AN ABSTRACT OF THE THESIS OF

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Title: Reproductive Endocrinology and Vaginal Cytology of the Female Llama (**Lama glama**).

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Bradford B. Smith

Four studies were conducted in the llama (**Lama glama**) evaluating changes in reproductive physiology, vaginal cytology, and growth.

Study I. Temporal changes in vaginal cytology were correlated with alterations in serum estradiol-17β and progesterone concentrations. A 2 * 2 factorial study examined the treatment effects of a) concurrent male exposure without copulation and b) collection of vaginal smears for cytologic examination on serum hormone concentrations. Repeated collection of vaginal samples produced: a) an increase in the relative percentage of cornified cells, b) a decrease in the percentage of intermediate cells; and c) no changes in serum estrogen or progesterone concentrations. The presence of a male did not influence serum estrogen, progesterone or vaginal cytology.

Study II. The life-span of the corpus luteum was determined following hCG-induced ovulation and sterile or fertile breedings. Peak plasma progesterone concentrations of 8.5 $\pm$ .3 ng/ml at 9.8 $\pm$ .8 days following either sterile breeding or hCG administration was observed. Luteal regression, began 10.3 $\pm$ .3 and 10.8 $\pm$ .8 days following sterile breeding or hCG adminstration, respectively, and was completed by day 12-13 post-stimulation. Following a fertile breeding, progesterone

increased significantly by 4 days post-breeding and remained above 2 ng/ml in all animals that subsequently delivered a full term cria. Fertile breedings could be differentiated from sterile breedings or hCG induced ovulation by 15 days post-stimulation by differences in progesterone concentration.

Study III. The changes in plasma concentrations of progesterone, estradiol-17β, total estrogens, T_3, T_4 and cortisol concentrations during pregnancy, parturition and the early postpartum period were determined in experiment III. Progesterone concentrations were significantly elevated by 5 days postbreeding, remained elevated throughout pregnancy until approximately 2 weeks prior to parturition and declined to < 0.5 ng/ml by the day of parturition. Total estrogen (TE) and estradiol-17β ($E_2\beta$) concentrations varied between 6-274 pg/ml and 4-114 pg/ml, respectively, during the first 9 months of pregnancy. Mean TE and $E_2\beta$ concentrations increased between 9 months and the end of pregnancy with peak mean concentrations of 827 $\pm$ pg/ml (TE) and 196 $\pm$ 10 pg/ml ($E_2\beta$) observed during the last week of pregnancy. $E_2\beta$ and TE concentrations declined rapidly immediately prepartum. Cortisol concentrations varied between 2.6 and 51.9 ng/ml (14.0 $\pm$ 0.5) from conception until 2 weeks prior to parturition when they began to decline. Only a slight increase in glucocorticoid concentrations were observed in association with parturition.

Study IV. The growth patterns of the llama from birth to 12 months of age was characterized. Regression analysis revealed a strong positive correlation between log transformed measurements of thoracic circumference and height with body weight. Thoracic circumference was a good predictor of body weight.

Reproductive Endocrinology and Vaginal Cytology of the Female Llama (**Lama glama**)

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CONTRIBUTION OF AUTHORS

Dr. Karen I. Timm is a member of the faculty of the College of Veterinary Medicine, Oregon State University, whose contributions to these experiments included data analysis, particularly those data related to body growth measurements.

Mr. Gilbert LeCren is a Research Assistant in the College of Veterinary Medicine, whose contributions to these experiments included computer graphics and radioimmunoassay analysis.

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REPRODUCTIVE ENDOCRINOLOGY AND VAGINAL CYTOLOGY OF THE FEMALE LLAMA (**LAMA GLAMA**)

I. INTRODUCTION

The six species of the Camelidae family are believed to have originated in western North America with two of the species migrating by way of land bridges into Asia and four into South America. The camelids arrived on the South American continent after the second emersion of the Central American isthmus during the Miocene, when the Andes Mountains were forming (Cardozo, 1975, 1981; Novoa, 1970; Franklin, 1981; Marshal, 1984; Jungius, 1972).

In Asia and North Africa, the genus **Camelus** is represented by two species: **Camelus bactrianus** (two humped camel) and the **Camelus dromedarius** (one-humped camel) (Hanacki et al., 1982; Novoa, 1970; Fernandez-Baca, 1975). In South America, there are four species of camelids: the llama (**Lama glama**), alpaca (**Lama pacos**), guanaco (**Lama guanaco**) and vicuna (**Vicugna vicugna**) (Simpson, 1941; Foote, 1968; Wheeler, 1984, 1988; Novoa, 1981). The current population of llamas and alpacas in South America number approximately 6 to 7 million and are distributed along the Andes Mountains between 11 and 21 degrees south latitude. The llama and alpaca normally live at elevations between 3000-5000 meters above sea level and were domesticated between the eleventh and twelfth centuries (Calle Escobar, 1984; Novoa and Wheeler, 1984). The guanaco and the vicuna are wild species. The guanaco exhibits a wide range of ecological adaptations from warm lowlands to cold grasslands at elevations ranging from sea level up to 4200 meters (Franklin, 1982, 1984; Wheeler, 1988). The vicuna is found between Peru (9 degrees, 30 minutes, south latitude) and Chile

(29 degrees south) and at elevations of up to 4000 meters above sea level (Franklin, 1974, 1984; Pearson, 1943, 1951; Novoa, 1970, 1983).

The four species of South American camelids (SAC) play an important role in the economy of the Andes Mountain countries: Chile, Argentina, Peru and Bolivia. In the United States the SAC, especially the llama--while not a major livestock species--have become popular, especially in the western regions of the United States, with increasing numbers of these animals currently being raised. Also, with the rapidly increasing value of these animals, there has been an increased recognition of the need to optimize the reproductive efficiency of the llama.

There is relatively little literature concerning the basic reproductive physiology of the SAC. Thus, it is important to study select aspects of the reproductive physiology of the llama leading toward a more complete understanding of the basic reproductive pattern of the llama with the goal of improving fertility. Also, although the llama is a member of the **Camelidae** family, there appear to be substantial differences between the genus **Camelus** and the genus **Lama**. Many aspects of reproductive physiology that have been established for the Bactrian (**Camelus bactrianus**) or dromedary (**Camelus dromedarius**) camels cannot necessarily be applied to the SAC.

In light of this paucity of accurate information, elucidation of the endocrine changes associated with conception, pregnancy, and parturition was the primary focus of this thesis. This study will deal with one species of the genus **Lama**, the llama (**Lama glama**).

II. LITERATURE REVIEW

The topics examined in this thesis are diverse. In the interests of organization and clarity, the literature review has been divided into sections as follows:

A. Camelidae Family - reproductive ecology.

A.1. South American camelidae

A.2. Bactrian and dromedary camel

B. Endocrine physiology, vaginal cytology, and sexual behavior in induced ovulators.

B.1. Endocrine physiology

B.2. Vaginal cytology

B.3. Sexual behavior

C. Corpus luteum life span in some domestic species

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D.1. Progesterone

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A. Camelidae Family - Reproductive ecology.

A.1. South american camelids (SAC).

Seasonal sexual activity in the genus **Lama** appears to be similar to the genus **Camelidae** in that it varies with the region where the observations were performed. It was reported by San

Martin (1961) that the alpaca in Peru breed from December to March. In contrast, Novoa (1970), gave evidence which refuted the existence of a strict breeding season and suggested that when males and females are not in permanent association, sexual activity can occur during the entire year. In North America, conception in the llama and alpaca occurs throughout the year.

Due to their numerical superiority in South America, most studies of the SAC have been conducted in Peru with the alpaca **(Lama pacos)**. Although puberty in the alpaca has been reported to occur as early as 10 months of age, females normally begin to demonstrate external signs of estrus and sexual behavior between 12 and 14 months of age (Sumar, 1983; Novoa, 1972, 1984; Fernandez-Baca, 1975). Although sexual receptivity may be observed by one year of age, llamas and alpacas in South America do not routinely breed, however, until approximately two years of age, probably due to inadequate nutrition (Novoa, 1980, 1984).

In addition to being a seasonal breeder under conditions of restricted nutrient availability in South America, the SACs also appeared to be induced ovulators. Fernandez-Baca et al. (1970, 1971), observed that the alpaca in Peru is an induced ovulator much like the rabbit, mink, and other species. He demonstrated that mounting, accompanied by penile intromission, appeared to be necessary to provide afferent impulses adequate for the release of LH and subsequent ovulation. He also suggested that, occasionally, the alpaca appeared to be capable of spontaneous ovulation without the mounting stimulus. San Martin (1961)

suggested that mated females that did not conceive became pseudopregnant, indicating that ovulation is induced by coitus. The validity of this observation has not been confirmed in other studies. Ovulation in the alpaca occurs 24 to 26 hours after copulation or injection of human chorionic gonadotrophic (hcG) (Fernandez-Baca 1970). Although ovulation occurs bilaterally with an equal frequency, 98.4% of embryos implant in the left uterine horn in alpacas (Fernandez-Baca 1973). Fernandez-Baca (1970) also indicated that following undisturbed single or multiple services by intact or vasectomized males, 20 to 30% of the bred females failed to ovulate and suggested that ovulation failure was likely to be an important contributing factor to the low fertility rates observed. Fernandez-Baca (1970) noted that 40 to 50% of the breeding age female alpacas in Peru failed to produce an offspring annually on most commercial alpaca farms. England (1969) confirmed that the llama and alpaca in Bolivia have a similar mode of ovulation. England's study of the histology and progesterone content of the CL indicated that the lifespan of the CL in the non-pregnant llama was less than 16 days and that the llama did not become pseudopregnant.

Fernandez-Baca et al. (1979), discussed the role of the uterus in regulating luteal function in the alpaca and examined differences in the regression of the corpus luteum located in the right or left ovary. They demonstrated that removal of both uterine horns and oviducts in the alpaca allowed the maintenance of corpora lutea on either ovary only up to day 70 post breeding.

Removal of the left uterine horn and oviduct alone prolonged the lifespan of the corpus luteum in the left ovary, while the corpus luteum in the right ovary showed early regression. Finally, Fernandez-Baca et al. (1979) demonstrated that when the right uterine horn and oviduct was removed, it failed to exert any effect on the lifespan of the corpora lutea as evidenced by early regression of the corpora lutea in both ovaries. The author suggested that the right uterine horn of the alpaca exerted a localized effect on luteolysis while the left uterine horn exerted both a local and systemic effect on luteal regression. This may also explain why corpora lutea located in the right ovary regress more rapidly than those located in the left ovary, an observation previously reported by Fernandez-Baca et al. (1970).

A.2. Bactrian camel and dromedary camel.

The production of meat, milk, hair, and hides from the genus **Camelus** and its usefulness as a pack animal are vital to the economies of several countries in Africa and Asia. It also provides nutrition and clothing for many poor people, as does the genus **Lama** in South America (Shalash 1965; Shimada and Shimada, 1985).

Members of the genus **Camelus** appear to be partially seasonal breeders (Shalash 1965). The female camel (**Camelus dromedarius**) is a seasonal breeder with the greatest ovarian activity occurring between December and May in Northern Africa. The ovaries remain responsive to stimulation, however, since Elias et al. (1985),

induced estrous in dromedary camel during the last part of the seasonal anoestrus using 7000 IU of PMSG (pregnant-mare serum gonadotropin). The greatest level of ovarian activity occurred during March. Rainfall and food availability appear to be the primary factor regulationg seasonal reproduction (Yagil 1986).

Members of the camelidae family are normally monocyesis with only a few cases of twins reported (Ismail, 1987). Although ovulation occurs bilaterally, 99.2% of the pregnancies are carried in the left horn (Shalash 1980). The gestation period is 389.87 ± 2.1 (SE) days with female camel calves having a mean gestation 1.3 days longer than male calves (Mehta, 1962). The placentas in the dromedary and Bactrian camels and the llama (Morton, 1961) are epitheliochorial. Camels are induced ovulators requiring coitus for ovulation to be induced (Shalash, 1964; Musa and Abusineina, 1978).

Elias et al. (1984), studying the sexual behavior of the camel, explained that the external signs of estrus in the camel are manifested by restlessness, swelling of the vulva and some vulval discharge. It must be stressed, however, that the external signs of estrus in the camel are far less evident when in a group, than those observed in the cow. The most characteristic sign of a female camel's willingness to breed is adoption of the sitting posture and mating stance (Musa and Abusineina, 1978; Josh et al., 1980).

Studies of the reproductive biology of the male camel in Israel have shown that the male has increased sexual activity from

December to March or April, as indicated by hormonal and behavioral changes (Yagil and Etzian 1980). The same authors indicated that the male camel is docile during the non-breeding season but will become aggressive during the December to April breeding season. During this same period of time, the males also secrete a profuse, watery-brown secretion from the paired glands situated on the back of the neck just below the ears. The secretions from the neck glands begin at the end of October and continue through April. The secretions have a strong, fetid odor. During the mating season, the male camel also periodically extrudes a balloon-like organ from the side of the mouth. This palatal flap is inflated with air, and the protussion of the balloon is accompanied by a loud gurgling and roaring sound. Concurrently, the animals spread urine over their backs with the aid of their tails.

