Some of the postpartum ewes were purchased animals and their dates of birth were not known.
- **Body Condition Score (BCS):** All animals were scored for body condition on a scale of 0 to 5 (Russell, 1984) (0= extremely emaciated, 1= spinous process prominent and sharp, 2= spinous process prominent but smooth, 3= spinous processes felt only as smooth round elevations, 4= spinous process felt only with pressure, 5= extreme fatness).
- **Postpartum Weights**: The postpartum weights of ewes/gimmers were taken within 24 hours of birth and the birth weight of lambs and weight of conceptus were also taken using a digital scale.
- **The Age at First Parturition**: This was calculated as the number of days from birth to day of first lambing.
- **Lambing Intervals:** This was calculated as the number of days between successive lambings.

Analysis of variance (Snedecor and Cochran, 1982), was used to analyze data on weight changes of animals, age at puberty, and length of postpartum return to oestrus between seasons, for ewes, and the age at puberty between seasons for the rainy season-born and dry-season born gimmers. The blood parameters between the two seasons were also analyzed using the analysis of variance.

The trends in progesterone concentration were presented as line graphs.

3.5.0 Study 2: On-Farm Baseline Data Collection

The second aspect of this study involved the analysis of data obtained from three sheep farms in the Northern Region. Available sheep reproduction records spanning the period 2000 to 2010 were retrieved from two government-run farms (the CSIR—Animal Research Institute Station at Nyankpala and the Ministry of Agriculture Disease Investigation Station in Savelugu) and one private farm (Akana Farms in the Gushiegu district).

3.5.1 Description of Farms

3.5.2 Akana Farms

Akana Farms is located at Kpatili, about 7km from the Gushiegu township in the Northern Region of Ghana. It is a private sheep farm that was established in 1999 in collaboration with MoFA to serve as a mulitiplier farm for Djallonké sheep in an open nucleus breeding scheme (ONBS). The main objective was to increase the transmission of the genes of animals of superior performance supplied by the Ejura Sheep Breeding Station (ESBS) (Abdulai Nabrizini, personal communication).

The animals at the farm are raised under the semi-intensive system of management where the sheep are allowed to graze close to the farm for 4 to 5 hours a day. Supplementary feeds offered to the animals include groundnut tops, rice straw, whole

cottonseed, corn chaff and maize stover. Water and mineral salt licks are also provided. Male and female animals are housed separately and grazed separately to control indiscriminate mating. The males are introduced into the female pen for mating at three different periods of the year (January to February, May to June and September to October). Lambs are weaned between 4 and 6 months of age. Gimmers are not allowed to mate until they are adjudged to be mature enough.

Birth dates, litter size, type of birth, birth weights and sex of lamb are recorded within 24 hours of lambing. Weaning weights and mortality records are also kept.

Routine flock health maintenance practices carried out at the farm include deworming, de-ticking and vaccinations. Veterinary technicians are called in to treat sick animals as and when necessary.

3.5.3 Savelugu Disease Investigation Station

Savelugu sheep farm is a disease investigation farm run by the Ministry of Food and Agriculture in the Savelugu/Nanton district. The farm keeps a flock of sheep and goats. The animals are kept under a semi-intensive system, where the animals are grazed on undeveloped pastures during the day and housed in pens at night. Supplementation with *Cajanus cajan* waste, groundnut tops and rice straw is done in the dry season.

Males and females are separated to avoid indiscriminate mating. The rams are however introduced into the females' pen for periods of 45 days at selected times of the year. Lambs are weaned at 4 to 5 months of age.

Animals are dewormed once a month and vaccinated against Peste des petits ruminants (PPR). Those animals presenting with signs of illness are treated with appropriate drugs.

3.5.4 CSIR-Animal Research Institute Station

The CSIR-ARI keeps a flock of Djallonké sheep kept at its Nyankpala station, located 16 km from Tamale. The animals are kept under a semi-intensive system where herdsmen direct the grazing of the animals within the confines of the station's undeveloped pasture lands. Animals are supplemented with crop residues such as *Cajanus cajan* waste, groundnut tops and rice straw. Supplementary feeding is increased in the dry season. Water is supplied in cement troughs at various points on the farm for the animals. The males move with the females year-round. No attempts are made to separate the rams from the ewes and weaning of lambs is not strictly practised.

Animals are routinely dipped against ectoparasites and dewormed monthly. Sick animals are treated with appropriate drugs when they show signs of sickness.

Records on birth dates, litter size, birth weights and sex of lambs are kept. Pre-weaning mortality data were missing from the records.

3.6. Parameters measured and statistical Analysis

The reproductive data from the three farms were analyzed to obtain the following information:

1. Fertility = Percentage of females giving birth out of total number of females of reproductive age exposed to males.
2. Age at first parturition = Number of days from birth to first lambing (Tuah and Baah, 1985)
3. Prolificacy = Number of progeny born of females giving birth (Baffuor-Awuah, 2007)
4. Parturition Intervals = Interval between successive parturitions for all females with more than one recorded parturition (Tuah and Baah, 1985)

5. Pre-weaning mortality= All deaths occurring between birth and weaning as a proportion of all lambs born (Abassa, 1995).
6. Annual reproductive rate (ARR) = $\frac{\text{Average litter size x (1-mortality rate)}}{\text{Parturition interval}}$ (Gatenby, 2002)

The effects of parity of dam, season and location on birth weights, age at first parturition and lambing intervals were analyzed using the General Linear Model, while the Chi-square test of association was used to analyze the influence of season of birth, sex and location on pre-weaning mortality rate. Genstat statistical software (Discovery Edition, 2008) and Statistical Analytical System (SAS) (Version 9) (SAS Institute, 2009) were used to analyze data on age at first parturition, lambing intervals and birth weights. SPSS version 17 (2009) software was used to analyze the pre-weaning mortality data.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1.0 Study 1: Progesterone Monitoring Study

4.1.1 Weight Dynamics of Gimmers

The mean age of the gimmers at the start of sampling was 138.6±3.38 days. The mean age of the rainy season gimmers was 136.4 days (range = 129 to 157 days) while that of dry season gimmers was 140.8 days (range=113 to 159 days). The respective initial weights for the rainy season and dry season gimmers were 10.13±0,48kg and 9.75±0.45kg. Seasonal differences in initial weight and age were not significant at the start of sampling (P>0.05), even though the rainy season gimmers were five days younger and slightly heavier. In the course of the experiment, however, the gimmers born in the rainy season grew at a rate that was 22% faster than the dry season born gimmers (P<0.05) (Table 2).

Table 2: Effect of season of birth on growth parameters of gimmers

Parameter	**Season of birth**		**SED**	**P Values**
	Rainy season	**Dry Season**		
Mean Initial weight (kg)	10.13	9.75	0.665	0.575
Average daily gain (g)	45.32[a]	37.05[b]	4.661	0.040
Mean Body Condition Score	2.74[a]	2.46[b]	0.0361	0.001
Number of animals	10	10		

Means in the same row with different superscripts are significantly different at the 95% level of probability. SED= Standard error of difference.

The mean growth rate of 41.18g/day is consistent with growth rates of 25—49 g/day reported by Mack (1983), Opasina (1984), Gbangboche *et al* (2006) and Bosso *et al* (2007) for Djallonké females aged 120 days and older. The superior growth rate of the rainy season-born gimmers may be attributed to better nourishment they received from their mothers, who had access to a relatively good supply of grazing material while they lactated. Similarly, the lambs grew faster during the rainy season period because of the comparatively stable supply of fresh pasture during that period. Tibbo (2006) observed higher growth rates of Menz lambs in the rainy season compared to the dry season (74 vs 54 g per day) and cited pasture availability in the rainy season as the reason for superior growth rate in that season. Other studies (Mukasa-Mugerwa *et al* (1994) and Rege *et al* (2002), Hassen *et al* (2002) and Abegaz *et al* (2000) confirm this. It has however been observed by Gbangboche *et al* (2006) that where humidity and ambient temperature favour the growth and survival of the larvae of nematodes, there is a decrease in the growth rate of lambs in the wet season.

Body condition score averaged 2.59 for all gimmers in the study. This score is mid-way between fair (2) and good (3) on Russell's (1984) six-point scale. The mean body condition scores of rainy season and dry season-born gimmers were statistically different (Table 2) ($P<0.05$). Pregnant animals had better body condition score compared to non-pregnant animals (2.68 vs. 2.52) ($P<0.05$).

Mukasa-Mugerwa and Lahlou-kassi (1995) reported a mean body condition score of 2.2 for Menz sheep in Ethiopia. They also found that the animals' body condition score in the rainy season was slightly better than in the dry season (2.3 vs. 2.2). The superior body condition score of the rainy season-born gimmers could be attributed to better nutrition received by gimmers during the rainy season while the superior body condition of the pregnant gimmers may be a result of the weight gained as a result of

accretion of fat that generally takes place during pregnancy in anticipation of lactation (pregnancy anabolism).

4.1.2 Age at Puberty of Gimmers

Mean age at first progesterone rise above the 1ng/ml threshold (puberty) was 220.6±9.18 days for all gimmers in this study (range 160-310 days). The rainy season-born gimmers however came into puberty 36 days earlier than the dry season born gimmers ($P<0.05$) (Table 3). The first display of oestrus, which was preceded by the first rise of progesterone, occurred at a mean age of 289.3±15.36 days, or 69 days after the first progesterone rise. There was no seasonal difference in age at first oestrus display ($P>0.05$). Mean weight at puberty and mean weight at mating were 12.08kg and 16kg respectively. The mean weight at puberty and mean weight at mating between seasons were similar ($P>0.05$).

A large body of evidence suggests that puberty usually occurs when a threshold amount of body weight has been achieved (Foster and Nagatani, 1994; Senger, 2003). Overall, the rainy season gimmers grew at a faster rate than the dry season gimmers (45.32g/d vs. 37.05g/d, Table 2) and they therefore may have reached the threshold body weight at which puberty occurs earlier than the dry season gimmers as a result of the observed difference in growth rate. In spite of the significant difference in age at first progesterone rise, however, the weights at puberty for both groups were similar (13.05kg vs. 12.65kg) ($P>0.05$). This observation was previously reported by Dyrmundsson (1973) and Foster and Nagatani (1999), who associated fast body growth with the early onset of puberty (although both authors defined puberty as the occurrence of the first ovulatory oestrus). Noakes *et al* (2001) have also reported that weight is more influential than chronologic age in determining the age of puberty. The

weight at first progesterone rise in this study closely matches the results obtained by Obese (1994) working with Djallonké gimmers in the humid zone of Ghana. In that study, puberty was attained when the gimmers reached 55.6% of their mature body weight. The gimmers in this study attained puberty at 66.7% of their body weight at parturition, which is higher than the 45—60% reported by Ibrahim (1998). The body weight at first lambing obtained in this study was 19.24kg, which is lower than the breed average reported by London *et al* (1994) to be between 20.9kg and 23.5kg at 3.5 to 4 years. The gimmers in this study were however only 18 months old and still had the potential to grow.

4.1.3 Age at First Parturition

Gimmers in this study produced their first lambs at a mean age of 460.2±17.82 days (range 381 to 624 days).The rainy season gimmers produced their first lambs at an average of 71 days earlier than the dry season gimmers (424.6 vrs 495.8 days) . The seasonal difference in mean age at first parturition was significant ($P<0.05$). The mean age at first parturition in this study occurred 178 days and 162 days earlier than results obtained by Tuah and Baah (1985) and Gbangboche *et al* (2006), respectively, who reported some of the highest values for this parameter for Djallonké gimmers (638 and 622 days). The results of this study however fell within the range of 431 and 572 days obtained by Armbruster *et al*, (1991) and Fall *et al* (1982) for sheep under a similar management system. The results in this study also closely match the results of Lesnoff and Lancelot (2010), who found that 66% of a flock of Djallonké sheep being monitored in Senegal produced their first lambs by 18 months of age, with the proportion of ewe lambs giving birth increasing to 90% by the second year of birth (24 months). The same study found that ewe lambs that were over 30 months old

without producing their first lambs were unlikely to ever do so and needed to be culled.