Rosenstrauch et al. (1978) found two distinct populations of Leydig cells in the testes of camels collected during the mating season. In contrast, only one population of Leydig cells was found during the non-mating season. This latter type of cell is characterized by reduced amount of smooth endoplasmic reticulum, (Tingari et al., 1979). These morphometric changes coincide with a decrease in gonadotrophin stimulation of the Leydig cells (Zirkin et al., 1980).

Yagil and Etzion (1980), reported that serum androgen concentrations in the male camel increased dramatically during the breeding season (> 30 ng/ml) in comparison to concentrations

observed during the remainder of the year (< 2 ng/ml). During the breeding season, the androgen concentration of the neck secretions also increased (> 36 ng/ml). The behavioral changes coincided with the period of elevated androgen concentrations.

B. Endocrine physiology, vaginal cytology and sexual behavior in induced ovulators.

B.1. Endocrine physiology of induced ovulators.

In most mammalian females, ovulation is a cyclic event, occuring at regular intervals unless the female is either prepubertal or pregnant. Females belonging to this group are termed spontaneous ovulators (Cross, 1973). In other species, ovulation follows stimulation of the cervix, normally by the penis during copulation. Females that normally ovulate only following copulation, the rabbit, cat, ferret, camel, llama, and mink, are classified as induced ovulators. In these species, coitus stimulates a reflex hypothalamic discharge of gonadotrophin-releasing hormone (GnRH) and a resultant pituitary release of luteinizing hormone (LH) (Jochle, 1975). The estrus cycle of the laboratory rat, mouse, and hamster have aspects of both spontaneous and induced ovulators, since although they ovulate spontaneously at regular intervals, they also require the act of coitus to produce a fully-functional corpus luteum. In the absence of coitus, the corpus luteum of diestrus secretes progesterone for only two or three days prior to regressing (Milligan, 1982). Mating also appears to stimulate the release of

prolactin from the anterior pituitary, a requirement for full luteal activity in the rat and mouse. There may be considerable overlap between spontaneous and induced ovulators, as the time of ovulation can be advanced by copulation in some spontaneous ovulators (Short, 1985).

Endocrinological studies have been conducted in different induced-ovulator species. A widely used model for studying induced ovulators is the rabbit. When LH concentrations increased significantly following coitus, ovulation occurred. Ovulation did not occur in animals following copulation in which serum LH concentrations did not increase (Duffy-Barbe et al., 1973). In contrast, no significant changes were observed in serum FSH concentrations following coitus, regardless of whether or not ovulation occurred. Another study showed that ovulation could be induced in rabbits by copulation, electrical stimulation of the amygdala, or intravenous administration of GnRH (Kanematsu et al., 1974). Wildt et al. (1980) demonstrated that coital stimulation plays a major role in regulating ovulation in the cat. They showed that multiple copulations enhanced the pituitary release of LH, in comparison to the amplitude of the LH release following a single mating. Similar results have been reported by Concannon et al. (1980) in the cat.

The South American camelidae family: llama, alpaca, guanaco, and vicuna, all appear to be induced ovulators (Novoa, 1970). In alpacas, it has been reported that ovulation can be induced either by copulation or following administration of human

chorionic gonadotrophin (hCG), and occurs 26 and 24 hours respectively after copulation or hCG stimulation (San Martin et al., 1968). Additional work demonstrated that penile intromission was necessary to stimulate an ovulatory release of LH in the alpaca, and mounting without penile intromission did not result in ovulation (Fernandez-Baca et al., 1970).

It appears that induced ovulation is a neuroendocrine interaction between the genital tract, hypothalamus, and ovaries. The mechanisms controlling reproduction in cats and rabbits have been most extensively studied. The mechanisms controlling reproduction in the genus **Lama** are far less well-characterized.

B.2. Vaginal cytology.

A partial evaluation of uterine and vaginal diseases, as well as an evaluation of the stage of the estrus cycle, may be obtained by evaluating changes in the vaginal cytology in some species. The changes in vaginal cytology are, however, somewhat species specific (Roszel, 1975).

Changes in vaginal cytology are normally a reflection of changes in ovarian steroid production. (McDonald, 1980). The effect of estrogens during estrus is to stimulate proliferation and maturation of the vaginal epithelium producing an increase in the keratinization of the epithelium (Roszel, 1975). The same author suggested that this estrogenic effect occurs in the vagina of many species although there is marked species variation in the thickness of the epithelium and the degree of keratinization.

Although the work was based on changes in the vaginal cytology of ewes, Sanger et al. (1958) suggested that estrogens have a direct effect on the vaginal epithelium of most female mammals. The same authors stated that changes occur in an orderly sequence and can be followed by studying vaginal smears taken at regular intervals. They also suggested that an increase in estrogens stimulated an increase in the number of cell layers lining the vagina and stimulated cornification of the superficial layers. Henricks (1951), studying vaginal cytology in the cow, observed that the nuclei of ephithelial cells were absent during estrus in a large number of cells. Schutte (1967) reported that the number of cells in vaginal secretions in the dog were altered in response to the level of estrogens, which caused proliferation of the endometrium and cornification of the vaginal epithelial cells. Christie (1972) reported a classification of vaginal smears during estrus cycle in dogs, as follows: a) Anuclear cells = epithelial cells which have no nucleus. b) Superficial cells = cells having a pyknotic nucleus. c) Large intermediate cells = cells that have a nucleus which is 7 to 11 um in diameter. d) Small intermediate cells = cells with a diamater of less than that of the large intermediate cells. e) Parabasal cells = cells that are rounded or oval and have a higher nuclear-cytoplasmatic ratio.

Among mustelids, another group of induced ovulators, vaginal smears have been used successfully to identify the reproductive status of the ferret (**Mustela putorius**) (Hamilton and Gould, 1940) and the mink (**Mustela vison**) (Travis et al., 1978). Stenson

(1988), working with the river otter (**Lutra canadensis**), suggested that estrus is characterized by a significant increase in the number of nucleated and non-nucleated cornified cells. The relative percentages of these cell types in vaginal smears were observed to further increase following mating. During metestrus, the vaginal cytology is characterized by large numbers of leucocytes and copious mucus secretions. Olson et al. (1984) and Lofstedt (1982), reported that the vaginal cytology in the feline during the follicular phase was characterized by anucleated superficial cells. Superficial cells with pyknotic nuclei remained constant throughout the estrous cycle. Studies on the dromedary camel (Joshi et al., 1978) found that the most prominent changes in vaginal cytology during estrus were a further flattening of the cornified epithelial cells, increased eosinophilic staining of the cytoplasm, and disappearance or further condensation of the nucleus. Musa et al. (1978) performed vaginal smears during the follicular phase of the estrous cycle in the female dromedary camel, and reported superficial epithelial cells and a small number of leukocytes.

B.3. Sexual behavior in induced ovulators.

Frequently observed indicators of estrus in many mammals include changes in the vaginal opening, perineal swelling, lordosis, and increased activity. These types of behavior and visual cues are hormone dependent (D'Souza, 1978). Caillot et al. (1983) described the receptive female rabbit's behavior, noting that the female reacted to the male by circling around the buck,

by vocalizing, by flattening to the floor and by trying to mount the male.

The sexual behavior of female cats is characterized by vocalizing frequently during estrus and rubbing her head and neck against various inanimate objects (Lofsteadt, 1982). The same author indicated that the queen in estrus also may crouch low on her forelimbs, elevate the perineal region, and deflect the tail laterally.

Sexual behavior in female camels during estrus is characterized by approaching the male, restlessness, swelling of the vulva, a clear mucous discharge from the vulva, and an orgling noise (Ismail, 1987; Yasin and Wahid, 1957; Musa and Abuseneina, 1978; Elias et al., 1984). The female may also spontaneously lie down when approached or touched by a male. She may also be, or induced, to lie down by the male passing his nose along her head, neck and side to the vulva, and then rubbing the vulva with his nose or neck, using his neck to push down on her neck or lumbar region or by biting at the leg joints, preventing the female from walking, and forcing her to lie down (Joshi et al., 1980; Shalash, 1980). In SACs, the characteristic sexual behavior and breeding pattern includes a vocalization (orgling) that appears to be an especially important indication of sexual receptivity (Franklin, 1982).

C. Corpus luteum life span in domestic species.

The development, maintenance, and regression of the corpus luteum (CL) have been investigated for many years. The endocrine and cellular mechanisms regulating progesterone synthesis and secretion have not, however, been fully elucidated in camelids.

The corpus luteum is a temporary endocrine gland that develops from the graafian follicle following ovulation (Hansel et al., 1973). The corpus luteum secretes progesterone and has an important regulatory role during the estrous cycle and pregnancy (Hansel, 1967). If pregnancy does not occur following estrus and mating, progesterone secretion from the corpus luteum is normally terminated by the release of a luteolytic factor (usually $PGF_{2\alpha}$) from the uterus allowing the reproductive cycle to begin again (Ginther, 1974).

The life span of corpora lutea differs between species and consists of three parts related to the pattern of progesterone secretion: a) rising progesterone concentrations, b) the plateau, and c) regression of the corpus luteum (Rothchild, 1981). Physical growth of the corpus luteum tends to coincide with the rising and plateau in progesterone concentrations in most species. Size regression, however, tends to take longer than the decline in progesterone production (Rotchild, 1965). In non-pregnant animals, the rise and plateau phases together can take as little as two days, e.g., in ferrets (Heap and Hammond, 1974), about 10 days in the mink (Moller, 1973), cats (Verhage et al., 1976), or as long as three weeks in the dog (Concannon et al., 1975).

Regression of the corpus luteum is relatively rapid and occurs within three to four days in the ewe (Stabenfeldt, 1969). In the cow, progesterone content of the corpus luteum increases rapidly between days three and twelve of the cycle and remains relatively constant until day 16. In the sow, progesterone concentrations increases very rapidly from day two to day eight post-breeding and then remain relatively constant until day 15 when regression begins (Erb et al., 1971). In the dromedary camel, luteolysis is completed by day 10 post-ovulation (Marie and Anouassi, 1987). Fernandez Baca, 1970, working with alpacas in Peru, suggested that the corpus luteum had regressed on day 13 after sterile mating or hCG injection. Xu et al. (1985) reported that progesterone concentrations had declined to 0.3 ng/ml by day 15 following a sterile mating in the Bactrian camel.

D. Hormonal changes during pregnancy, parturition and post-partum in select domestic species.

A comparison of hormone concentrations in different species before and during parturition is complicated by the variety of analytical and sampling procedures that have been used. The information that is now available related to hormone concentrations emphasizes the complexity of the endocrine regulation of parturition in different species. The following examples have been selected from different domestic species including human and non-human primates.

D.1. Progesterone during pregnancy.

Studies of progesterone changes in general show that the concentration of progesterone declines in all mammals before parturition, except in the human in which plasma progesterone concentrations remain constant or increase slightly as parturition approaches (Csapo et al., 1971; Llauro et al., 1968). The following review characterizes the species-specific changes in progesterone concentrations during pregnancy.

Sow:

During the first 14 days of pregnancy, the plasma progesterone concentration was similar to that found during the luteal phase of the estrous cycle, 20-30 ng/ml. Starting about day 15 post-breeding, progesterone concentration gradually declined to 10-15 ng/ml (Guthrie, Hernicks and Handlin 1972). Baldwin and Stabenfeldt, 1975, reported that progesterone concentrations began to decline approximately 2 weeks prior parturition, declining from approximately 15 ng/ml to 2-4 ng/ml by 2 days prior to parturition. Another study reported plasma progesterone concentrations during late pregnancy in the sow varied between from 6-12 ng/ml until immediately prior to parturition when it declined rapidly (Ash and Heap 1975). Molokwu and Wagner (1973) reported that mean progesterone concentrations in the sow started to decline on day 5 prepartum. This decline was very rapid from day 4 prepartum (11 ng/ml) to day 1 postpartum (0.5 ng/ml). The concentration remained fairly constant at about 0.3 ng/ml from days 2 to 7 postpartum. Killian et al. (1973),

reported that progesterone concentrations were constant during the last 3 weeks of gestation but declined rapidly from 10 ng/ml on day -3 to less than 1 ng/ml by day 1 postpartum.

Robertson and King (1974) reported that the progesterone concentrations in sows remained fairly constant (10 - 12 ng/ml) throughout pregnancy until 20 to 15 days before parturition. The progesterone concentration dropped over the last 15 days of gestation and declined to a concentration of 4.7 ng/ml on the day of parturition. A further rapid decline to a level of < 0.5 ng/ml was observed within 24 hours of farrowing.

Ewe:

The changes in progesterone during the periparturient period are slightly different in the ewe, with progesterone concentrations beginning to decline 4 days prior to parturition. By the day of parturition, mean progesterone concentrations were reported to have declined to approximately 1.0 ng/ml (Chamley et al., 1973). Stabenfeldt et al. (1972) reported that progesterone concentration in sheep began to decline about 130-135 days following conception and reached a base concentration below 1 ng/ml by 1 day postpartum. The data also indicated that parturition in ewes can occur even if the progesterone concentrations remain elevated (1.5 and 2.0 ng/ml). Thompson (1973), in agreement with Stabenfeld, stated that parturition in the sheep occurs in the presence of significant progesterone concentrations. Plasma progesterone concentrations in control sheep were approximately 8-10 ng/ml within 24 hours prepartum and

declined to less than 1 ng/ml at 24 hours postpartum. Stabenfeld et al. (1972) reported a difference in plasma progesterone concentration between ewes with single and twin pregnancies.