The fact that the animals in this study were allowed to run with the rams for the purposes of the experiment may have helped reduce the age at mating and hence the age at first parturition (Wilson, 1989).

The rainy season gimmers produced their first lambs at an earlier age than the dry season gimmers, which is in agreement with the observations of Fall *et al* (1982) and Gbangboche *et al* (2006). Again, this could be traced to the fact that animals born in the rainy season received better nourishment from their dams that had access to plentiful feed during the rainy season and therefore grew faster and reached puberty earlier than dry season born lambs.

4.1.4 Birth Weights of Lambs

The mean birth weight of lambs born to the gimmers in this study was 1.56 kg. Gimmers born in the rainy season produced lambs that were heavier ($P<0.05$) than dry season born gimmers (1.77±0.08kg vs. 1.40±0.132kg) (Table 3). Mean birth weights of the male and female lambs were 1.61±0.136kg and 1.57±0.103kg respectively, and were not significantly different from each other ($P>0.05$). Placenta weights averaged 124.2±3.72g and did not differ between seasons. The placenta weight had a significant influence on the birth of lambs ($r=0.65$; $P<0.05$). The coefficient of determination was 38.6%; meaning that 38.6% of variation in lamb birth weight is attributable to the weight of the placenta. The relationship between the placenta weight and birth weight in this study was given by:

$$Lamb\ birth\ weight = Placenta\ weight \times 0.01495 - 0.272$$

The regression equation above suggests that the birth weight increases as the placenta weight increases.

The mean birth weight of 1.56 kg observed in this study is slightly lower than birth weights reported for Djallonkés by Tuah and Baah (1985) and Obese (1994), who obtained 1.77 kg and 1.71 kg, respectively. Other studies (Fall *et al*, 1982; Tuah and Baah, 1985; and Kabugah and Akowuah, 1991) also found the season of lambing to significantly influence the birth weight of lambs. In all those studies, mean birth weights of lambs born in the rainy season were found to be higher than the mean weights of lambs born in the dry season and this was attributed to the quality and quantity of pasture available to the pregnant animal during pregnancy.

4.1.5 Sex Ratio

Eleven (11) male and 9 female lambs were born to the primiparous ewes; a proportion of 55% males to 45% females. This ratio did not depart significantly from the expected theoretical sex ratio of 50:50. A similar report was published by Obese (1994) and Abdul Wahid (1988) on sheep. Kent (1992) reported that slightly fewer male births (49.56%) than female births occur in sheep. Other studies by Karam (1957) and Skjervold (1979) corroborate the observations of Kent (1992).

4.1.6 Prolificacy

All the gimmers in this study gave birth to single lambs. Nulliparous ewes are known to have a low prolificacy at their first parturition, with the fecundity increasing with parity, depending of course on the ovulation rate of the breed (Tuah and Baah, 1985; Hoque *et al*, 2002; Hanford *et al*, 2006).

4.1.7 Pregnancy Anabolism

Pregnancy anabolism (mean weight gained by the gimmers during pregnancy, after accounting for the weight of the foetus and placenta) was 3.49kg (range 1.37kg to 6.37). Weight gains were similar for both seasons ($P>0.05$). Addah and Karikari (2008) reported weight gains of between 2.5 kg and 9.6 kg for pregnant primiparous Djallonké ewes supplemented at different stages of gestation. The ewes that gained the least weight in that study did not receive supplementary feed throughout pregnancy. Mukasa-Mugerwa *et al* (1994) observed weight losses of 7.5kg and gains of up to 17.5kg in pregnant Menz ewes supplemented at various stages of gestation. Unsupplemented counterparts gained only 0.9kg on the average during gestation.

Table 3: Effect of Season on Reproductive Parameters of Gimmers

Parameter	Number of animals	Overall mean	Rainy season gimmers	Dry season gimmers	SED	P Values
Mean age at first P4 rise (days)	20	220.6±9.18	$202.4±10.63_a$	$238.7±13.03_b$	16.81	0.045
Mean weight at first P4 rise (kg)	20	12.85±0.27	13.05±0.46	12.65±0.29	0.540	0.468
Mean age at first overt oestrus (days)	20	289.3±15.36	262.4±9.5	316.2±27.3	28.9	0.079
Mean weight at first overt oestrus (kg)	20	15.63±0.53	16.05±0.63	15.20±0.86	1.071	0.438
Mean age at first parturition (days)	20	460.2±17.82	$424.6±11.14^a$	$495.8±30.57^b$	32.54	0.042
Mean lamb birth weight (kg)	20	1.56±0.08	$1.77±0.08^a$	$1.40±0.13^b$	0.154	0.032
Placenta weight (g)	20	124.2±3.72	128.6±5.62	119.7±4.73	7.35	0.241
Gestation length (days)	20	148.7±0.8	149.3±1.08	148.0±1.37	1.745	0.479
Pregnancy anabolism/maternal weight gain (kg)	20	3.49±0.34	3.85±0.58	3.12±0.36	0.68	0.297

Means in the same row with different alphabet superscripts are statistically significant at the 95% level of probability. SED=Standard error of difference

4.1.8 Progesterone Profiles of Gimmers

Progesterone was at basal levels (mean= 0.160±0.005ng/ml) in blood samples taken from all the gimmers at the beginning of the trial and only increased beyond the 1ng/ml threshold when the gimmers reached a mean age of 220.6±9.18 days. Ninety-five per cent of the gimmers showed brief elevations in serum progesterone concentration (mean=1.205ng/ml) before the first display of oestrus. The first progesterone rise in most of the animals lasted for a short period (1 to 4 days, with a mean of 2.2 days) before dropping to basal levels. There was no difference between seasons for concentration of progesterone at first rise (1.25ng/ml and 1.15ng/ml for the rainy and dry seasons respectively) (Table 4).

Table 4: Effect of season on first progesterone rise

Parameter	Overall mean	Rainy season gimmers ± SEM	Dry season gimmers ± SEM	P Values
Progesterone concentration at first rise (ng/ml)	1.21±0.039	1.25±0.069	1.15±0.024	0.249
Duration of first rise (days)	2.11±0.285	2.44±0.444	1.80±0.359	0.271
Proportion of gimmers experiencing first rise (%)	95%	100	90	

SEM=Standard error of means

The period from the first progesterone rise to the first overt oestrus display varied widely among individual gimmers and featured an average of 1.4 rises in progesterone above basal levels in the intervening period. Figure 5 and Figure 6 show some patterns of progesterone secretion in some of the gimmers in the rainy season and dry season, respectively (the vertical arrows in the figures indicate mating). All

gimmers showed an initial rise of progesterone before oestrus with the exception of DB110 that showed no detectable progesterone in the peripheral blood before it came into oestrus for the first time at the age of 437 days (Figure 7)(vertical arrows in the figure indicate mating). That gimmer (DB110) experienced a progesterone rise after mating that lasted for 28 days (interoestrus interval = 35 days) before dropping to basal levels. The animal then came into oestrus and was mated 35 days after the first oestrus.

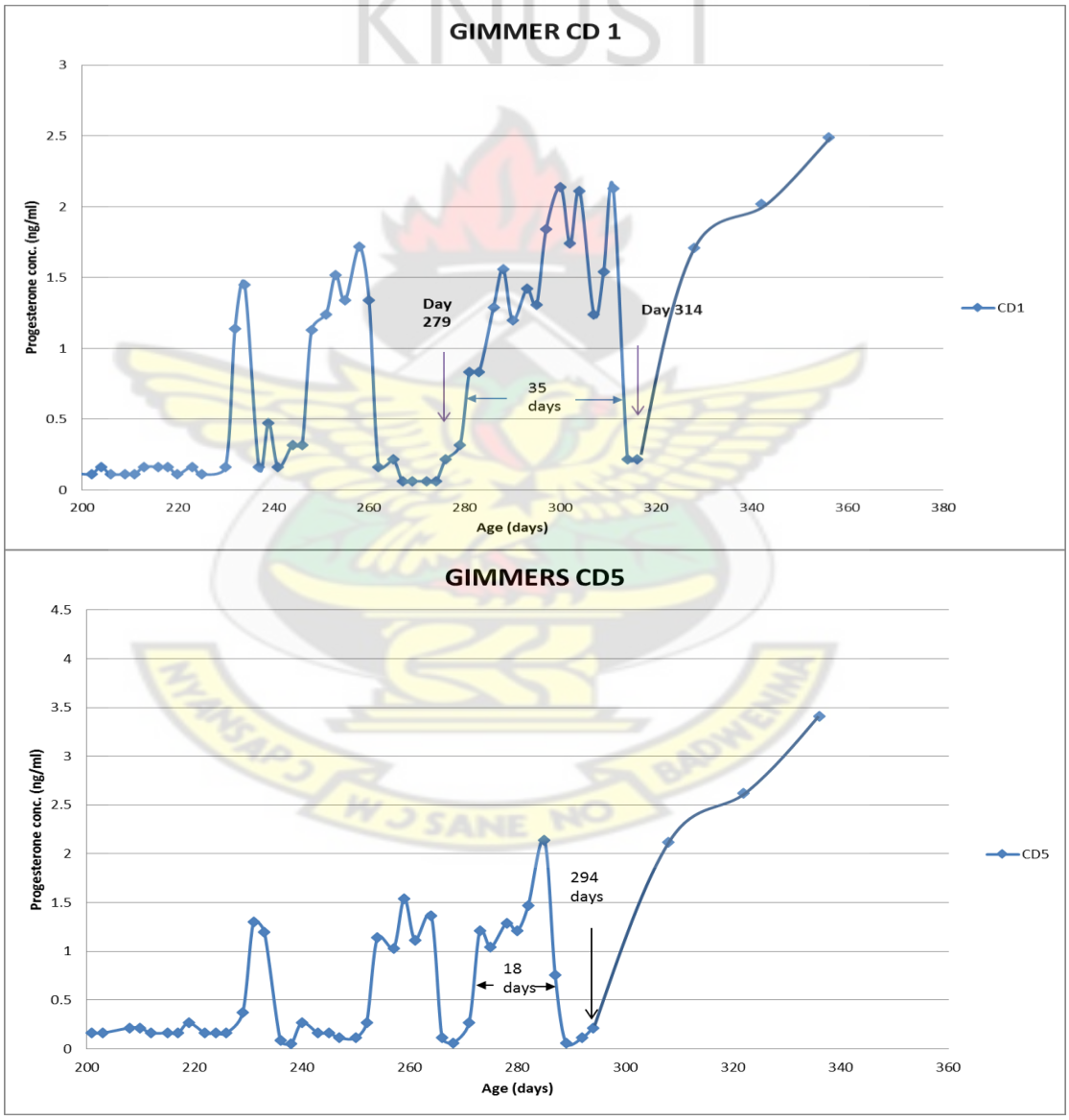
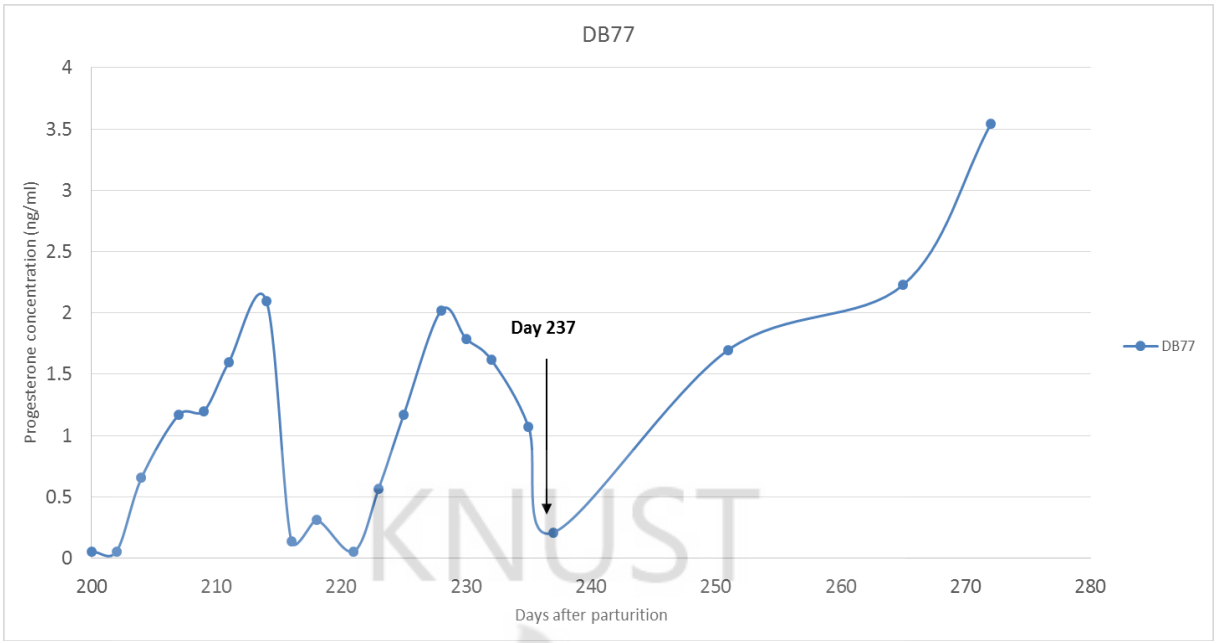


Figure 5: Progesterone profile of two regularly bled rainy season born gimmers.



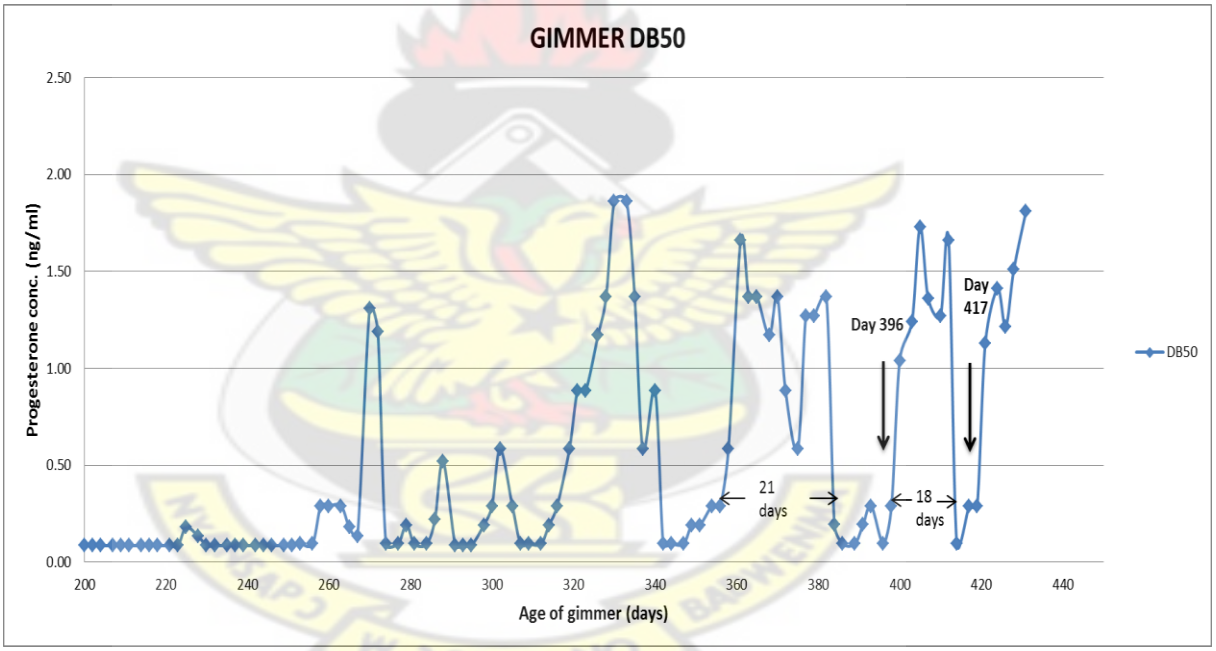


Figure 6: Progesterone profiles of two dry season-born gimmers.

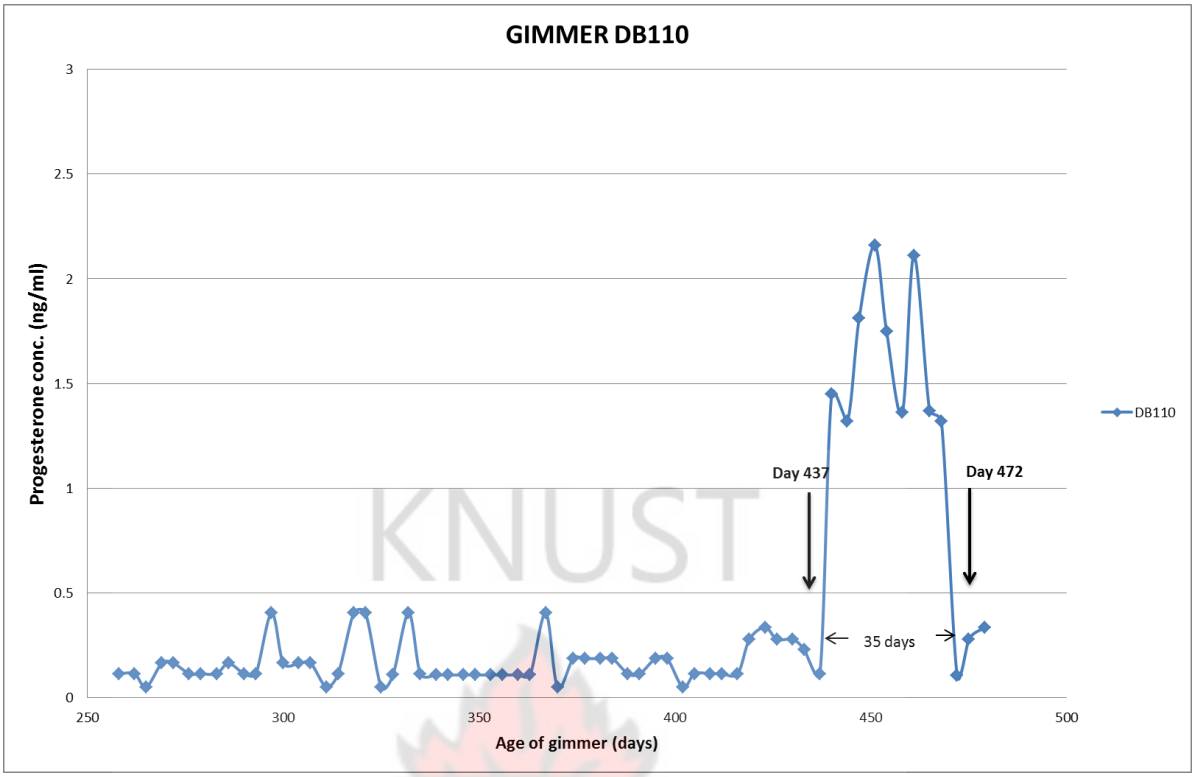


Figure 7: A gimmer (DB110) displaying a prolonged first rise of progesterone.

Forty-three percent (43%) of the luteal progesterone elevations shown after the first rise were short-lived, lasting for only 1-9 days before declining to basal levels. Another 43.3% of them were normal, lasting 10 to 14 days, and about 13% were longer than 20 days (Figure 8).

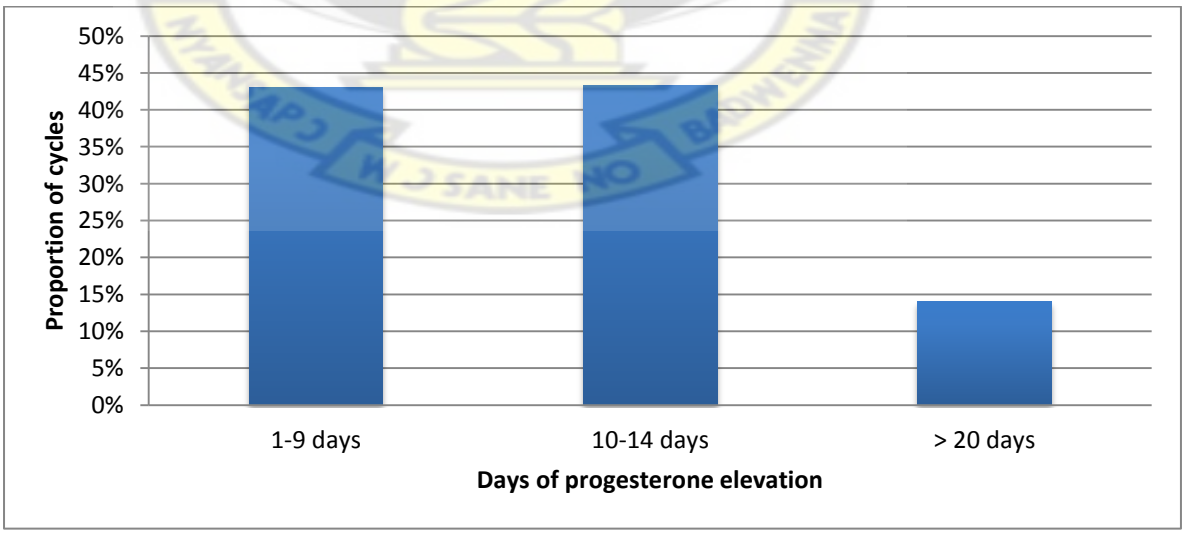


Figure 8: Duration of progesterone rise of gimmers

The patterns of serum progesterone concentration in this study are consistent with those observed by Sutama *et al* (1988) among adolescent Javanese thin-tailed sheep. Their study revealed that 83% of ewe lambs showed one or more significant elevations in peripheral progesterone level before their first ovulation. Such transient increases in progesterone in pubertal ewes before the first oestrus have also been observed by Foster and Ryan (1981), Berardinelli *et al* (1980), Keisler *et al*, (1983) and Obese (1994). The pronounced progesterone peaks that preceded ovulation were thought to have originated from luteinized follicles that failed to ovulate (Bartlewski, 1999). It has been suggested by Senger (2003) and Fabre-Nys and Martin (1991) that priming of the central nervous system with progesterone is required before the full display of oestrus is possible, and this may be the reason for the brief initial progesterone rises observed in most of the gimmers. Gimmer DB110 (Figure 7) did not show any detectable progesterone rise prior to oestrus display. It has been reported that even though progesterone priming is not strictly essential for initiation of ovulatory cycle, it is critical for the display of oestrus (Foster and Jackson, 2006). Mukasa-Mugerwa and Zere (1991), working with postpartum Menz ewes, however found that 37% of them did not show any prior progesterone rise before display of oestrus and suggested that the progesterone priming may not be a strict requirement.

The progesterone rises that occurred after the initial rise and before the first overt oestrus may reflect the phenomenon of "silent ovulations" (Senger, 2003; Foster and Jackson, 2006). Sutama *et al* (1988) found, upon inspection of the ovaries of adolescent gimmers, that 67% of them ovulated without showing oestrus (silent ovulations) and showed characteristic progesterone peaks. Silent ovulations have been ascribed to the initial high sensitivity of the GnRH surge to oestradiol which prevents adequate quantities of the steroid to induce behavioural oestrus.

Seventy percent (70%) of the rainy season gimmers conceived at the first mating compared to 44% of the dry season gimmers (Figure 9). A further 20% of the rainy season gimmers conceived following a second mating compared to 56% of the dry season ewes.