Thompson and Wagner (1974) found that plasma progesterone concentrations were higher in ewes with multiple fetuses than in those with a single fetus. Chamley et al. (1973) working with ewes during late pregnancy and parturition found that mean plasma progesterone concentrations on day -10 were 15.5 ng/ml and from day -4 the concentration began to decrease and by day 0 the concentration was 1.0 ng/ml. After parturition, the plasma concentration in all animals was in the range of 0.1-0.6 ng/ml.

In other work by Basset et al. (1969), the plasma progesterone concentration in the pregnant ewe remained between 2.0 and 2.5 ng/ml until about 50 days after mating. From days 50 to 130 of gestation, plasma progesterone concentrations increased to between 6.5 and 7.6 ng/ml. Basset also suggested that the decline in plasma progesterone concentration before parturition was not consistent because determinations of plasma progesterone obtained daily from a number of animals during the week before parturition were variable and the decrease did not occur in some animals until less than 24 hours before parturition. Basset also noted lower plasma progesterone concentration in ewes with a single fetus than in ewes carrying twins or triplets.

Cow:

Plasma progesterone concentration during the last month of pregnancy varied between 2.5 and 7.5 ng/ml before declining to

between 0.3 and 0.5 ng/ml at calving time (Pope et al., 1969). Stabenfeldt et al. (1970) reported an average plasma progesterone concentration of 4.6 ng/ml between days 140 and 200 of gestation, mean concentrations of 6.8 ng/ml at day 250 before declining to approximately 4 ng/ml at 10 days prior to parturition. In the same study they reported that the plasma progesterone concentration fell rapidly to less than 1 ng/ml by 24 hours before parturition. Hunter et al. (1977) reported that maternal plasma progesterone concentrations decreased very rapidly during the 36 to 48 hours before parturition, to a concentration of less than 1 ng/ml. Smith et al. (1973) reported that the plasma progesterone concentration in pregnant cows remained as high as 7.6 ng/ml until day -2, fell to 3.0 ng/ml at day -1, and decreased to 0.6 ng/ml at parturition, remaining near this low concentration for the first nine days postpartum. Fairclough et al. (1975) found that the plasma progesterone concentration decreased from approximately 8 ng/ml to 4 ng/ml over the period of 10 to 12 days prepartum when the concentration fell to term. Henricks et al. (1972) suggested that the concentration of plasma progesterone in pregnant cows increased from 1.2 ng/ml on day 3 to concentrations of 8.2 ng/ml and 9.9 ng/ml on day 12 and after day 12, the progesterone concentration increased to 13.9 ng/ml. In the same study, the plasma progesterone concentrations during the last 5 days of gestation remained steady at approximately one third the plasma progesterone concentration observed during early pregnancy until day -1 before parturition when it fell to 0.7 ng/ml. Hunter et

al. (1977) reported that maternal plasma progesterone concentrations fell at the end of gestation, decreasing more rapidly over the last 48-36 hours to concentrations of less than 1 ng/ml.

Mare:

The primary corpus luteum of pregnancy was maintained beyond day 15 post-ovulation with plasma progesterone concentrations reaching a peak, approximately 10 to 15 ng/ml, by approximately day 25 of gestation. Plasma progesterone concentration then decreased until approximately days 40 to 50, when progesterone concentrations increased, reaching a second peak 80 to 90 days post-breeding (Holtan et al., 1975). Serum progesterone concentration declined from 80 to 90 days of gestation until day 150. The decline in plasma progesterone production corresponded with the period of time when the maternal ovaries and their corpora lutea were no longer needed to maintain pregnancy (Squires et al., 1974). After approximately day 90, pregnancy was maintained by progestins produced by the fetal placenta unit (Gajman et al., 1975).

Humans and Non human Primates:

In the human, plasma progesterone concentration reached peak concentration of 17.3 ng/ml 2 to 3 weeks prior to parturition. At the onset of parturition, the plasma concentration decreased slightly to 14.6 ng/ml (Csapo, 1971). Llauro et al. (1968) reported that from the thirty-fourth week of pregnancy until the beginning of labor the plasma-progesterone concentration was

approximately constant (19.7 ng/ml to 20.7 ng/ml). There was, however, a marked drop in the plasma progesterone concentrations from the time of removal of the placenta, 11.7 ug/ 100 ml, until 2 hours postpartum (5 ug/ 100 ml). Within 24 hours following parturition, the plasma progesterone concentration declined to 1.9 ng/ml. Similar concentrations were found in the plasma during the luteal phase of the menstrual cycle.

Scott et al. (1984) working with pregnant rhesus macaques reported that plasma progesterone concentrations peaked in both fetal and maternal plasma at night. Plasma progesterone concentrations increased in the fetuses before parturition from 6.8 ng/ml to 12 ng/ml.

D.2. Glucocorticoids during pregnancy.

Sow:

Plasma corticosteroids in the sow are composed of primarily cortisol (> 70%) and corticosterone (Ash and Heap, 1975). The same study reported that plasma corticosteroid concentration (mainly cortisol) was approximately 33 ng/ml and showed no consistent change at the time of parturition. Baldwin and Stabenfeldt (1975) reported plasma corticosteroid concentration of 9 ng/ml during early pregnancy, which declined to 4 ng/ml at the end of parturition. From day +2 to day +37 postpartum plasma corticosteroid concentration varied from 2.5 to 7 ng/ml. Molokwu and Wagner (1973) indicated that plasma corticoids began to rise during the last 2 to 3 days before parturition. Maximum plasma cortisol concentrations (approximately 012 ng/ml were observed at

parturition. Within 48 hours, post-partum plasma cortisol concentrations declined to prepartum concentrations of approximately 60 ng/ml. Killian et al. (1973) reported that plasma glucocorticoid concentrations remained constant at between 20 and 35 ng/ml until 24 hours prepartum, increased rapidly to a peak of 51 ng/ml on the day of parturition, and then returned to normal concentration within 36 hours post partum.

Ewe:

Glucocorticoid changes in the ewe during late pregnancy and at parturition were reported by Chamley et al. (1973). Plasma corticosteroid concentration on day -3 prepartum varied between 8.8 and 25.4 ng/ml and began to rise 6 to 18 hrs prior to parturition reaching peak concentrations of 14.0 to 155 ng/ml. By 12 hrs postpartum, the plasma corticosteroid concentration declined to basal concentrations. It was suggested that during the prepartum period plasma corticosteroids were generally higher in twin-bearing ewes than in those ewes carying a single fetus. Thompson and Wagner (1974) found that plasma corticosteroid concentrations in samples collected from the jugular vein of control ewes varied between 8.7 ng/ml on day -3 up to 35.1 ng/ml and 28.2 ng/ml on day 0 and day 1 respectively. By 48 hours postpartum, plasma glucocorticoid concentrations had declined to 8.4 ng/ml. Chamley et al. (1973) reported mean plasma corticosteroid concentrations of 17.3 ng/ml rose during the 18 hours preceeding parturition, to a peak plasma concentration of 38.6 ng/ml. Studies by Thompson (1973) indicated that corticoid

concentrations in plasma began to rise approximately 24 to 48 hours prior to parturition. Corticoid plasma concentration reached a peak of 36 ng/ml at parturition compared to a prepartum plasma concentration of 15 to 20 ng/ml. Corticoid plasma concentrations returned to prepartum levels within 24 to 48 hours postpartum.

Cow:

Smith et al. (1973) reported that glucocorticoid plasma concentration remained low until 1 day prior to parturition (approximately 6 ng/ml) increased to 10.3 ng/ml 12 hours before parturition and to 16.7 ng/ml at the time of parturition. In the same study, it was shown that by 12 hours, postpartum glucorticoid plasma concentrations declined to 5.1 ng/ml. Adams and Wagner (1970) suggested that there was a significant increase in maternal glucocorticoid concentrations in cows 4 days prior to parturition. Hunter et al. (1977) reported that at 30 days prepartum only 50 to 60% of the corticosteroid fraction was cortisol, whereas in the last 10 days of gestation, the proportion of cortisol increased to over 90%. Fairclough et al. (1975), comparing results between maternal and fetal corticosteroid concentrations, found that fetal plasma corticosteroid concentration increased from approximately 10 ng/ml at nine days prepartum to a maximum concentration of 60 to 90 ng/ml at parturition. In contrast, maternal plasma corticosteroid concentration remained below 20 ng/ml. Similar results were reported by Hoffman et al. (1979) measuring cortisol plasma concentrations from blood in the uterine and umbilical

veins of pregnant cows. They also reported that cortisol plasma concentrations declined in the dam and increased in the fetus during the final phase of gestation. Adams and Wagner (1970) reported glucocorticoid plasma concentrations of 6 to 7 ng/ml between 5 and 7 days prepartum, 10 to 12 ng/ml between 1 and 2, and 15 to 16 ng/ml at day 0, returning to the concentration of 4 to 6 ng/ml on days 3 to 7 post partum.

Human and non-human primates:

Scott et al. (1984) working with pregnant rhesus macaques found that the fetal cortisol plasma concentrations varied between 7.5 and 20 ng/ml. In this report no consistent trends in maternal, fetal or amniotic fluid cortisol concentrations were noted in relation to parturition. In women, the concentration of cortisol in blood reaches its maximum values in the last trimester of gestation (Heap and Flint, 1984).

D.3. Estrogens during pregnancy.

Sow:

Plasma estrogen concentrations began to increase during the last week before parturition in the sow (Molokwu and Wagner, 1973). Estrone concentrations increased from 1,200 pg/ml reaching a peak of 2,368 pg/ml by two days prepartum and then declined rapidly to 200 pg/ml by twenty-four hours postpartum and to 7 pg/ml by one-week postpartum. Molokwu and Wagner (1973) observed that plasma estradiol concentrations reached 75 to 80 pg/ml prior to parturition and declined to 4 to 5 pg/ml by one-week postpartum. Guthrie (1972) found that total plasma unconjugated

estrogens during the first twenty-four days of pregnancy varied between 10 and 28 pg/ml. Ash and Heap (1975) found that total unconjugated plasma estrogens increased to concentration of up to 3 ng/ml during late pregnancy and then declined after the onset of parturition. Estrone was the predominant unconjugated estrogen measured.

Ewe:

Chamley et al. (1973) reported that mean estradiol-17β plasma concentrations on day 3 prepartum was 24.0 pg/ml and began to rise 48 hours preceeding parturition, reaching a peak concentration of 141.8 pg/ml a few hours before parturition. Challis et al. (1974) working with ewes found that total unconjungated plasma estrogen concentrations increased from 2.5 to 3.5 ng/ml five days before parturition to peak concentrations of 75 to 880 pg/ml sixteen to twenty-four hours prior to parturition. Bedford et al. (1972) reported that plasma estrone was quantitatively the most important estrogen in the sheep and that the duration of the estrogen peak was from 4 to 48 hours before parturition. Thompson (1973) reported that peak plasma estrone concentrations, 800 - 900 pg/ml, occurred in the sheep within 24 hours of lambing.

Cow:

Estradiol concentration in the cow reached peak plasma concentrations of 250 to 300 pg/ml 2 days before parturition (Smith et al., 1973). The same authors also suggested that plasma estrogen concentration began to decrease 24 to 48 hours prepartum.

Henricks et al. (1972) measured total estrogens in the cow and reported that the highest concentrations occurred at parturition, increasing from 510 pg/ml fourteen days pre-partum to 2,600 pg/ml at parturition.

Mare:

The first significant post-conception increase in total plasma estrogen concentrations was observed between days 35 and day 60 of gestation (Terqui and Palmer, 1979). This elevation was attributed to ovarian steroid production as it did not occur in the ovariectomized mares. A second surge in total plasma estrogens occurred beginning at day 60 post-conception and came from the fetal placenta unit. Ovariectomy of the dam did not suppress this rise (Neely et al, 1983). Nett et al. (1975) observed different types of estrogens that increased starting at day 80 and peaked around day 210 of gestation, declining thereafter, in a pattern similar to that previously reported for the urinary estrogens of pregnancy in the horse (Cole and Sounders, 1935).

D.4. Tetraiodothyronine (Thyroxine) or T_4 and Triiodothyronine (T_3).

The relationship between pituitary function, the thyroid gland, and the ovary during pregnancy is complex. In mammals, pregnancy is regulated to some degree by the thyroid hormones T_3 and T_4. Thyroid hormones in humans are essential for normal menstrual cycles, fertility, and milk secretion (Ganong, 1983). Thyroxine concentrations did not change significantly during

gestation in the sheep (Henneman et al., 1955) and goat (Flamboe and Reineke, 1959). In contrast, T_4 concentrations increased during last trimester of pregnancy in the bovine (Soliman et al., 1964). Refsal et al. (1984) indicated that T_4 and T_3 concentrations were constant in the heifer during the majority of gestation. The same author reported that both T_4 and T_3 concentrations decreased during the last month of pregnancy. They suggested that this effect was probably in response to the metabolic changes associated with the initiation of lactation. This data also agrees with Magdub et al. (1977) who reported that thyroid hormones are important for normal growth and development of the mammary gland and for increasing milk production. Riis and Madsen (1985) suggested that plasma T_4 concentration dropped sharply at parturition and remained at a low concentration for one to three weeks, after which it again increased. This phenomenon appears to be a physiological adaptation similar to that of the fasting. Strbak et al. (1976) reported that during the last trimester of pregnancy, considerably higher T_4 and T_3 plasma concentrations were found in bovine fetuses than in the cows. The authors suggested that maternal and fetal thyroid hormone pools are relatively independent of one another. Finally, in the dromedary camel, T_4 and T_3 concentration increased gradually during pregnancy, reaching maximum concentrations during the last trimester of pregnancy (Hesmat, 1984).