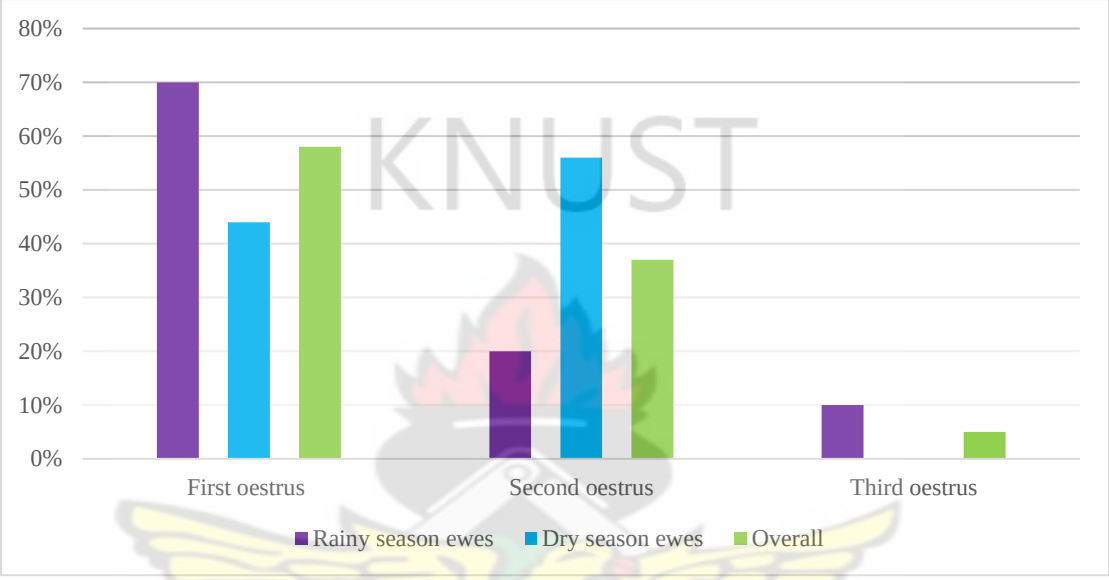


Figure 9: Conception rate to first, second and third oestruses in gimmers.

4.1.9 Gestational Progesterone Profiles of Gimmers.

The gestational progesterone profiles of rainy season and dry season gimmers are shown in Figure 10. Serum progesterone concentrations were basal (0.42ng/ml) immediately following mating (day 0), and increased significantly to 1.72ng/ml by day 14. From day 14, progesterone levels rose steadily (P>0.05) until day 42, when the increases were significant (2.67ng/ml) compared to the day 14 levels. Progesterone levels increased significantly again at day 70 and day 98 from the day 42 levels. Peak progesterone levels were recorded at day 126 (6.95ng/ml), and by day

140, levels began to decline until parturition when progesterone concentration averaged 0.89ng/ml.

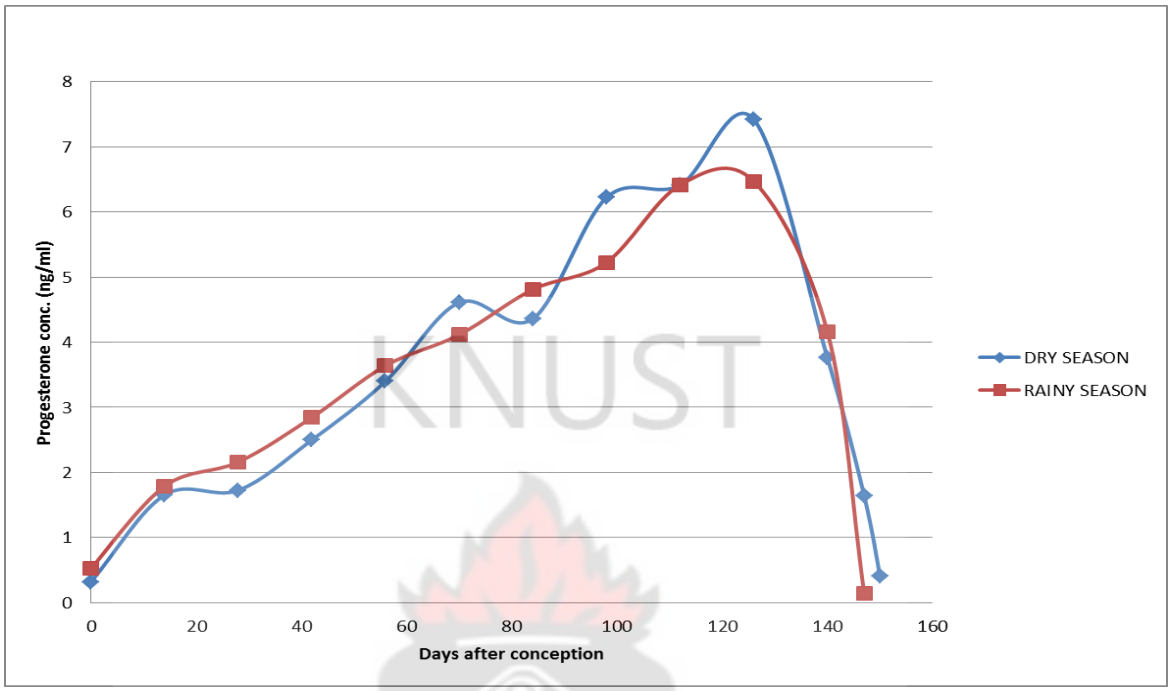


Figure 10: Progesterone profiles of gimmers during gestation.

The pattern of progesterone in pregnancy is similar to patterns observed by Mukasa-Mugerwa and Viviani (1992) and Obese (1994). Progesterone is essential to the maintenance of pregnancy in sheep. It is produced in early pregnancy by the ovarian/corpus luteum until approximately day 60 of gestation when the placenta begins to contribute to the progesterone output (Noakes *et al*, 2001). The significant increase in progesterone levels around day 70 of gestation in this study may reflect the contribution of the placenta to the total progesterone output. The decline in progesterone prior to parturition is also consistent with observations of Obese (1994) and Jainudeen and Hafez (2000). Progesterone declines prior to parturition due to the actions of foetal cortisol which activates the synthesis of enzymes to convert progesterone to oestradiol. In addition to converting progesterone to oestradiol, foetal corticoids also cause the placenta to produce PGF2alpha which causes the corpus

luteum of pregnancy to regress (Jainudeen and Hafez, 2000; Senger, 2003; Gibb *et al*, 2006).

4.1.10 Packed Cell Volume (PCV) and Blood Glucose

Table 5 shows packed cell volume (PCV) and blood glucose values for the gimmers in this study. PCV values averaged 28.9% for all gimmers and was significantly higher for rainy season gimmers compared to the dry season gimmers ($P<0.05$). Pregnant animals tended to have higher PCV values compared to non-pregnant ones though the difference was not significant ($P>0.05$). The animals also had higher PCVs when sampled during the rainy season ($P<0.05$). These PCV values fall within the ranges of 27 to 35 reported for sheep in normal condition of health (Aiello, 1998; Obese, 1994).

Table 5: Effect of Season, Sampling Period and Pregnancy on Glucose and PCV values.

Variable	**Glucose (mmol/L)**	**P Values**	**PCV (%)**	**P Values**
Overall	2.84±0.043		28.9±0.176	
Season of birth				
Rainy season	3.00±0.07	0.133	29.0±0.256	0.443
Dry season	2.78±0.06		28.8±0.243	
Season of sampling				
Rainy season	2.89±0.06	0.141	29.4_a±0.286	0.005
Dry season	2.80±0.05		28.5_b±0.215	
Physiological state				
Pregnant	2.79±0.06	0.167	29.1±0.281	0.006
Non-pregnant	2.87±0.06		28.7±0.213	

PCV tends to reflect an animal's adaptability to its environment. The tendency for higher PCV values during the rainy season may reflect the generally favourable conditions for the gimmers during that period.

Mean glucose level was 2.84mmol/L. The gimmers born in the rainy season and those born in the dry season had blood glucose levels that were not statistically different (P>0.05). Glucose levels for pregnant and non-pregnant gimmers also did not differ significantly (P>0.05). The mean glucose levels fell within the range of 2.44 to 4.49mmol/L reported for healthy sheep.

4.2.0 Reproductive Performance of Postpartum Ewes

4.2.1 Weight Dynamics of Postpartum Ewes

Season had no significant effect on the initial weights of the ewes at parturition (P>0.05) although ewes lambing in the rainy season tended to be slightly heavier (Table 6). In the course of lactation however, the dry season ewes tended to lose weight while the rainy season ewes experienced a net weight gain, even though the difference was not significant (P>0.05). Five months into lactation (the age at which natural weaning would normally take place) 70% of the dry season ewes were still losing weight compared with 44.4% of the rainy season ewes. Dry season ewes lost weight for close to 80 days postpartum, 29 days longer than the rainy season ewes. It is suggested that this may be due to the fact that dry season ewes had to nurse their lambs through a period of relatively low supply of quality feed. According to Land (1978) lactation generally increases metabolic and nutrient requirements which have to be met by commensurate intake of the right amounts of nutritious feed. When feed supply is inadequate, dams sacrifice their own body nutrient stores to cater for the lambs which lead to a loss of weight around that time (Mbayahaga *et al*, 1998). The ewes that lambed in the rainy season, on the other hand, lactated while they still had free access to luxuriant and nutritious pasture. The ewes that lambed in the rainy season also had a significantly better body condition score compared to those that

lambed in the dry season (P<0.05), and this may be attributed to the relatively better supply of feed in the rainy season.

Table 6: Effect of Season on Postpartum Weight Changes of Ewes

Variable	Rainy Season Ewes	Dry Season Ewes	P Values
Mean weight of ewes at parturition (kg)	23.25±0.63	21.90±0.74	0.097
Mean weight change over 5 months of lactation (kg)	0.09±0.17	-0.08±0.17	0.42
Proportion of animals losing weight at 5 months (natural weaning)	44%	70%	
Duration of lactational weight loss (days)	49.11±9.7	78±11.4	0.073
Body condition score (BCS) of postpartum ewes	2.97±0.03[a]	2.81±0.03[b]	P<0.05

4.2.2 Postpartum Return to Ovarian Activity and Oestrus

The mean number of days at which all ewes resumed ovarian cyclicity after their last parturition (as evidenced by the first rise of progesterone above 1ng/ml) was 69 days postpartum (range 19 to 126 days) (Table 7). Seasonal differences in number of days to first rise of progesterone were not significant (P>0.05) although the rainy season ewes resumed cycling 3 days earlier (68 days vrs 71 days). A period of ovarian inactivity follows parturition during which uterine involution takes place. Uterine involution is usually expected to be completed by 28 to 30 days after parturition in sheep (Senger, 2003), however the number of days to the resumption of ovarian cyclicity is highly variable. Mbayahaga *et al* (1998) reported that Burundian ewes returned to cyclical activity 77 days postpartum while Schirar *et al* (1989) reported

that it took only 28 days for Prealpes du Sud ewes to resume cycling after parturtion. Mandiki *et al* (1990) reported the length of time to resumption of ovarian activity in US Texel ewes to range from 44 to 57 days.

4.2.3 Postpartum Progesterone Profiles

Postpartum peripheral blood progesterone concentration was low (0.203 and 0.213ng/ml for dry season and rainy season ewes respectively) until 69 days postpartum. The mean number of days to the first rise of progesterone above the 1ng/ml postpartum was 68.11 and 71.4 days for rainy season and dry season ewes respectively. Seasonal differences in mean number of days to first rise of progesterone were not statistically significant (P>0.05). The mean progesterone concentration at first rise was 1.546ng/ml. This initial rise in P4 was maintained for less than 7 days before dropping to basal levels again (Figure 11).

In general, three kinds of postpartum progesterone profiles were observed. In the first set of profiles (Figure 11), postpartum ewes showed an initial, brief rise of progesterone before coming into oestrus about 26 days later (range 12 to 54 days) or 84 days postpartum. There were no elevations in progesterone levels between the first rise and the first overt oestrus and all the ewes in this group conceived when mated at the first oestrus (the vertical black arrows in the Figure 11 indicate mating). The mean number of days from the first rise to conception for the rainy and dry season ewes was 31 and 22 days respectively. The difference was not statistically significant (P>0.05). Seven postpartum ewes (3 rainy season and 4 dry season) showed this profile.

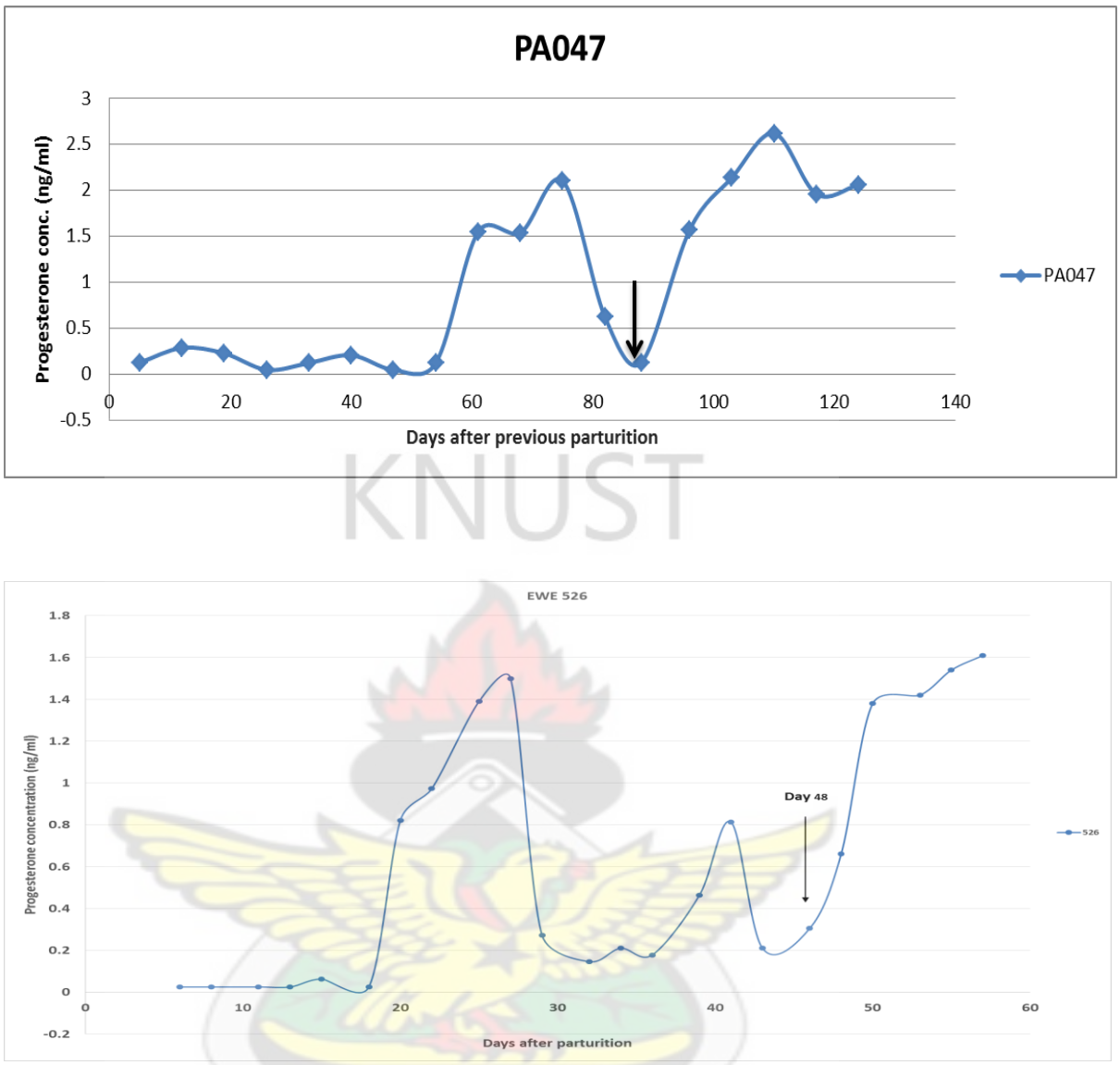


Figure 11: Ewes PA047 and 526 conceiving after experiencing one elevation in P4.

In the second set of progesterone profiles (Figure 12), postpartum ewes experienced from 1 to 4 oestrous cycles (an average of 1.62 oestrous cycles) between first rise and conception (the vertical black arrows in the figure indicate mating). Most of those cycles (76.5%) were irregular and had luteal phases lasting no more than 10 days. However, 23% of the luteal phases were normal. Some of the ewes came into oestrus and were mated but did not conceive the first time. All of the eleven ewes conceived on the first and second oestruses (Fig 14). Eleven out of the 19 postpartum ewes studied, showed this type of profile.

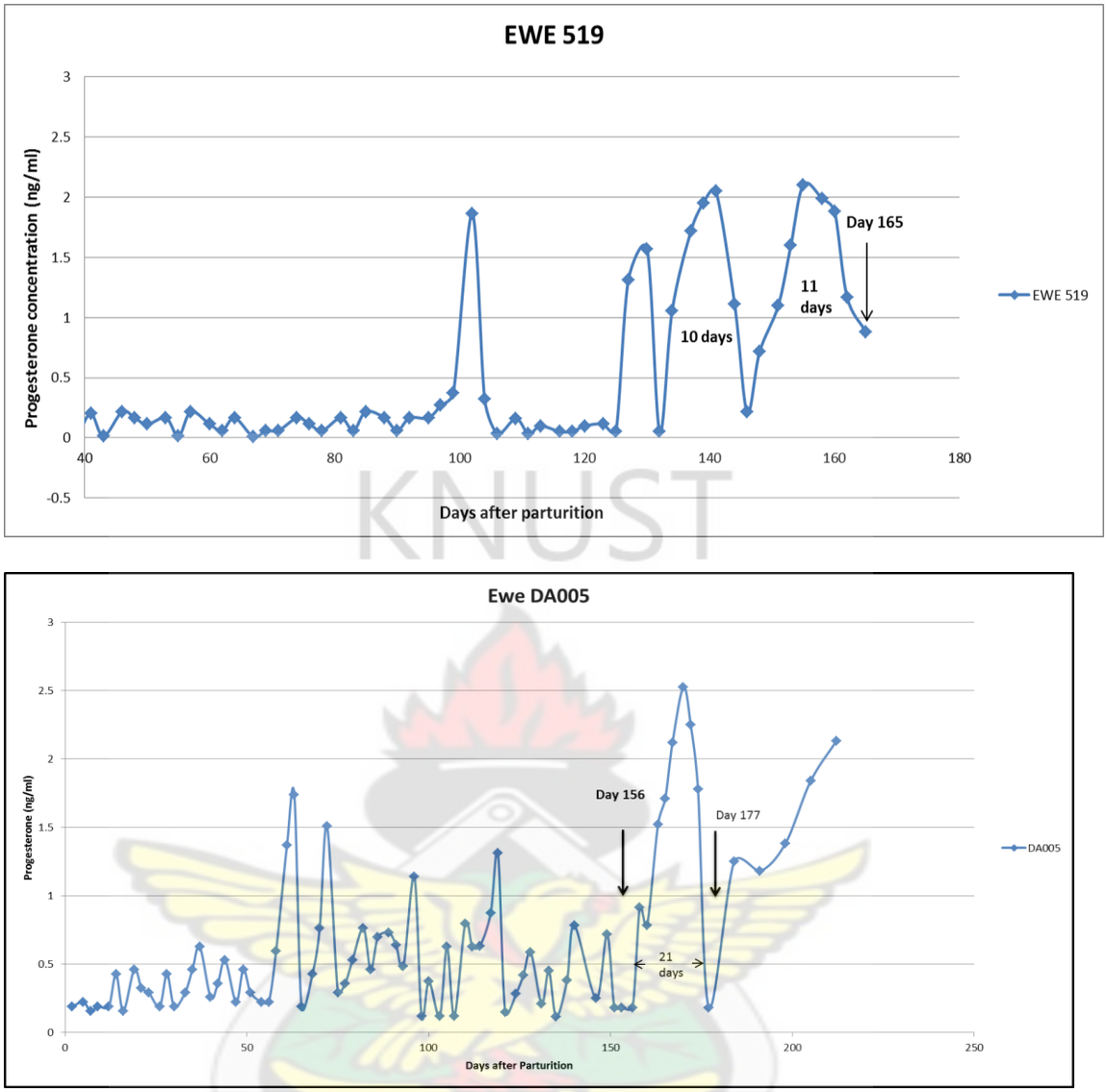


Figure 12: Progesterone profile for rainy season ewes DA005 and 519 showing irregular oestrous cycles with multiple luteal phases.

Figure 12 shows the progesterone profiles of two ewes (519 and DA005) that were bled every other day until they resumed cycling and conceived. The profile of ewe 519 shows progesterone elevation at 100 days postpartum which lasted for just one day before declining to basal levels. It experienced 3 more elevations lasting for 4 days, 10 days and 11 days before being mated. Ewe DA005 experienced first rise of progesterone 68 days postpartum and experienced 3 short-lived rises in progesterone

and one normal rise before conceiving. The regular cycle was preceded by mating. A second mating took place 21 days after the first.

A third pattern of progesterone profile was observed where one ewe came into oestrus and conceived without showing any initial rise of progesterone (Figure 13).

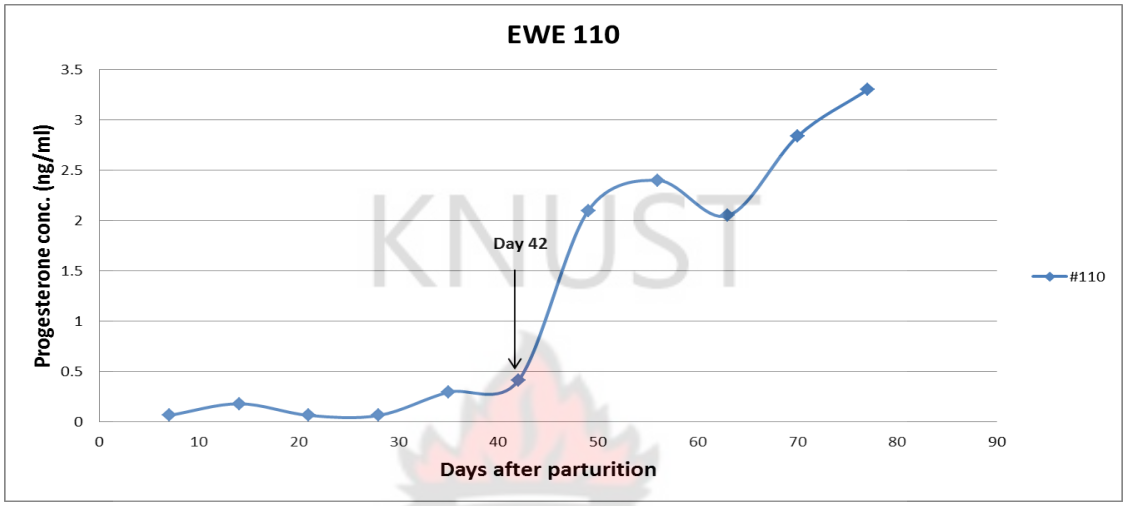


Figure 13: Ewe 110 conceiving without displaying any prior luteal rise of progesterone.

Ewes were assumed to be pregnant if the serum samples collected on day 21 and day 35 after mating continued to show elevated progesterone levels.

Resumption of full postpartum ovarian activity is often preceded by silent ovulations and irregular oestrous cycles. Hunter (1968) and Noakes *et al* (2001) reported that the first oestrous cycles following parturition are generally short and anovulatory and the first ovulations are not usually associated with overt oestrus. Mukasa-Mugerwa and Zere (1991) observed silent ovulations in 66% of ewes returning to ovarian cyclical activity after parturition. Mbayahaga *et al* (1998) showed that Burundian ewes displayed progesterone profiles indicative of silent ovulations. Edey *et al* (1978) and Bartlewski (1999) have explained that some silent ovulations are characterized by the presence of ovarian follicles that luteinized and attained progesterone-secreting ability without ovulation. Keane (1975), Noakes *et al* (2001) and Hafez *et al* (2000) have

suggested that silent ovulations, which occur in pre-pubertal ewes, ewes returning from seasonal anoestrus and postpartum ewes, provide the postpartum progesterone required to prime the central nervous system (CNS) to become sensitive to oestrogen which then triggers full oestrus behaviour (Legan *et al*, 1991). The only ewes in this study that conceived without any apparent ovarian activity did so relatively early after parturition. Mukasa-Mugerwa and Zere (1991) observed that 37% of postpartum ewes did not show any progesterone rise prior to conception in Menz ewes and concluded that the initial progesterone rise may not be an absolute requirement.