E. Growth characteristics of select domestic species.

The increased demand for SACs, especially llamas and alpacas in United States, has caused increased interest in efficient production of these animals. Accurate methods for predicting their weights through a measurable parameter are desirable. Measurements of various parameters have been used to describe and characterize changes in size and shape (Touchberry, 1951).

Measurements such as body weight, external dimensions, milk production, and egg production are often used to assess animal production, different breeding methods, and the effects of different rations (Touchberry, 1950). Such measurements can have a high degree of objectivity if carefully taken. Other methods depend to a considerable extent upon the position of the animal and may vary considerably with undetected variations in the accuracy with which the operator applies the tape measure. In pigs, for example, body measurements such as thoracic circumference have been reported to be highly and positively correlated with body weight (Grenev and Machev, 1970). Due to this high and positive correlation, equations to predict body weight using a single or a combination of body characteristics have also been developed (Grenev and Machev, 1970). Lush and Copeland (1930) found that single observations of measurement were in most cases accurate enough to obtain significant differences between animals. They found, however, that accuracy was improved when averages, based on two measurements, were used.

Carrol and Huntington (1988), working with horses, found highly significant correlations between weight and circumference, length and

height. Circumference and body length showed the best correlation with weight in this study. In the same species, Henneke et al. (1983) found a high positive correlation between weight and circumference. The measurement of height in horses is required for classification and competition. There are two different methods, one uses the standard measuring stick and the other uses a laser-beam measuring unit. Hickman and Colles (1984) found that the standard measuring stick is a practical and satisfactory method for measuring horses, and the laser-beam method is satisfactory for research purposes and provides acceptable accuracy.

III. SEXUAL BEHAVIOR, VAGINAL CYTOLOGY, AND ESTRADIOL-17β AND PROGESTERONE CONCENTRATIONS IN THE NON-PREGNANT LLAMA (**LAMA GLAMA**)

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ABSTRACT

Temporal changes in vaginal cytology and sexual receptivity were correlated with alterations in serum estradiol-17β and progesterone concentrations in the multiparous non-pregnant llama (**Lama glama**). This 2 * 2 factorial study examined the treatment effects of a) concurrent male exposure without copulation and b) collection of vaginal smears for cytologic examination on serum hormone concentrations. Exposure to the male did not produce significant changes in the relative numbers of cornified, intermediate, and parabasal cells in the vaginal smears. Mean estradiol-17β concentrations in the groups not examined for vaginal cytology increased over the 15-day sampling period, while the estradiol-17β concentrations in the vaginal cytology study groups remained constant during the same period. Progesterone concentrations remained uniformly low during this time period in all groups. Repeated collection of vaginal samples for cytologic examination may alter the relative cellular composition within the reproductive tract. Cellular and hormonal changes were not correlated.

INTRODUCTION

Although the non-pregnant llama is usually considered to be a continuously receptive and fertile breeder, it has been observed that the non-pregnant llama does have periods of differing receptivity to the male (Fernandez-Baca, 1978). At present, no information is available relating the normal changes in estrogen and progesterone concentrations with either differences in vaginal cytology or changes in sexual receptivity. In addition, the normal vaginal cytology of the llama has not been adequately described. The ability to correlate changes in vaginal cytology, blood hormone concentrations, and receptive behavior should greatly enhance our ability to diagnose and treat fertility problems in the llama.

Vaginal cytology has been effectively used to study the relationship between changes in the genital tract and reproductive hormone concentrations in the dog, the cat (Olson et al., 1984; Lofstedt, 1982), ferret (Hamilton and Gould, 1940), mink (Travis et al., 1978), river otter (Stenson, 1988), and dromedary camel (Joshi et al., 1978). Alterations in serum hormone concentrations in induced ovulators have also been investigated as a technique to evaluate the reproductive system in the rabbit (Duffy-Barbe et al., 1973), cat (Wild et al., 1980), mink (Moller, 1973), and dromedary camel (Homeida et al., 1988). Alterations in serum estrogen concentrations, have also been demonstrated to influence sexual behavior in the cat (Lofstedt, 1982), rabbit (Caillot et al., 1983), dromedary camel (Ismail, 1987), and in the South American camelids (Franklin, 1982; Yagil, 1986; Joshi et al.,

1978; Singh and Prakash, 1964; Shalash, 1980; and England, 1969), all induced ovulators.

The objectives of this study were to describe the normal vaginal cytology of the llama (**Lama glama**) and to examine the correlation between changes in vaginal cytology, estrogen and progesterone concentrations, sexual behavior in the presence of the male llama, and to determine if physical stimulation of vaginal tissues while obtaining vaginal swabs could change hormone secretions and vagina cytology.

MATERIALS AND METHODS

Animals: Twenty sexually-mature non-pregnant multiparous females and three intact-male llamas from a commercial herd in the Willamette Valley of Oregon were studied during June and July 1987. Animals were fed grass hay and given free access to pasture. Trace-mineral salt mix and water was available **ad lib.**

Experimental Design: The females were randomly assigned to one of four groups in a 2 * 2 factorial design (Table 1). Factors being examined were a) exposure to the male and b) collection of vaginal smears.

Sample Collection: Blood samples were collected daily for 15 days by venapuncture of the internal jugular into evacuated serum and EDTA tubes.[1] The EDTA samples were placed on ice and centrifuged within 2 hours of collection. Plasma was harvested and stored at -20°C until analyzed. Serum samples were allowed to clot at room temperature for 30 minutes, centrifuged, and the serum stored at -20°C until analyzed.

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[1]Vacutainer, Becton Dickinson, Rutherford, New Jersey 07070.

Progesterone Assay: Progesterone concentrations were measured using a commercial radioimmunoassay kit.[2] Samples were run in a total of 6 assays with intra- and interassay coefficients of variation of 7% and 16%, respectively. The assay validation for use in the llama has been previously reported (Leon et al., 1989).

Estradiol-17β Assay: Estradiol-17β was measured using a validated radioimmunoassay.[3] Samples were run in a total of 2 assays with intra- and interassay coefficients of variation of 5% and 16%, respectively. The assay validation for use in the llama has been previously reported (Leon et al., 1989).

Vaginal Smear: In groups C and D, vaginal smears were collected at the time of blood collection. The animal was restrained in a standing position, the tail elevated, and the external genitalia cleansed with an iodine surgical soap followed by a water rinse. A lubricated vaginal speculum, (a cut and smoothed 12 ml syringe case) was inserted into the vagina and a sterile swab passed through the speculum, a distance of 6 to 8 cm. The vaginal mucosa was swabbed with a gentle rotary motion and the swab withdrawn without contacting the external genitalia. The swab was rolled onto a clean glass slide, air dried, fixed, and stained with Diff-Quick[4] stain, a modification of the Wright-Giemsa stain technique. A 5-second fixation was followed by a 10-second immersion in a buffered-eosin solution followed by immersion in a

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[2]Diagnostic Products Corporation Kit DPC, Los Angeles, California.

[3]Radioassay System Laboratories, Carson, California.

[4]American Scientific Products. Mc Gaw Park, Il 60085.

buffered-thiazine dye solution. Excess fixative or stain was drained between steps. The slides were rinsed in water and air dried after the final staining.

The smears were microscopically examined for cornified cells (C) (keratinized cells), intermediate cells (I), parabasal cells (P), red blood cells (RBC) and polymorphonuclear cells (PMN). One hundred (100) cells were counted on each smear. The percentage of C, I and P were calculated and compared between exposed (group D) and not exposed females (group C) for comparative days during the experiment. The number of erythrocytes and PMNs were noted separately and not included in the computations of the percentages of each cell type.

Sexual behavior: In order to study the sexual behavior of the female llama, animals from group B and D were exposed to the male daily for fifteen days. The females were exposed to 1 of 3 sexually mature, sexually-experienced intact males of proven fertility for periods of up to 3 minutes. Previous experience with this herd had indicated that if the male did not attempt to mount the female within 3 minutes after introduction, the probability of mounting behavior occurring within the following 30 minutes was very low. Each male was used for a period of five consecutive days. At the end of each test day, the male was permitted to breed one female not in the study group. The female was placed in the pen with the male. The occurrence of observed mating behaviors was noted and their duration recorded using a videotape camera. A description of receptivity criteria was made using similar pattern to that suggested by Caillot et al. (1983) in rabbit. The characteristics measured included: spitting, head to head, kicking,

aggressive standing, upright and laid-back ears. A llama was considered not receptive when the female did not assume the prone position for mating and was considered receptive when she did. If she assumed the prone position when approached by the male, the male was removed to prevent intromission. If the female did not assume the prone position, she was considered non-receptive.

Statistical Procedure: Prior to statistical evaluation, the estrogen concentrations were transformed to natural logarithms to normalize the variance. The progesterone concentrations were not transformed since the variance was similar for all treatment groups. The hormone data was analysed by both regression analysis and a repeated measure analysis of variance (ANOVA). The treatment groups evaluated by the ANOVA, exposure to the male and vaginal cytology, each had 2 levels within the group. The levels for the male exposure treatment were the presence or absence of a male while for the vaginal cytology treatment, the levels were vaginal smear or no vaginal smear. Group by treatment interactions were tested. Differences with a $P < 0.05$ were considered significant.

The regression analysis tested the null hypothesis that the regression slope was equal to zero using a Student's t-test. The slopes from individual groups were also compared. The slopes of groups A and B (no smears with and without male exposure) did not differ and the data from the two groups was pooled. The slopes from groups C and D (smears with and without male exposure) did not differ and the data was also combined. The slopes of the combined groups (vaginal cytology or no cytology) were compared. The intercepts were also tested using a

Student's t-test. The results of the vaginal cytology were also compared by regression analysis. The groups (exposure (B and D) or no exposure (A and C) to the male) were compared.

RESULTS

No significant differences ($P > 0.05$) between progesterone concentrations in the females exposed or not-exposed to the male or in the females with or without vaginal smears were identified using either ANOVA or regression analysis. Mean progesterone concentrations for the 4 groups during the fifteen day study period were 0.18 +- 0.01 (SEM). Concentrations of estradiol-17β were not significantly different between females exposed (Groups B and D) or not-exposed (Groups A and C) to the males over the fifteen day period, thus further analysis was done on the pooled groups examining the effects of collecting vaginal smears. There was a significant ($P < 0.05$) difference in the regression slopes fit to the estradiol-17β data over the fifteen days studied between the groups. Although the regression slope of the vaginal smear group was not different from zero, the regression slope fit to the estrogen data in the groups without vaginal smears was significantly different ($p > .05$) from zero. The intercepts of the two regression lines did not differ (Fig. 1). Mean estradiol-17β concentrations over the fifteen days were 11.8 $\pm$ 0.8 pg/ml (range < 2.5-37.2 pg/ml) in the non-vaginal smear group and 7.6 $\pm$ 0.7 pg/ml (range < 2.5-27.3 pg/ml) in the vaginal smear group. Significant ($P < 0.05$) group by time interactions were detected by ANOVA.

In the vaginal smears, the cornified epithelial cells were the most-numerous cell types identified and counted during the experimental period. These cells are larger than the parabasal and intermediate cells, have either no nucleus or, if present, a small, dark and centrally-located nucleus. The cell borders of the cornified cells were angulated and folded. The second most common group of cells were the intermediate cells. These cells varied in size but were generally intermediate in size between the smaller parabasal cells, and the larger cornified cells. The nucleus was round and the cytoplasm stained pink to red. The third, and least common cell type was the parabasal cells. In comparison with the intermediate and cornified cells, the cells were smaller, round, had a large nucleus and a pink staining cytoplasm.

There were no significant differences ($P > 0.05$) in the cellular pattern of the vaginal smears between the females that were exposed to the male and those not exposed to the male (Fig. 2). As a result, the data from the two groups (C and D) was combined for subsequent analysis. The relative percentage of cornified cells in the vaginal smears increased signficantly ($P < 0.05$) between day 1 and 15 of the study. Associated with the increase in cornified cells was a significant ($p < 0.05$) concurrent decline in the relative percentage of intermediate cells. The percentage of parabasal cells did not change significantly ($P > 0.05$) during this period.

The female llama was determined to be sexually receptive if she assumed the recumbent position. This usually occurred within 60 seconds following the female's introduction into the male's pen. (Figure 3). The percentage of females submitting to the male during the study

varied between 30 and 100%. The mean time to submission increased significantly ($p < 0.05$) over the 15 days examined. The females that did not submit were not included in the computation of submission time. Following introduction of the female to his pen, the male would usually pursue her around the pen until she assumed a recumbent position. The male would frequently make an "orgling" sound as he pursued the female. Non-receptive, as well as some receptive, females would periodically spit and kick at the male. The data on the frequency of spitting, head to head, kicking, agressive standing, upright and laid-back ears showed no consistent patterns and were not presented. No changes in mucous secretions, and coloration or size of the vulva were noted during the study.

The data from three individual animals in Group D was presented in Figure 4. The animals were representative of the cytologic, endocrine and behavioral changes observed in the study.