The percentage conception rate for the ewes to the first and second mating is presented in Figure 14. Sixty-seven percent of the rainy season ewes conceived upon being mated at the first overt oestrus compared to 90% of the dry season ewes. The rest of the dry season animals (10%) and rainy season ewes (33%) conceived on the second oestrus.

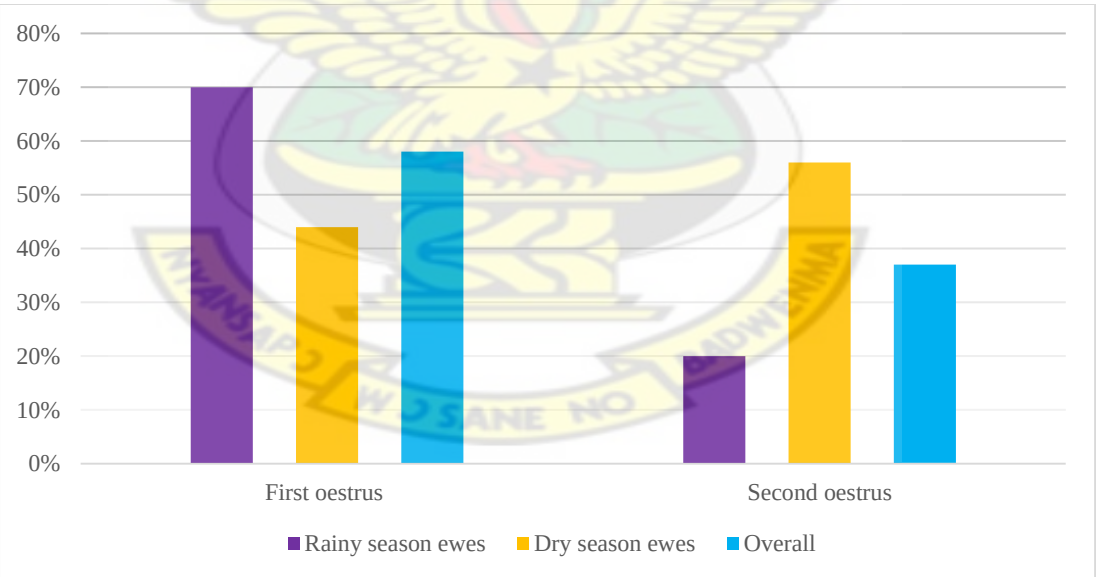


Figure 14: Percentage conception rate to first and second oestruses for postpartum ewes.

4.2.4 Gestational Progesterone Profiles

The gestational progesterone profiles of three rainy season ewes and two dry season ewes are presented in Figure 15. The pattern was similar to the progesterone profiles of the gimmers already described. Season had no effect on the progesterone profile during pregnancy. The peak progesterone levels were however higher among the ewes.

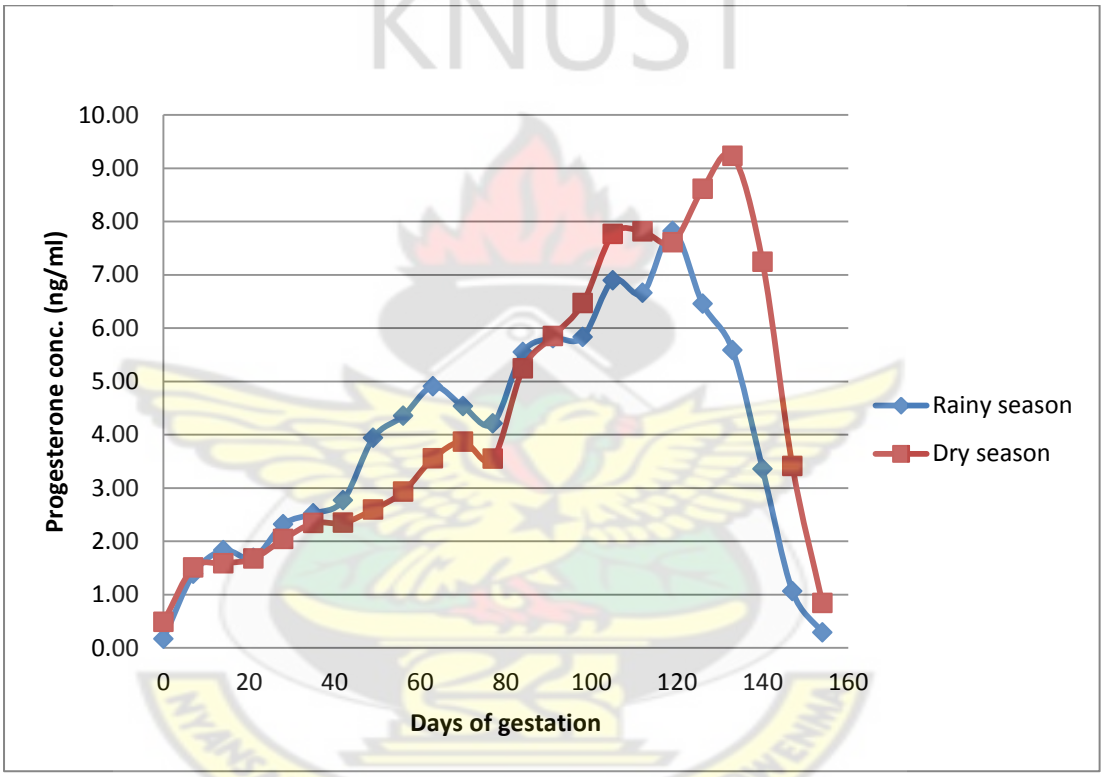


Figure 15: Gestational progesterone profile for ewes

Table 7: Effect of Season on Reproductive Parameters of Ewes.

Parameter	Number of animals	Overall	Rainy season ewes	Dry season ewes	SED	P Values
Mean days from lambing to first P4 rise (days)	19	69±6.73	68.11±6.19	71.40±11.88	15.03	0.815
Mean days from lambing to first overt oestrus (days)	19	108.1±10.10	101±12.48	114±15.93	20.56	0.52
Mean days from first rise to conception (days)	19	46.89±7.29	46.89±9.95	46.9±11.08	13.86	0.99
Lamb Birth Weight (kg)	18	2.04±0.1	2.32±0.13[a]	1.83±0.11[b]	0.17	0.013
Gestation Length (days)	18	151.4±0.5	152.2±0.75	150.8±0.63	0.99	0.164
Dam Postpartum Weight (kg)	18	22.04±0.69	21.73±1.05	22.3±0.92	1.38	0.68
Lambing Interval (days)	18	266.7±11.35	264.2±14.65	268.7±17.41	23.51	0.852
Placenta Weight (g)	18	151.6±6.94	175.2±6.68	132.7±6.66	9.56	0.097
Pregnancy Anabolism (kg)	18	1.64±0.29	1.48±0.41	1.76±0.41	0.59	0.908

Means in a row with different superscripts are statistically different at the 95% level of probability. SED=Standard error of difference

4.2.5 Lambing Intervals

Overall lambing intervals averaged 266.7±11.35 days in this study (Table 7). The season of previous lambing did not significantly influence the lambing interval (P>0.05). The lambing interval in this study is close to the range of 242 and 264 days reported by Tuah and Baah (1985), Oppong-Anane (1971) and Gbangboche *et al* (2006) for the same breed. Gbangboche *et al* (2006) and Tuah and Baah (1985) did not find any significant differences in lambing intervals between ewes that lambed in the rainy season and those that had previously lambed in the dry season. The non-significant difference between seasons in this study suggests that the relatively longer period of weight loss for the dry season ewes was not severe enough to induce a delay in the resumption of ovarian activity and conception. It was observed that most of the animals (89% of rainy season ewes and 50% of dry season ewes) conceived while still nursing lambs. The fact that supplementary feed was supplied to the animals in the dry season may have prevented severe weight losses and consequent disturbance of reproductive function.

4.2.6 Lamb Birth Weights

The mean lamb birth weight for all lambs born to ewes was 2.04kg (Table 7). The lambs born to rainy season ewes were 27% heavier than lambs born to dry season ewes (P<0.05). The significant difference may reflect the better nourishment of ewes that previously lambed in the rainy season and their subsequent quick recovery in body weight and condition. On the other hand, the rainy season ewes were 0.57kg lighter in body weight at parturition than their dry season counterparts, despite having produced heavier lambs. The postpartum weight difference was however not significant (P<0.05).

4.2.7 Secondary Sex Ratio

Eight male lambs and 10 female lambs were born to the postpartum ewes; a proportion of 56% males to 44% females. This ratio did not depart significantly from the expected theoretical sex ratio of 50:50. Similar reports have been published by Obese (1994) and Abdul Wahid (1988) on sheep. Kent (1992) reported that slightly fewer male births (49.56%) than female births occur in sheep.

4.2.8 Gestation Length

Mean gestation length for the ewes was 151.4 days (Table 7). Rainy season ewes carried their pregnancies almost 2 days longer than the dry season ewes, but the difference was not significant (P>0.05). Male lambs and female lambs were carried for 151.80 and 151.16 days respectively. There was no significant difference between the gestation lengths of male and female lambs (P>0.05).

The gestation length in this study is consistent with the gestation length reported for sheep by various authors (Obese, 1994; Mukasa-Mugerwa *et al* 1994; Ibrahim, 1998; Jainudeen and Hafez, 2000; Senger, 2003) who reported gestation lengths ranging from 145 to 152 days.

4.2.9 Blood Glucose and Packed Cell Volume (PCV) for Ewes

Mean blood glucose level among the ewes was 2.78mmol/L (Table 8). Mean glucose levels did not differ according to season of birth, season of sampling or whether the animals were pregnant or not.

Table 8: Effect of season, sampling period and pregnancy on PCV and Glucose levels of ewes.

Variable	Glucose (mmol/L)	P Values	PCV (%)	P Values
Overall	2.78±0.05		27.64±0.297	
Season of birth				
Rainy season	2.75±0.072	0.133	27.16±0.515	0.237
Dry season	2.81±0.069		27.67±0.362	
Season of sampling				
Rainy season	2.65±0.074	0.141	27.05^{a}±0.533	0.004
Dry season	2.84±0.064		28.17^{b}±0.293	
Physiological state				
Pregnant	2.71±0.062	0.167	28.31^{a}±0.321	0.006
Non-pregnant	2.81±0.08		26.66^{b}±0.547	

Means in the same columns with different superscripts are significantly different at the 95% level of probability.

The mean blood glucose levels are consistent with the normal blood glucose levels reported by the Bergman (1963), Obese (1994) and Aiello (1998). Obese (1994) reported lower values for pregnant sheep compared to non-pregnant sheep (2.85mmol/L vs 3.11mmol/L). Taabazuing (1982) observed a decrease in blood glucose levels as pregnancy advanced and attributed this to the increased demand for maternal glucose by the foetus as pregnancy advanced; a fact which becomes evident when the ewe is carrying multiple foetuses or one large foetus (Kronfeld, 1972).

Packed cell volume averaged 27.6% for all ewes (Table 8). The season in which sampling took place had a significant effect on PCV ($P<0.05$), but the season in which the last lambing took place did not appear to have any effect on PCV ($P>0.05$). Pregnant ewes maintained higher PCV levels than their non-pregnant counterparts ($P<0.05$). The range of PCV values indicate that all the ewes in study were generally in good health. High PCVs represent adaptability to the environment (Baker *et al*,

2003). Ibrahim (1998) stated that low PCV values may be used as an indicator of anaemia, possibly linked to parasite infestation. Baker *et al* (1994) also reported that it could be a good indicator of worm burdens, especially *Haemonchus contortus*. The lower PCVs for rainy season ewes in this study is contrary to the report by Taabazuing (1982) who reported higher PCV values for the rainy season compared to the dry season (26% vs. 24%). Data from Opasina (1984) show that the lowest PCVs (16.4%) were recorded at the peak of the rainy season in Ibadan, even though the highest (26.6%) was also recorded in the early part of the rainy season. It is possible that worm infestation at the peak of the rainy season could have led to the lower PCVs in the rainy season relative to the dry season when animals are relatively free of worms. It is also possible that dehydration in the dry season could have resulted in the higher PCVs observed during the dry season period (Rastogi, 2007).

4.2.10 Mortality of Experimental Animals

Two ewes died in the course of the progesterone-monitoring study. The laboratory postmortem revealed that one of them had died of acute pneumonia. The second animal, which died during pregnancy, became lame and died shortly after losing the ability to walk.

4.3.0 Study II: Baseline Data Collection

Analysis of retrospective data from two government livestock stations and one private farm yielded information on age at first parturition, lambing rate, prolificacy, birth weight of lambs, parturition interval and pre-weaning mortality. The effect of various environmental factors on these parameters was estimated. Where the data for estimating the reproductive indices of some stations were missing or not collected, those stations were excluded from the analyses.

4.3.1 Fertility/Lambing Rate

For the purposes of this study, a more practical definition of fertility had to be adopted for estimating the fertility rate since records of diagnosed pregnancies that did not result in parturition were not kept, neither were there data on non-return rates after mating. The fertility/pregnancy rate was therefore defined as the number of ewes lambing as a proportion of the number of females of reproductive age that were available for mating (gimmers that had been moved to the breeding females' pen were added to the number of ewes to avoid overestimation of fertility).

Percentage pregnancy rates for sheep at Akana farms and Savelugu station from 2000 to 2008 are presented in Table 9.

Table 9: Percentage of females of mating age lambing from 2000—2008.

Year	**Akana farms**			**Savelugu farm**		
	Females available	Females lambing	Lambing percentage (%)	Available females	Females lambing	Lambing percentage (%)
2000	58	56	96.55	19	11	57.89
2001	80	60	75.0	27	22	81.48
2002	83	62	74.69	34	18	52.94
2003	82	64	78.04	33	21	63.63
2004	67	61	91.04	40	23	57.5
2005	82	72	87.80	42	16	38.09
2006	80	59	73.75	32	11	34.37
2007	72	69	95.83	40	14	35
2008	83	81	97.59			
Average			85.6%			52.6%

Fertility does not appear to be a problem for the sheep kept at Akana farms since the lowest recorded pregnancy rate was 74%, which was higher than the average fertility rate for sheep at the Savelugu farm. During the years when fertility was lowest at the Savelugu station, a high proportion of the females were found to be gimmers that had failed to conceive during their first year.

Reports for Nigeria, Cameroon and Cote d'Ivoire show high conception rates for Djallonké sheep. Dettmers *et al* (1976); Branckaert (1977) and Berger and Grinisky (1980) reported fertility rates of 77.5%, 96%, and 94%, respectively.

4.3.2 Age at First Parturition

Djallonké sheep in this study area produced their first lamb at an average age of 594.8 days (19months). Age at first parturition differed significantly between stations ($P<0.05$) (Table 10). The ages at first parturition for the Savelugu farm and Akana farms were similar, but both were higher than the age at first parturition for CSIR-ARI sheep. There was no significant difference between seasons for the age at first parturition ($P>0.05$).

Table 10: Effect of Some Non-Genetic Factors on Age at first Parturition of sheep

Factor	Number of observations	Age at First Parturition (days)	P Values
Overall mean		594.8±15.32	
Season			
Rainy season	43	566.7±22.95	0.117
Dry season	61	614.6±20.28	
Origin			
Akana farms	85	$600.8±16.08_a$	0.043
Savelugu farm	8	$671.2±14.70_a$	
CSIR-ARI farm	11	$496.1±34.16_b$	

The controlled mating management system practised at Akana farms and Savelugu could account for the higher ages at first parturition observed on those stations. The rams at the CSIR-ARI station ran with the females all-year-round, thus providing ample opportunity for them to service young females at the earliest opportunity. Wilson (1989) pointed out that restricted access of rams to gimmers, usually to allow gimmers to achieve a certain minimum age or weight before being bred, accounts for

gimmers lambing at older ages than gimmers who ran with rams throughout the year. The same observation was made in the first part of this study where a ram was introduced into the flock, resulting in an average age at first parturition of 460 days. The sole exception to this trend in the literature was Tuah and Baah (1985), where, in spite of uncontrolled mating the gimmers, the mean age at first lambing run into 21 months. A possible reason for this may be the existence of gimmers in the flock that produced their first lambs at a relatively older age. The sample sizes considered for the age at first parturition were small and may have been a factor in the different ages at first parturition observed on the three stations.

4.3.3 Prolificacy

The study revealed a generally low prolificacy in the study area (Table 11). Prolificacy generally increased with increasing parity ($P<0.05$). The difference in prolificacy between ewes lambing in the dry season and those lambing in the rainy season was not statistically significant ($P>0.05$).

Table 11: Effect of various factors on birth weight and prolificacy of Djallonké sheep

Factor	Number of observations	Birth weight (kg) ± S.E.M.	Number of observations	Prolificacy ± S.E.M.
Overall mean		2.57±0.05		1.05±0.0074
Parity				
1st	359	2.49±0.03[d]	348	1.03±0.01$_b$
2nd	202	2.48±0.04[d]	197	1.03±0.012[b]
3rd	146	2.6±0.04[cd]	138	1.05±0.018[b]
4th	127	2.46±0.04[cd]	118	1.09±0.029[b]
5th	90	2.52±0.05[cd]	85	1.06±0.025[b]
6th	54	2.67±0.07[bc]	49	1.10±0.041[ab]
7th	30	2.87±0.10[ab]	28	1.10±0.052[ab]
8th	41	2.95±0.08[a]	35	1.20±0.057[a]
Season				
Rainy season	450	2.57±0.03[a]	420	1.04±0.01
Dry season	599	2.46±0.03[b]	578	1.06±0.01
Sex				
Male	511	2.52±0.03		
Female	538	2.48±0.03		
Location				
Akana farm	804	2.67±0.02[a]	761	1.06±0.01[a]
Savelugu farm	186	2.03±0.03[b]	178	1.04±0.02[ab]
CSIR-ARI farm	59	1.59±0.04[c]	59	1.00±0[b]
Birth type				
Singles	938	2.53±0.02[a]		
Twins	111	2.25±0.05[b]		

Means in the same column with different alphabet superscripts differ significantly at the 95% probability level.

The low prolificacy of Djallonké sheep in this study is a reflection of the low number of twinnings that occurred within the flocks studied (about 6%). Baffuour-Awuah (2007), Karbo (2007) and Fall *et al* (1982) reported generally low figures (1.08, 1.03 and 1.12, respectively) for the Djallonké breed in the humid Forest Zone of Ghana, the Guinea Savannah Zone of Ghana and Senegal, respectively. Gbangboche *et al*

(2006) and Tuah and Baah (1985), however reported higher figures of 1.39 and 1.30 for Cote d' Ivoire sheep and Ghanaian sheep in the Humid Forest Zones, respectively. These observations may reflect different levels of feeding and management.

4.3.4 Birth Weight

The birth weight of Djallonké lambs averaged 2.6 kg. The birth weight was influenced by season, type of birth, parity and location (Table 11). Rainy season-born lambs tended to be heavier than their dry season counterparts (2.57 vs. 2.46kg) ($P<0.01$). Birth weights increased significantly as parity increased. The lambs born as singles were significantly heavier than lambs born as twins ($P<0.01$). The birthweight of male lambs and female lambs was not significantly different ($P>0.05$). Akana farms sheep produced the heaviest lambs followed by Savelugu Sheep, with CSIR-ARI sheep having the lightest birth weight ($P<0.01$).

The mean birth weight of Djallonké lambs in this study is higher than the birth weights of 1.7, 1.77 and 1.59kg reported by Tuah and Baah (1985), Obese (1994) and Fall *et al* (1982), respectively. The selection for high body weight was the main breeding objective at Akana farms, and this may account for the high birth weight. The birth weight of lambs on that farm has increased progressively since the establishment of the farm in 1999. The higher birth weights at Akana farms may also be a reflection of the higher parities of the ewes on that farm compared to ewes on the other farms. The higher mean birth weight observed in the rainy season is consistent with reports by Tuah and Baah (1985), Kabugah and Akowuah (1991) and Tibbo (2006) who reported higher mean birth weights for the rainy season and attributed it to the better quality and quantity of pasture available to the pregnant animal during this season. The relatively lower birth weight of the twin lambs, compared to lambs

born as singles is probably due to competition *in utero* for space and nutrients by twin lambs (Rhind *et al*, 1980; Greenwood *et al* 2000 and Gardner, 2007). It has been reported by Robinson *et al* (1999) that as the number of foetuses increases, the number of caruncles attached to each foetus decreases thereby reducing the amount of nutrients per lamb and the rate of clearing waste products, which consequently affects the birth weight. Similar results have been published by Tuah and Baah (1985) and Kabugah and Akowuah (1991).

4.3.5 Lambing Intervals

Lambing intervals averaged 269.6±2.83 days for all ewes (Table 12). Mean lambing intervals for the rainy season and dry season were 274.6 days and 265.7 days, respectively and were not statistically different from each other ($P>0.05$). Lambing intervals decreased from the first parturition onwards ($P<0.05$). Tuah and Baah (1985) and Ibrahim (1998) observed a continuous decline in the lambing interval among the same breed of sheep and posited that the decline in lambing interval with each successive parturition was a result of older ewes requiring less time to recover condition before rebreeding, following parturition.

Table 12: Effect of some non-genetic factors on lambing intervals of sheep

Factor	Number of observations	Lambing intervals (days)	P Values
Overall mean		267.4	
Season			
Rainy season	269	272.9	0.214
Dry season	334	262.9	
Parity			
2nd	158	280.0[a]	0.052
3rd	124	262.6[ab]	
4th	107	269.8[ab]	
5th	82	269.5[ab]	
6th	54	261.9[ab]	
7th	39	254.9[ab]	
8th	22	237.3[b]	
9th	17	244.7[b]	
Origin			
Akana farms	510	268.4[a]	0.001
Savelugu farm	46	292.0[b]	
CSIR-ARI farm	47	232.2[c]	

Means in the same column with different alphabet superscripts differ significantly at the 95% level of probability

The lambing interval for CSIR-ARI sheep was 60 days and 36 days shorter than the lambing intervals of sheep at the Savelugu farm and Akana farms, respectively ($P<0.05$). The lambing intervals between Akana farms sheep and Savelugu farm sheep also differed significantly ($P<0.05$). The controlled mating practised on some stations appeared to play a role in lengthening the lambing intervals (Mukasa-Mugerwa and Lahlou-Kassi, 1995).

4.3.6 Pre-weaning Lamb Mortality

The pre-weaning survival rate of Djallonké lambs is presented in Table 13. Overall mortality rate was 28.1% for the sheep at Akana farms. Season influenced mortality rate; the mortality rate of lambs born in the dry season was higher than that of lambs

born in the rainy season (36.3% vs. 16.7%) (P<0.01). Type of birth and sex of lambs did not significantly influence the pre-weaning mortality rate of lambs (P>0.05).

Table 13: Effect of season, sex and type of birth on the pre-weaning mortality rate of lambs at Akana farms

Source of Variation	**Number born (%)**	**Viability to weaning**		P Values
		#Surviving (%)	**# Dying (%)**	
Overall	804 (100%)	578 (71.9%)	226 (28.1%)	
Season				
Rainy season	336 (41%)	280 (83.3%)	56 (16.7%)[a]	0.0001
Dry season	468 (59%)	298 (63.7%)	170 (36.3%)[b]	
χ^2=37.401 df=1				
Sex				
Male	386 (48.0%)	274 (71.1%)	112 (28.9%)	0.583
Female	418 (52.0%)	304 (72.6%)	114 (27.4%)	
χ^2= 0.302 df=1				
Type of Birth				
Single	720 (89.56%)	518 (71.9%)	202 (28.1%)	0.921
Twin	84 (10.44%)	60 (71.4%)	24 (23.6%)	
χ^2 =0.010 df=1				

Proportions in the same column with different alphabet superscripts differ significantly at the 99% level of probability

Pre-weaning mortality constitutes an important constraint to sheep production in many countries (Yapi *et al* 1990). The mortality rate in sub-Saharan Africa has been reported by Ibrahim, (1998) to fall within the range of 10 to 50%. Ginistry (1977), Dettmers *et al* (1976), Otesile *et al* (1982), Fall *et al* (1982) and Dettmers and Loosli (1974) reported pre weaning mortality rates of 10%, 20%, 18%, 33%, 20% and 16% for Djallonké sheep in West Africa. In Ghana, Tuah and Baah (1985) reported a pre-

weaning mortality rate of 20.95%. Station sheep (which conditions Akana farms roughly mimics) consistently suffer mortalities far less than what is common in traditionally-managed flocks. Baffuor-Awuah *et al* (2007) and Bonniwell (1978), found mortality rates of 13% and 7-9% respectively for station-managed flocks but found mortality rates in village flocks to be as high as 38%. Turkson (2003) followed a flock of village Djallonké sheep for a year and found that of the 34% lambs dying within 12 months of birth, 76% of the lambs died within 3 months of birth.