DISCUSSION

It has previously been reported that although the llama is considered to be an induced ovulator, a few animals will spontaneously ovulate (England et al., 1969). None of the animals in this study ovulated and the plasma progesterone concentrations were uniformly low throughout the sampling period. The estrogen concentrations in contrast changed in a less predictable manner. Although the presence of the male did not alter estrogen concentrations, the collection of vaginal smears did affect serum estrogen concentrations. There is no apparent explanation for the significant increase in estrogen concentrations in

the non-vaginal smear groups (A and B) during the sample period. It is equally unclear why the vaginal cytology groups (C and D) did not change in the same manner as the control groups.

Examination of the results from individual animals (Figure 4) suggests that estrogen concentrations do change in a cyclical manner in some animals. One animal (llama #028) had estrogen concentrations increase from 4 to 20 pg/ml within 4 days before declining to < 2.5 pg/ml during the subsequent 6 days. Other animals showed cyclical, albeit less-dramatic changes, e.g., llama #143, while others, e.g., llama 132, exhibited only minor fluctuations. The same range of changes were observed in the other animals. The mean estrogen concentrations in the non-pregnant llama appear to be similar to those reported for the phylogenetically related Bactrian and dromedary camels (Xu et al., 1985, Elias et al., 1984).

The predominant cells encountered in the vaginal smears were cornified, intermediate and parabasal. Cytological characteristics of these cells are similar to those reported in other species, including the bitch (Rotzel, 1975), cat (Olson et al., 1984; Lofstedt, 1982), ferret (Hamilton and Gould, 1940), mink (Travis et al., 1978), river otter (Stenson, 1988), and dromedary camel (Joshi et al., 1978).

The cellular components of the vaginal smears were not different in the females exposed to the male or not exposed to the male. Cornified cells predominated, and there was an overall increase in the percentage of cornified cells and a concurrent decrease in the percentage of intermediate cells (Fig. 2). Predominance of cornified cells in the vaginal smears has been reported in the river otter

(Stenson, 1988), and dromedary camel (Joshi et al., 1978) during periods of sexual receptivity. In cats, vaginal cytology and a predominance of cornified cells has been used to confirm behavioral estrus (Stabenfeldt and Shille, 1984), although complete cornification of cells has not been seen in some animals that still became pregnant (D'Souza, 1978).

It is not clear why the process of collecting vaginal smears appears to have significantly altered the cellular composition of the vagina. There is substantial evidence in other species to indicate a correlation between estrogen concentrations and alterations in vaginal cytology. In some animals in this study, (Fig 4 - llama #143) there appear to have been changes in vaginal cytology composition that were correlated with alterations in serum estrogen concentrations. This relationship did not, however, apply to other animals (Fig 4 - llama #028) in which marked changes in estrogen concentrations were not reflected in changes in vaginal cytology.

Unlike the Bactrian and dromedary camels in which there are external signs of estrus such as edema, or changes in the color of the vulva, frequency of urination, or vulvar secretions (Ismail, 1987; Shalash, 1980), no similar changes were observed in the llama during periods of sexual receptivity. Likewise, changes in vaginal cytology did not correlate with either hormonal differences or behavioral changes in the female. Neither vaginal cytology nor alterations in hormone concentrations appears to be a viable alternative to the male for the accurate evaluation of sexual receptivity. Likewise, the process of collecting vaginal smears appears to significantly alter the cellular composition of the vagina and does not provide an accurate reflection of

either sexual receptivity or indirectly of serum estrogen concentrations.

Table III.1 Treatment groups evaluating the effects of vaginal cytology and exposure to the male on changes in vaginal cytology, hormone concentrations, and behavioral characteristics.

	Exposure to the Male: Not-Exposed	Exposure to the Male: Exposed
No vaginal smears	Group A (n = 5)	Group B (n = 5)
Vaginal smears	Group C (n = 5)	Group D (n = 5)

Fig. III-1 Changes in mean (+ SEM) serum estradiol-17β concentrations as a function of time. No vaginal samples were collected in groups A and B (o) while daily vaginal smears were collected in groups C and D (•). The dashed regression lines were fitted to the pooled data (n = 10).

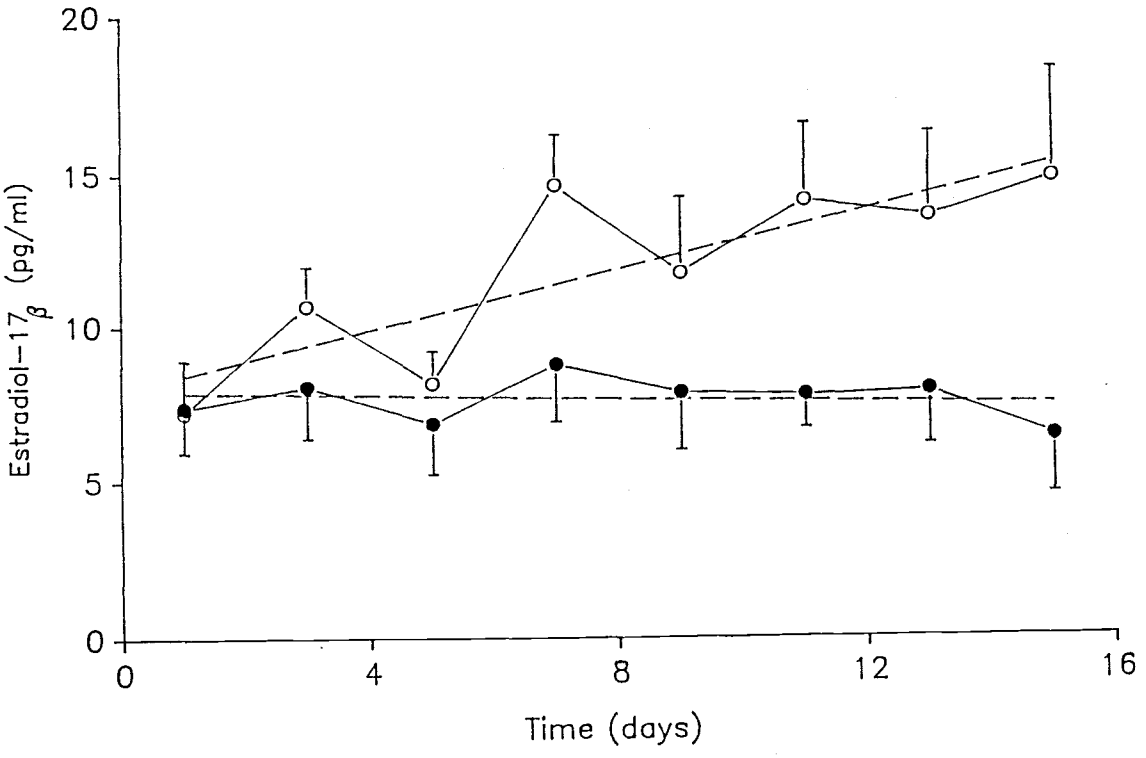


Fig. III-2 Changes in the mean (± SEM) percentages of cornified, intermediate, and parabasal cells in vaginal smears as a function of time. The cellular changes in the non-male exposed (Group C o-o) and the male exposed group (Group D ●-●) did not differ and the dashed regression line for each cell type was fitted to the pooled data.

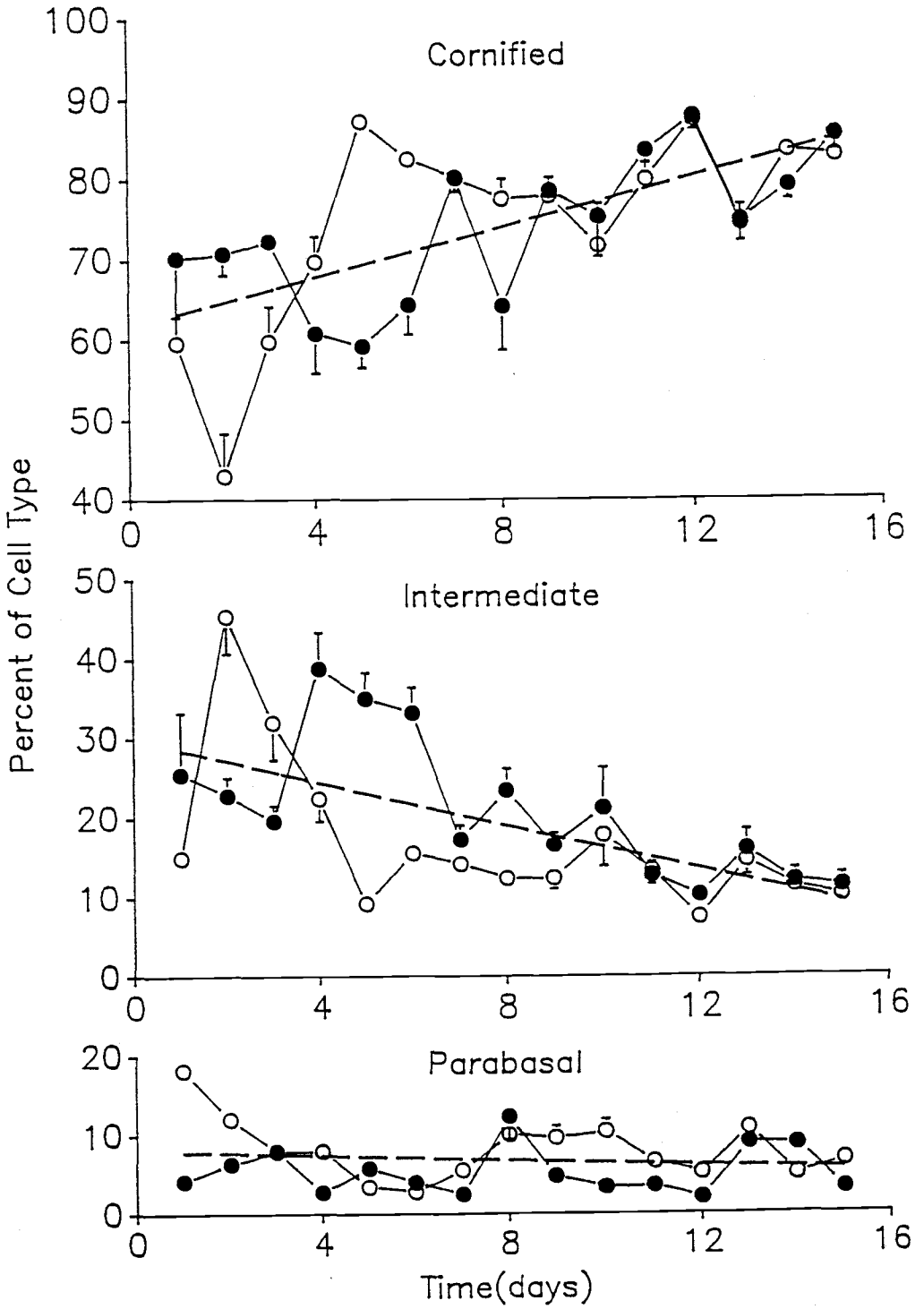


Fig. III-3 Mean submission time (seconds) following introduction of females to the male's pen. (Left axis). Number of animals in vaginal cytology groups (Groups C and D; n = 10) submitting to the male within 3 minutes following exposure. (Right axis). The dashed regression line was fitted to the submission time data.