Reports of the effect of season on mortality rate are varied, Tuah and Baah (1985) and Turkson (2003) observed no significant effect of season on mortality rate but Fall *et al* (1982), Abassa (1995) reported higher preweaning mortalities in the rainy season. Traore (1985), Bourzat (1980) and Faugere *et al* (1988) found that more deaths occurred in the dry season in Mali, Burkina Faso and Senegal, respectively. In all three countries, pneumopathies and malnutrition were found to be the main causes of death.

Turkson (2003) pointed out that the wide-ranging differences in mortality reported within the country and across the West Africa sub region may be attributed to significant differences in management styles and climatic conditions.

Pre-weaning mortality for both single births and multiple births were similar ($P>0.05$) in this study (28.1% and 23.7%). The results of this study are contrary to Awumbila and Sumani (1992) who observed higher mortalities as litter size increased. The latter team attributed the higher mortalities among twins to their lower birth weights. Perhaps because of the small number of singleton births observed in this study, enough attention was paid to them to ensure their survival. In addition to this, the mean birth weight of twin lambs in this study was quite high (2.25kg). Survival

reduces considerably when birth weights are 1 kg or less (Yapi *et al*, 1990; Abassa, 1995)

The effect of sex of lamb on pre-weaning mortality was not significant, the values for males and females being 28.9 and 27.4% respectively (P>0.05). Fall *et al* (1982), Tuah and Baah (1985) and Turkson (2003) also reported that the sex of the lamb did not significantly influence the pre-weaning mortality rate of lambs.

4.3.7 Annual Reproductive Rate (ARR)

Based on a pre-weaning mortality rate of 28%; lambing interval of 271 days and a prolificacy of 1.06, the ARR was computed to be 103% or 1.03 lambs per ewe per year. The ARR in this study is lower than most ARRs reported for Djallonké sheep. Wilson (1987) and Wilson (1988) reported an annual reproductive rate of 1.36 and 1.33, respectively for Burkina Faso sheep while Armbruster (1988) reported 1.97 for sheep in Cote d'Ivoire. Data from Tuah and Baah (1985) and Kabugah and Akowuah (1991) showed ARRs of 1.1 and 1.5 respectively. The low prolificacy of sheep in this study coupled with a high pre-weaning mortality rate easily accounts for the low ARR. A modest improvement in prolificacy, combined with the control of pre-weaning mortality to about 15% would improve the productivity of Djallonké sheep in the study area.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In the light of the results of this study, the following conclusions may be drawn:

- Djallonké gimmers in the study area reach puberty when they are 7 months old and are first mated when they are 8 months old.
- A number of silent ovulations precede the first overt oestrus in most animals but some animals display oestrus without silent ovulations.
- Older ewes returning to oestrus from a previous lambing resume ovarian activity approximately 70 days postpartum and lamb about 8 months after their last parturition, irrespective of the season in which they previously lambed.
- It is more advantageous to time lambing to occur in the rainy season as it will generally result in faster recovery of the dam and, for female lambs born in the rainy season, an earlier puberty and younger age at first parturition.
- Prolificacy is low, both in young animals and older ones, and pre-weaning mortalities are high.

5.2 Recommendations

- It is recommended that attention be paid to providing prophylactic treatments and other disease control measures to reduce the high pre-weaning mortality.
- Improving on the performance of Djallonkés in terms of prolificacy and pre-weaning mortality would improve the annual reproductive rate.

- Collection of detailed data, especially on mortalities and fertility would greatly aid decision making, especially with regard to deciding which animals are valuable and worth keeping and also what factors contribute the most to mortalities.

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APPENDIX

ANOVA TABLES

Table 1: Age at First Progesterone Rise of Gimmers

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Season of birth	1	6588	6588	4.66	0.045
Residual	18	25444	1414		
Total	19	32033			

Table 2: Weight at First Progesterone Rise

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Season of birth	1	0.800	0.800	0.55	0.468
Residual	18	26.250	1.458		
Total	19	27.050			

Table 3: Age at First Oestrus of Gimmers

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Season of birth	1	14472	14472	3.46	0.079
Residual	18	75188	4177		
Total	19	89660			

Table 4: Weight at First Oestrus for Gimmers

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Season of birth	1	3.612	3.612	0.63	0.438
Residual	18	103.325	5.740		
Total	19	106.938			

Table 5: Gestation Length for Gimmer

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Season of birth	1	8.45	8.45	0.52	0.479
Sex of lamb	1	0.01	0.01	0.00	0.982
Residue	17	274.09	16.12		
Total	19	282.55			

Table 6: Gestation Length for Ewes

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Season of birth	1	9.344	9.344	2.15	0.164
Sex of lamb	1	1.782	1.782	0.41	0.532
Residual	15	65.31	84.355		
Total	17	76.444			

Table 7: Birth weight of Lambs Born to Gimmers

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Season of birth	1	0.6845	0.6845	5.49	0.032
Sex of lamb	1	0.0013	0.0013	0.01	0.920
Residual	17	2.1197	0.1247		
Total	19	2.8055			

Table 8: Birth Weight of Lambs Born to Ewes

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Season of birth	1	1.0617	1.0617	7.92	0.013
Sex of lamb	1	0.0000	0.0000	0.00	0.995
Residual	15	2.0107	0.1340		
Total	17	3.0724			

Table 9: Placenta Weight of Ewes

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Season of birth	1	2397.3	2397.3	3.11	0.097
Residual	16	12341.8	771.4		
Total	17	14739.1			

Table 10: Lambing Interval (Ewes)

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Season of birth	1	88	88	0.04	0.852
Residual	16	39308	2457		
Total	17	39396			

Table 11: Weight Change Over Lactation (Ewes)

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Season of birth	1	0.7317906	0.7317906	0.66	0.4200
Error	93	103.7475778	1.1155654		
Total	94	104.4793684			

Table 12: Body Condition Score for Gimmers

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Model	2	6.43553368	3.21776684	39.23	<.0001
Error	265	21.73521259	0.08201967		
Corrected total	267	28.17074627			
Source	DF	Sum of squares	Mean square	F value	F pr.
PHYSTAT	1	1.41164225	1.41164225	17.21	<.0001
SEASON	1	4.68973597	4.68973597	57.18	<.0001

Table 13: Body Condition Score for Ewes

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Model	2	3.63860438	1.81930219	21.47	<.0001
Error	186	15.76213636	0.08474267		
Corrected total	188	19.40074074			
Source	DF	Sum of squares	Mean square	F value	F pr.
PHYSTAT	1	2.42943880	2.42943880	28.67	<.0001
SEASON	1	1.25983263	1.25983263	14.87	0.00002

Table 14: Glucose (Gimmers)

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Model	3	2.3231345	0.7743782	1.67	0.1741
Error	236	109.4114905	0.4636080		
Corrected total	239	111.7346250			
Source	DF	Sum of squares	Mean square	F value	F pr.
Season	1	1.04946473	1.04946473	2.26	0.1338
Samplingseason	1	1.01290297	1.01290297	2.18	0.1407
Physiologicalstat	1	0.89033305	0.89033305	1.92	0.1671

Table 15: Glucose (Ewes)

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Model	3	3.56977836	1.18992612	2.87	0.379
Error	169	69.99727367	0.41418505		
Corrected total	172	73.56705202			
Source	DF	Sum of squares	Mean square	F value	F pr.
Season	1	0.20794555	0.20794555	0.50	0.4796
Samplingseason	1	1.32813807	1.32813807	3.21	0.0751
Physiologicalstat	1	2.03369474	2.03369474	4.91	0.0580

Table 16: PCV (Gimmers)

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Model	3	63.340035	21.113345	2.88	0.0365
Error	238	1742.940956	7.323281		
Corrected total	241	1806.280992			
Source	DF	Sum of squares	Mean square	F value	F pr.
Season	1	4.31607945	4.31607945	0.59	0.4434
Samplingseason	1	57.83653975	57.83653975	7.90	0.0054
Physiologicalstat	1	1.18741622	1.18741622	0.16	0.6876

Table 17: PCV (Ewes)

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Model		259.745596	86.581865	5.90	0.0007
Error		2702.211851	14.685934		
Corrected total		2961.957447			
Source	DF	Sum of squares	Mean square	F value	F pr.
Season	1	20.6471527	20.6471527	1.41	0.2373
Samplingseason	1	127.5488596	127.5488596	8.69	0.0036
Physiologicalstat	1	111.5495839	111.5495839	7.60	0.0064

Table 18: Age at First Lambing (Retrospective Data)

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Model	3	208016.474	69338.825	3.01	0.0339
Error	100	2306005.439	23060.054		
Corrected total	103	2514021.913			
Source	DF	Sum of squares	Mean square	F value	F pr.
Season	1	57809.9257	57809.9257	2.51	0.1165
Station	2	150206.5483	75103.2742	3.26	0.0426

Table 19: Birth Weight (Retrospective Data)

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Model	12	150.4766047	12.5397171	25.61	<.0001
Error	1036	507.3003400	0.4896721		
Corrected total	1048	657.7769447			
Source	DF	Sum of squares	Mean square	F value	F pr.
Station	2	120.6858911	60.3429456	123.23	<.0001
Season	1	3.8185172	3.8185172	7.80	0.0053
Sex	1	0.6703427	0.6703427	1.37	0.2423
Type	1	12.1168312	12.1168312	24.74	<.0001
Parity	7	18.2039212	2.6005602	5.31	<.0001

Table 20: Lambing Intervals (Retrospective Data)

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Model	10	155530.654	15553.065	3.49	0.0002
Error	592	2640570.254	4460.423		
Corrected total	602	2796100.909			
Source	DF	Sum of squares	Mean square	F value	F pr.
Station	2	86348.60747	43174.30373	9.68	<.0001
Parity	7	62291.64766	8898.80681	2.00	0.0537
Season	1	6890.39925	6890.39925	1.54	0.2144

Table 21: Prolificacy (Retrospective Data)

Source of variation	DF	Sum of squares	m.s.	v.r	F pr.
Model	10	1.47050350	0.14705035	2.81	0.0019
Error	987	51.60765281	0.05228739		
Corrected total	997	53.07815631			
Source	DF	Sum of squares	Mean square	F value	F pr.
Station	2	0.31723264	0.15861632	3.03	0.0486
Season	1	0.00835943	0.00835943	0.16	0.6894
Parity	7	1.24081396	0.17725914	3.39	0.0014

Table 22: Pre Weaning Mortality (Retrospective Data)

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.010[a]	1	.921		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.010	1	.921		
Fisher's Exact Test				.899	.505
Linear-by-Linear Association	.010	1	.921		
N of Valid Cases	804				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 23.61.

b. Computed only for a 2x2 table

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.302[a]	1	.583		
Continuity Correction[b]	.222	1	.638		
Likelihood Ratio	.302	1	.583		
Fisher's Exact Test				.584	.319
Linear-by-Linear Association	.301	1	.583		
N of Valid Cases	804				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 108.50.

b. Computed only for a 2x2 table

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	37.401[a]	1	.000		
Continuity Correction[b]	36.435	1	.000		
Likelihood Ratio	39.022	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	37.355	1	.000		
N of Valid Cases	804				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 94.45.

b. Computed only for a 2x2 table