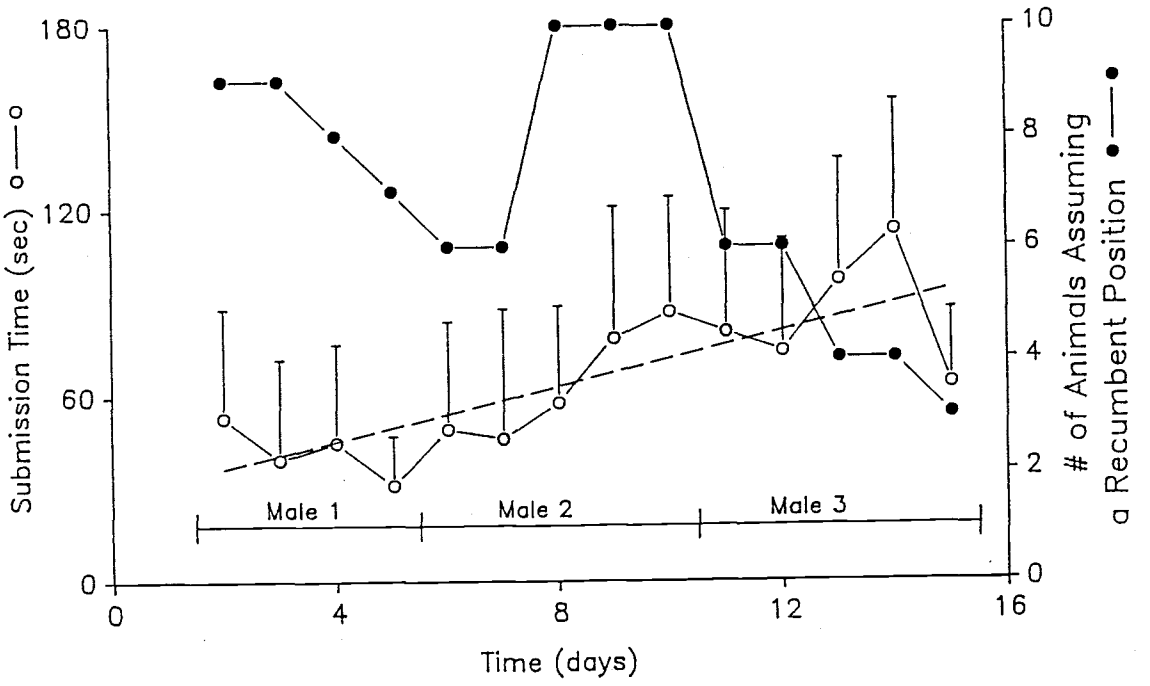
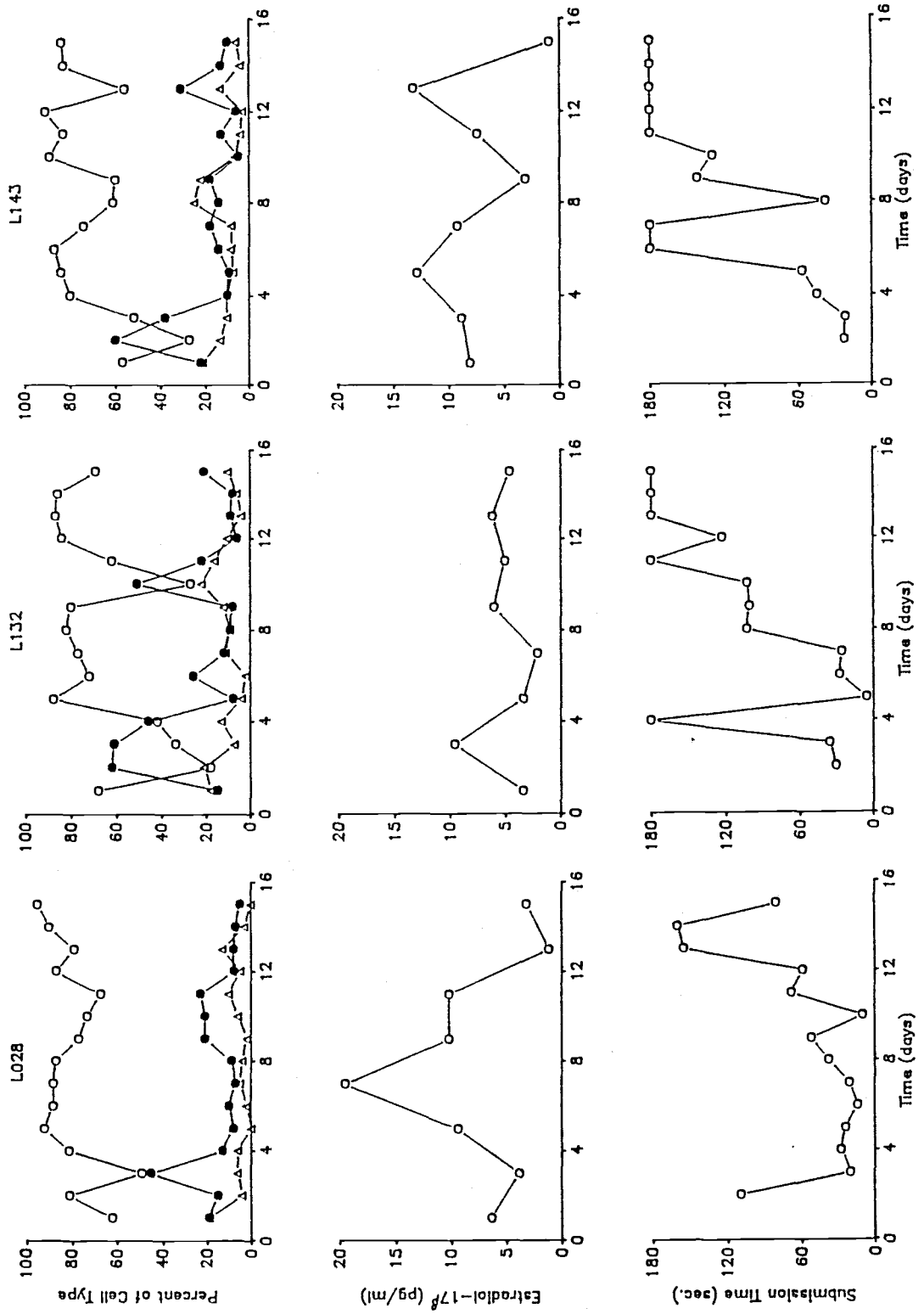


Fig. III-4 Individual cytology, estradiol 17B and behavioral results from llamas # 028, 132 and 143 as a function of time. The o symbol represents the cornified cells, • the intermediate cells, and Δ the parabasal cells.



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The authors wish to thank Commander Bud Deacon and Mr. Dan Schoenthal for their help in making animals available and assisting in sample collection.

REFERENCES

Caillot, M., C. Dauphin-Villemant, and L. Martinet. 1983. Oestrus behaviour and circulating progesterone and oestrogen levels during pseudopregnancy in the domestic rabbit. **J. Reprod. Fert.** 69: 179-186.

Dufy-Barbe, L., P. Franchimont and J.M.A. Faure. 1973. Time-courses of LH and FSH release after mating in the female rabbit. **Endocrinology.** 92:1318.

Elias, E., E. Bedrak, and R. Yagil. 1984. Estradiol concentration in the serum of the one-humped camel (**Camelus dromedarius**) during the various reproductive stages. **Gen. Comp. Endocrinol.** 56: 258-264.

Elwishy, A.B., M.A. Omar, J.J. Parrish, and N.A. Homeida. 1983. The foetal thyroid of the dromedary: its relation to body weight and dimensions and to the weight of the dam's thyroid. **Vet. Res. Com.** 6: 289-296.

England, B.G., W.C. Foote, D.H. Matthews, A.G. Cardozo and S. Riera. 1969. Ovulation and corpus luteum function in the Llama (**Lama glama**). **J. Endocr.** 45:505-513.

Franklin, W.L. 1982. Lama language. Modes of communication in the South American camelids. **Llama World.** Vol.1, number 2:7-11.

Hamilton, W.J., and J.H. Gould. 1940. The normal oestrous cycle of the ferret: the correlation of the vagina smear and the histology of the genital tract, with notes on the distribution of glycogen, the incidence of growth, and the reaction to intravitam staining by trypan blue. **Trans. Roy. Soc. Edin.** 9: 87-104.

Homeida, A.M., M.G.R. Khalil, and A.A.M. Taha. 1988. Plasma concentrations of progesterone, oestrogens, testosterone and LH-like activity during the oestrous cycle of the camel (**Camelus dromedarius**). **J. Reprod. Fert.** 83: 593-598.

Ismail, S.T. 1987. A review of reproduction in the female camel (**Camelus dromedarus**). **Theriogenology** 28(3): 363-371.

Joshi, C.K., K.K. Vyas and P.K. Pareek. 1978. Studies on oestrus cycle in Bikaneri she-camel (**Camelus dromedarius**). **Indian J. Anim. Sci.** 48:141-145.

Leon, J., and B.B. Smith. 1989. Endocrine changes during pregnancy, parturition, and early postpartum in the llama (**Lama glama**). (Submitted to **J. Repro. Fert.**).

Lofstedt, R.M. 1982. The estrous cycle of the domestic cat. **Continuing Education** 4: 52-58.

Olson, P.N., P.W. Husted, T.A. Allen, and T.M. Nett. 1984. Reproductive endocrinology and physiology of the bitch and queen. **Vet. Clin. North Am.** 14: 927-946.

Rotzel, J.F. 1975. Genital cytology of the bitch. **Vet. Scope** 19: 2-15.

Shalash, M.R. 1980. Reproduction in camels. 9th Internat. Congress on Animal Reproduction and A.I. Madrid. pp 559-564.

Singh, V and A. Prakash. 1964. Mating behavior in camel. **Indian Vet. J.** 23: 475-476.

Stenson, G.B. 1988. Oestrus and the vaginal smear cycle
Wildt, D.E., S.W.J. Seager and P.K. Chakraborty. 1980. Effect of copulatory stimuli on incidence of ovulation and on serum luteinizing hormone in the cat. **Endocrinology** 107:1212.

Xu, Y.S., H.Y. Wang, G.Q. Zeng, G.T. Jiang and Y.H. Gao. 1985. Hormone concentrations before and after semen-induced ovulation in the bactrian camel (**Camelus bactrianus**). **J. Reprod. Fert.** 74:341-346.

IV. LIFE SPAN OF THE CORPUS LUTEUM IN THE LLAMA (LAMA GLAMA)

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ABSTRACT

The life-span of the corpus luteum in the llama (**Lama glama**) has not been determined. The objective of this study was to determine the luteal life-span following hCG-induced ovulation and sterile or fertile breedings.

Peak plasma-progesterone concentrations of 8.5 ± 1.3 ng/ml (SEM) and 8.9 ± 1.8 ng/ml were observed 9.3 ± .3 and 9.8 ± .8 days following either sterile breeding or the intravenous administration of 5000 IU of hCG respectively in multiparous llamas (**Lama glama**). Luteal regression, began 10.3 ± .3 and 10.8 ± .8 days following sterile breeding or hCG administration respectively and was completed by day 12-13 post-stimulation. Following a fertile breeding, progesterone increased significantly by 4 days post-breeding and remained above 2 ng/ml (2.6 ± .1, Range: 2.3 - 5.5 ng/ml) in all animals that subsequently delivered a full-term cria. Fertile breedings could be differentiated from sterile breedings or hCG induced ovulation by 15 days post-stimulation. The results suggest that pregnancy can be confirmed as early as 15 days post-breeding by monitoring plasma progesterone concentration.

INTRODUCTION

The llama (**Lama glama**) is considered to be an induced ovulator. In general, with induced ovulators, a non-fertile service or other ovulatory stimulus is followed by a non-fertile period related to the functional life-span of the corpus luteum. In many species, the life-span of the corpus luteum has been investigated by taking frequent blood samples and measuring serum-progesterone concentrations. Although data for the South American camelids is incomplete, the life span of the phylogenetically-related dromedary camel (**Camelus dromedarius**) has been established following mating with a vasectomized male (Marie and Anouassi, 1987). Luteal regression in the camel began approximately 8 days following mating and was completed by day 12 post-copulation. Similar results have been reported by Musa and Abusineina (1978), who observed that the corpus luteum had a life-span of approximately one week when monitored by rectal palpation. The life-span of the corpus luteum in the alpaca (**Lama pacos**) has been estimated at between 8 and 13 days (Fernandez Baca et. al., 1970).

The purpose of this study was to determine the life span of the corpus luteum in the llama (**Lama glama**) following fertile and sterile mating and administration of human chorionic gonadotropin (hCG).

MATERIALS AND METHODS

Animals: Twenty-five animals from a commercial llama herd in the Willamette Valley of Oregon were used for the study. All females were multiparous animals and housed under identical conditions. All samples for Groups A and B were collected during July, 1988. Samples for Group C were collected in July, 1987. Animals were divided into three groups. Group A was composed of four healthy, non-pregnant, multiparous females and one vasectomized male. The male was surgically vasectomized 12 months prior to his use in this study. Bilateral removal of the vas deferens was histologically confirmed at the time of surgery. Group B was composed of four healthy, non-pregnant, multiparous females, while Group C was composed of seventeen healthy, non-pregnant, multiparous females and three intact, healthy males. All animals weighed between 136 and 150 kg and were housed outdoors in large fields. Animals were fed a combination of grass hay and a free choice loose, trace-mineral salt supplemant. Water was available **ad lib.**

Experimental protocol: The females in Group A were bred one time to the vasectomized male. The breedings lasted between 20 and 26 minutes with a mean duration of 23 minutes. The animals in Group B were administered 5,000 IU of human chorionic gonadotrophin (hCG)* as an intravenous bolus injection. Following breeding practices used by the farm operator, the animals in Group C were bred twice at 6 hour intervals to 1 of 3 males. Females in Group C had a normal delivery 346 to 359 (351 $\pm$ 5) days post-breeding.

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* hCG, Human chorionic gonadotrophin, Burns Veterinary Supply, Oakland, California.

Blood sampling: Blood samples were collected prior to hCG stimulation or mating and then daily for a period of 15 days. Samples were collected by venipuncture of the internal jugular vein into evacuated tubes containing EDTA. Following collections, the samples were mixed, placed on ice, centrifuged within 2 hours of collection, and the plasma stored at -20°C until analyzed for progesterone.

Progesterone Assay: Progesterone concentrations were measured using a commercial radioimmunoassay kit.[f] Samples were run in a total of 5 assays with an intra- and interassay coefficients of variation of 7% and 15%, respectively. The assay was validated for use in the llama by evaluating recoveries following the spiking of unknown llama samples with progesterone. Following the addition of 0.5, 2.0, and 10.0 ng progesterone to llama plasma, mean recoveries were 92% ± 2.0%, 99% ± 14%, and 105% ± 7.0%, respectively. Following the addition of 50, 100, and 200 ul of llama plasma pooled from 3 samples, progesterone concentrations of 1.3 ± 0.2, 2.1 ± 0.03, 3.9 ± 1.6 ng/ml, respectively, were measured. All assays were conducted using a sample volume of 100 ul of plasma. The results indicate reasonable parallelism between the progesterone in llama plasma and the reference standard.

Statistics: Progesterone concentrations were presented as a mean ± standard error of the mean (SEM). Progesterone concentrations on day 9 post-breeding or hCG stimulation were compared using a student's T-test.

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[f] Diagnostic Products Corporation Kit (DPC), Los Angeles, California.

RESULTS

Following sterile mating (Group A), all animals ovulated (Figure 1A). Progesterone concentrations remained low during the first 4 days post-coitus (< 1.0 ng/ml) in all animals, and then increased to a peak concentration of 8.5 ± 1.3 ng/ml at 9.3 ± 0.3 days post-mating. Progesterone concentrations declined rapidly after day 9-10 and were < 1 ng/ml by day 15 post-mating.

Following hCG administration (Group B), all animals ovulated (Figure 1B) and showed changes in progesterone concentration similar to those observed following sterile mating. Progesterone concentrations remained low (1.0 ng/ml) during the first 4 days post-injection and then increased steadily to a maximum of 8.9 ± 1.8 ng/ml by 9.8 ± 0.8 (8 - 11) days post-injection. Progesterone concentrations then declined abruptly from maximum concentrations, generally beginning the following day, and declined to < 1.0 ng/ml by day 13 to 15 post-breeding.

Following fertile mating (Group C), all animals ovulated and had a relatively consistent pattern of elevated plasma concentrations (Figure 1C). Progesterone concentrations remained low during the first 4 days post-coitus (< 1.0 ng/ml) in all animals, increased significantly by day 5 post-coitus, and remained above 2.0 ng/ml (3.3 ± 0.1; 2.3 - 5.5 ng/ml) from day 6 through day 15. Peak progesterone concentrations on day 9 post-sterile breeding or hCG stimulation did not differ ($P > 0.05$), while progesterone concentrations in both groups were significantly higher than those observed following a fertile mating ($P < 0.05$).

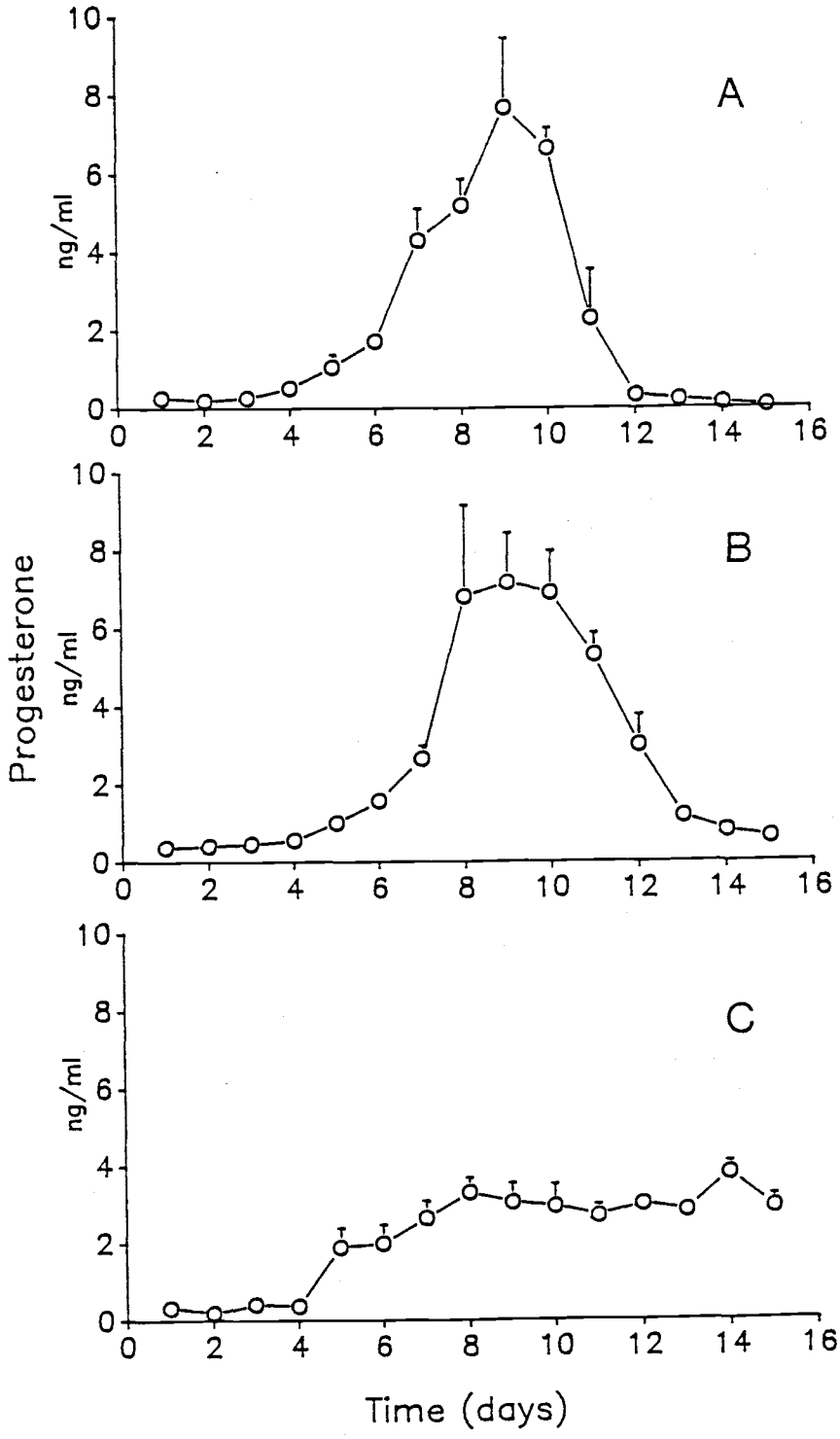
DISCUSSION

The life span of the corpus luteum in the llama is relatively short in comparison to other species. Although it has not been confirmed in the llama, it is assumed that ovulation occurs 24-26 hours after mating or hCG injection as has been reported in the alpaca (Fernandez Baca et. al., 1970). In this study, luteolysis began 9 to 10 days post-breeding and was completed 10-12 days after ovulation. These results agree with previous observations in the phylogenetically-related dromedary camel. In this species, ovulation occured 36 hours after coitus (Williamson and Payne, 1978) with luteolysis begining at day 7 and being completed by 10 days post-ovulation (Marie and Anouassi, 1987). Following a sterile mating in the Bactrian camel, plasma progesterone concentrations were 2.4 ng/ml and 0.3 ng/ml at 10 and 15 days respectively (Marie and Anouassi, 1987). In comparison with other members of the camelidae family, the progesterone pattern in the llama is characterized by the absence of a plateau and a relatively early luteolysis. It is not clear why the progesterone concentrations observed in this study following either hCG administration or sterile breeding were approximately double those observed following a fertile mating.

Elias et. al., (1984) reported progesterone concentrations of 3 to 7 ng/ml during early pregnancy in the dromedary camel, concentrations somewhat higher than those reported in this study. The relatively short life span of the corpus luteum has been observed in other members of the South American camelidae. England et. al., (1969), working with alpacas in Peru, observed matings and ovulations 12 days following previous non-

fertile breedings, suggesting that the previous CL had regressed and the females had returned to sexual receptivity. Chen and Yuen (1985) also reported mating in the female camel 12-13 days after sterile mating. The results of this study suggest that pregnancy can be confirmed by measuring an elevated progesterone concentration (> 1.5 ng/ml) as early as 15 days post-mating. The short life span of the corpus luteum (12 to 13 days) in this study is similar to that observed in Bactrian and dromedary camels.

Fig. IV-1 Serum progesterone concentrations in the llama following intravenous administration of 5000 IU of hCG (Figure 1A) (n = 4); following mating with a vasectomized male (Figure 1B) (n = 4); or following a fertile breeding (Figure 1C) (n = 17).



ACKNOWLEDGEMENTS

The authors wish to thank Commander Bud Deacon and Mr. Dan Schoenthal for their help in making animals available and assisting in sample collection.

REFERENCES

Chen, B.X., Z.X. Yuen & G.W. Pan. (1985) Semen-induced ovulation in the Bactrian camel (**Camelus bactrianus**). **J. Reprod. Fert.** 73:335-339.

Elias, E., E. Bedrak & R. Yagil. (1984) Peripheral blood levels of progesterone in female camels during various reproductive stages. **Gen. Comp. Endocrinol.** 53:235-240.

England, B.G., W.C. Foote, D.H. Matthews, A.G. Cardozo & S. Riera. (1969) Ovulation and corpus luteum function in the llama (**Lama glama**). **J. Endocr.** 45:505-513.

Fernandez-Baca, S., D.H.L. Madden & C. Novoa. (1970) Effect of different mating stimuli on induction of ovulation in the alpaca. **J. Reprod. Fert.** 22:261-267.

Fernandez-Baca, S., W. Hansel & C. Novoa. (1970) Corpus luteum function in the alpaca. **Biol. Reprod.** 3, 252-261.

Marie, M. & A. Anouassi. (1987) Induction of luteal activity and progesterone secretion in the nonpregnant one-humped camel (**Camelus dromedarius**). **J. Reprod. Fert.** 80:183-192.

Musa, B.E. & M.E. Abusineina. (1978) The oestrous cycle of the camel (**Camelus dromedarius**). **Vet. Rec.** 103:556-557.

Williamson, G. & Payne, W.J.A. (1978) **An Introduction to Animal Husbandry in the Tropics**, pp. 484-498. Longmans. London.

V. ENDOCRINE CHANGES DURING PREGNANCY, PARTURITION AND THE EARLY POSTPARTUM PERIOD IN THE LLAMA (**LAMA GLAMA**)

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ABSTRACT

The hormonal changes associated with pregnancy, parturition and the postpartum period in the llama (**Lama glama**) have not been determined. The objective of this study was to characterized changes in plasma progesterone, serum estradiol-17β, serum total estrogens, triiodotyronine (T_3), tetraiodotyronine (T_4) and cortisol concentrations during pregnancy, parturition and the early postpartum period in the llama.

Progesterone concentrations tended to increase by 5 days postbreeding and remained elevated (> 2.0 ng/ml) throughout pregnancy. Approximately 2 weeks prior to parturition, plasma-progesterone concentrations began to decline, dropped markedly during the final 24 hours prior to parturition, and returned to basal concentrations (< 0.5 ng/ml) by the day of parturition. Total estrogen (TE) and estradiol-17β ($E_2\beta$) serum concentrations varied between 6-274 pg/ml and 4-114 pg/ml, respectively, during the first 9 months of pregnancy. Mean TE and $E_2\beta$ serum concentrations increased between 9 months and the end of pregnancy with peak mean concentrations of 827 $\pm$ 58 (SEM) pg/ml (TE) (Range: 64 - 1658) and 196 $\pm$ 10 pg/ml ($E_2\beta$) (31 - 294), respectively, during the last week of pregnancy. The TE and $E_2\beta$ concentrations declined to concentrations of 87 $\pm$ 14 pg/ml (7 - 488) and 25 $\pm$ 5 pg/ml (2.5 -142) respectively, during the first week postpartum. Plasma cortisol concentrations varied between 2.6 and 51.9 ng/ml (14.0 $\pm$ 0.5) from conception until 2 weeks prior to parturition when they began to decline. Only a slight increase in plasma-cortisol concentrations were observed in association with parturition. The absence of a significant

periparturient increase in cortisol concentrations may be the result of the sampling frequency. T_3 concentrations varied between 0.5 and 4.5 ng/ml (1.9 ± 0.1) throughout pregnancy and the periparturient period. T_4 concentrations varied between 21.3 and 91.5 ng/ml (56.5 ± 0.8 SEM) from conception until approximately 39 weeks of gestation when T_4 concentrations began to decline. T_4 concentration declined from 43.0 ± 5.3 ng/ml 15 days prepartum to 23.5 ± 5.5 ng/ml immediately prior to parturition. T_4 concentrations increased to 52.8 ± 3.9 ng/ml by 1 day postpartum. The hormonal changes observed during pregnancy and the periparturient period are similar to those observed in other species. Mean gestation length for the 14 animals in this study was 350 ± 4.5 days (SD).

INTRODUCTION

The hormonal changes associated with pregnancy, parturition and the postpartum period in the llama (**Lama glama**) are poorly defined. A detailed understanding of the normal hormonal changes observed during these periods may allow better management, treatment or prevention of fertility problems in this species.

The endocrine changes occurring during pregnancy, parturition, and the early postpartum have been studied in numerous species (Bazer and First, 1983; Wagner et al., 1974). A decline in serum progesterone (P_4) concentration prior to parturition is observed in the cow (Hunter et al., 1977; Fairclough et al., 1975), ewe (Chamley et al., 1973; Thompson and Wagner, 1974), pig (Molokwu and Wagner, 1973; Robertson and King, 1974) and goat (Thorburn et al., 1972). In contrast, progesterone concentrations in the human and other primates decline during or shortly after parturition (Llauro et al., 1968; Csapo, 1971). Changes in progesterone concentrations in the phylogenetically-related dromedary camel are similar to those observed in most other species with progesterone concentrations gradually declining prior to parturition (Elias et al., 1984). A rise in corticoid concentrations preceeding parturition has been reported in the cow (Smith et al., 1973; Adams and Wagner, 1970), ewe (Thompson and Wagner, 1974; Thompson, 1973), and pig (Ash and Heap, 1975; First and Bosc, 1979). Total estrogen (TE) and estradiol-17β ($E_2\beta$) concentrations have been observed to increase in a variety of species prior to parturition (Bedford et al., 1972); including the cow (Peterson et al., 1975; Hoffman et al., 1977), ewe (Bedford et al., 1972; Thompson, 1973), and pig (Molokwu and Wagner,

1973; Guthrie, 1972). Elias et al. (1984) and Agarwal et al. (1987) reported a similar increase in estrogen concentrations in the camel 2 days prior to parturition. Soliman et al. (1963) suggested that thyroid hormones increased during late pregnancy in the cow, while Heshmat et al. (1984) reported that plasma triiodothyronine (T_3) and tetraiodothyronine (T_4) concentrations in the dromedary camel increased throughout pregnancy.

The purpose of this study was to characterize the changes in plasma progesterone, estradiol-17β, total estrogens, T_3, T_4 and cortisol concentrations during pregnancy, parturition, and the early postpartum period in the llama (**Lama glama**).

MATERIALS AND METHODS

Animals: Fourteen 4 to 8-year-old, multiparous, healthy, female (136-150 kg body weight) and 3 intact male (5 to 12 years of age) llamas from a commercial herd in the Willamette Valley of Oregon were used in the study. Animals were fed a combination of grass hay and allowed free access to pasture. Trace-mineral salt mix and water were available **ad lib.** Following breeding practices used by the farm operator, the animals were bred twice at 6-hour intervals to 1 of the 3 males. The day of mating was designated day 0.

Blood sampling: Blood samples were collected from mid-July 1987 to August 1988. Samples were collected every other day for the first 30 days following breeding and then at 7-day intervals between 30 and 60 days of gestation. Starting 60 days postbreeding, samples were collected at monthly intervals until the end of the 10th month of

gestation; one sample was collected at 10.5 months, and then 3 times per week until 1 week postpartum. Animals that failed to conceive as determined by serum-progesterone determinations and the birth of a live cria were not included in the study. Blood was collected by venipuncture of the internal jugular vein into evacuated serum and EDTA tubes.[g] The EDTA samples were placed on ice and centrifuged within 2 hours of collection. Plasma was stored at -20°C until analyzed. Serum samples were allowed to clot at room temperature for 30 minutes, centrifuged, and the serum stored at -20°C until analyzed.

Hormone assays: Progesterone, triiodothyronine, tetraiodothyronine, and cortisol-plasma concentrations were measured by radioimmunoassay (RIA) using direct-reading solid phase commercial assay kits.[h] The validation of the T_3 and T_4 assays for use in the llama has been previously reported (Smith et al., 1989).

Progesterone assay: Samples were run in a total of 17 assays with an intra- and interassay coefficients of variation of 6% and 16%, respectively. The assay was validated for use in the llama by evaluating recoveries following the spiking of unknown llama samples with progesterone. Following the addition of 0.5, 2.0, and 10.0 ng progesterone to llama plasma, mean recoveries were 92.0% ± 2.0%, 99.0% ± 14.0%, and 105.0% ± 7.0%, respectively. Following the addition of 50, 100, and 200 ul of plasma pooled from 3 samples, progesterone concentrations of 1.3 ± 0.2, 2.1 ± 0.03, 3.9 ± 1.6 ng/ml, respectively, were measured. All assays were conducted using a sample volume of 100

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[g] Vacutainer, Becton Dickinson, Rutherford, New Jersey 07070.

[h] Diagnostic Products Corporation, Los Angeles, California.

ul of plasma. The results indicate reasonable parallelism between the progesterone in llama plasma and the reference standard.

Cortisol Assay: Samples were run in a total of 9 assays with an intra-and interassay coefficients of variation of 9% and 10%, respectively. The assay was validated for use in the llama by evaluating recoveries following the additional cortisol to llama plasma samples. Following the addition of 4.0, 8.0, and 40.0 ng/ml cortisol, mean recoveries were 99.0% ± 1.0, 104.0% ± 0.6, 90.0% ± 2.0, respectively. Following the addition of 25, 50, and 100 ul of plasma, cortisol concentrations of 26.0 ± 3.0, 48.0 ± 4.0, 94.0 ± 2.0 ng/ml, respectively, were measured. All assays were conducted using a sample volume of 50 ul. The results demonstrate reasonable parallelism between the cortisol in llama plasma and the reference standard.

Total estrogen and estradiol-17β assays: Serum estradiol-17β and total estrogen concentrations were measured using commercial radioimmunoassay kits[1] validated for use in the llama. Prior to measurement by RIA, samples were extracted by mixing 800 ul of serum with 8 ml of a 3:2 ethyl acetate:hexane (vol:vol) mixture. The mixture was vortex mixed, and the organic phase removed by aspiration. The aqueous phase was dried under nitrogen at 40°C, and reconstituted with 2.4 ml of assay buffer (0.1 M phosphate-buffered saline with gelatin, pH 7.9) prior to overnight storage at 4°C. Each assay tube contained 0.5 ml of the diluted sample, 0.1 ml of I^{125}-labelled estrogen-17β and 0.1 ml of either anti-total estrogen or anti-estrogen-17β antiserum (depending on the assay). Following 90 minutes of incubation at room temperature,

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[1] Radioassay Systems Laboratories, Carson, California.

400 ul of anti-rabbit-IgG in 3% PEG was added and incubated for an additional 60 minutes at room temperature. The supernatant was decanted following 30 minutes of centrifuging at 1500 x g, and the tubes were dried and counted in a gamma counter equipped with automated data-reduction facilities.[j] Extraction efficiency for the estrogen assays was evaluated by adding trace amounts of tritiated $E_2\beta$ to serum and measuring the activity following the extraction procedure. Due to the high and consistent recoveries 91 ± 6%, assay values were not corrected for extraction efficiency. Serum blank values were subtracted from assayed samples. The minimum detectable estradiol-17β and total estrogen concentrations for both assays were 2.5 pg/ml.

Total Estrogen Assay: Samples for total estrogen (TE) were run in a total of 10 assays with an intra- and interassay coefficients of variation of 6% and 14%, respectively. The assay was validated for use in the llama by evaluating recoveries following the addition of known amounts of estradiol-17β to llama samples. Following the addition of 50, 100, and 200 pg/ml estradiol-17β mean recoveries were 96% ± 10.0, 88% ± 19.0, 94% ± 13.0, respectively. Following the addition of 250, 500, and 1000 ul of serum, total concentrations of 45 ± 4, 76 ± 12, 139 ± 12 pg/ml, respectively, were measured. All assays were conducted using a sample volume of 800 ul.

Estradiol-17β Assay: Samples were run in a total of 10 assays with an intra- and interassay coefficients of variation of 5% and 16%, respectively. The assay was validated for use in the llama by evaluating recoveries following spiking of unknown llama samples.

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[j] Cobra, Packard Instrument Corporation, Chicago, Illinois.

Following the addition of 50, 100, and 200 pg/ml estradiol-17β, mean recoveries were 102.0% ± 14, 96.0% ± 19, 95.0% ± 9.0, respectively. Following addition of 250, 500, and 1000 ul of plasma, estradiol-17β concentrations of 29 ± 4, 60 ± 11, 113 ± 11 pg/ml, respectively, were measured. All assays were conducted using a sample volume of 800 ul.

Statistical procedures: Hormone concentrations and variance were reported as the mean and the standard error of the mean (SEM), respectively. Temporal changes in hormone concentrations during the last two weeks of pregnancy were evaluated by fitting a linear regression to the data. The null hypothesis that the regression slope was equal to 0 was tested using a Student's t-test. The data collected between days 1 and 7 postpartum were tested in the same manner. Analysis of the data was performed using the Statistical Applications System (SAS) program (version 6.0) running on a microcomputer.

RESULTS

Changes in progesterone, estradiol-17β, and total estrogen concentrations during the first 35 days following conception are shown in Figure 1. Mean progesterone, estradiol-17β, total estrogen, T_3, T_4, and cortisol concentrations from conception until 1-week postpartum are shown in Figure 2. To facilitate visualization of the data during periods of frequent sampling, data from samples collected within a 7-day period were pooled (mean = 18; Range: 5 to 37 samples/data point). Due to the variability in the length of gestation, the changes in progesterone, $E_2\beta$, TE, cortisol, T_3, and T_4 concentrations from individual animals were more pronounced than indicated in Figure 2. To

more clearly examine the endocrine changes associated with parturition, the day of parturition for each animal was defined as day 0. Hormone concentrations for the 15 days prior to parturition and the first 7 days postpartum are shown in Figure 3, plotted relative to the day of parturition. Each data point represents an average of 6 observations (range: 3 to 112 samples/data point).

Progesterone concentrations increased by 5 days post-conception (Fig. 1) and remained > 2.0 ng/ml until 15 days prior to parturition (Fig. 3). Between 15 and 1 day prepartum, progesterone concentrations declined significantly ($P < 0.001$) from a mean concentration of 3.8 ± 0.8 ng/ml to 1.4 ± 0.2 ng/ml. Between day 1 prepartum and the day of parturition, progesterone concentrations further declined to 0.4 ± 0.01 ng/ml. During the first week, post-partum progesterone concentrations remained low (< 0.5 ng/ml) and did not change significantly ($P > 0.05$).

Plasma cortisol concentration remained relatively constant (14.0 ± 9.0 ng/ml) through most of pregnancy. Cortisol concentration tended to increase slightly (26.0 ± 4.1 ng/ml) at week 45 of gestation and then tended to decline to earlier concentrations. Between 15 and 1 day prepartum, cortisol concentration decreased significantly ($P < 0.01$) from a mean concentration of 18.7 ± 5.1 ng/ml to 11.7 ± 2.3 ng/ml. There was a slight but non-significant increase in cortisol concentrations on the day of parturition. Cortisol levels did not change significantly with time during the postparturient period ($P > 0.05$).

Total estrogen concentrations remained relatively constant (67.0 ± 5.0 pg/ml) from conception until 36 weeks of gestation, then increased,

and reached peak concentrations of 827.0 ± 58.0 pg/ml at 49 weeks postconception. Total estrogen concentrations remained elevated during the 2 weeks prepartum until 24 hours prepartum, and declined significantly ($P < 0.05$) to 171.0 ± 87.0 pg/ml at parturition. The concentrations of total estrogens after parturition remained stable at 76.0 ± 11.0 pg/ml during the first week postpartum ($P > 0.05$).

Estradiol-17β concentrations were also reasonably constant (18.0 ± 21.0 pg/ml) from conception until approximately week 37 of gestation, then increased to a maximum concentration of 196.0 ± 10.0 pg/ml at week 48 postconception. No significant changes ($P > 0.05$) were observed during the 2 weeks prepartum until the day of parturition when $E_2\beta$ concentrations declined rapidly to a concentration of 42.0 ± 26.0 pg/ml on day of parturition. During the next seven days, $E_2\beta$ concentration remained low 25.4 ± 4.9 pg/ml and did not vary significantly ($P > 0.05$).

Triiodothyronine (T_3) concentrations averaged 1.9 ± 0.9 ng/ml (0.5 to 4.4 ng/ml) between conception and parturition. No significant changes ($P > 0.05$) were observed during pregnancy or the periparturient period. Thyronine (T_4) concentrations were reasonably constant until week 41 of gestation (58.1 ± 0.9 ng/ml) (range: 21.3 to 91.5), then declined ($P < 0.02$), to a minimum concentration of 24.0 ± 5.0 ng/ml one day before parturition. Starting at one day prepartum, T_4 concentrations again increased to concentrations of 53.0 ± 4.0 ng/ml one day postpartum. The T_4 concentration did not vary significantly ($P > 0.05$) during the first week postpartum.

The 14 animals in the study had a gestation of 350 ± 4.5 days SD (346 to 359 days). All animals had normal unassisted deliveries.

DISCUSSION

Plasma-progesterone concentrations in the llama were significantly elevated by five days postconception and remain elevated during pregnancy. The mean progesterone concentrations (3.0 to 4.5 ng/ml) were similar to those reported in many other species during the same stage of gestation. Progesterone concentrations during the first month postbreeding in the pig have been reported to vary between 6 - 12 ng/ml (Killian et al., 1973, Ash and Heap, 1975), 2 - 10 ng/ml in the cow (Pope et al., 1969; Evans and Wagner 1976), 2 - 3 ng/ml in the ewe (Basset et al., 1969), and between 3 - 7 ng/ml (Elias et al., 1984; Agarwal et al., 1987) in the dromedary camel.

Progesterone concentrations in the llama declined slightly between 18 and 27 weeks of pregnancy. A similar transitory decline in progesterone concentrations has been observed in the dromedary camel at 21 weeks of pregnancy (Elias et al., 1984). The physiologic significance of this observation is unknown as the role of the placenta in steroidogenesis in the llama has not been elucidated. The regulatory mechanism(s) associated with the gradual decline in progesterone concentrations during the two weeks prior to parturition is also unknown. A similar prepartum decline has been observed in the dromedary camel although the time course of the decline is different. In the camel, progesterone production has been reported to decline starting at 5 months of gestation (Elias et al., 1984). The final decline in plasma progesterone concentrations began 24 to 48 hours prepartum, temporal changes similar to those reported in some other species (Smith et al., 1973; Hunter el al., 1977; Fairclough et al., 1975; Pope et al.,

1969; Stabenfeldt et al., 1972; Basset et al., 1969; Chamley et al., 1973; Ash et al., 1975; Baldwin and Stabenfeldt, 1975; Robertson et al., 1974; Challis et al., 1974).

The normal changes in cortisol concentration during pregnancy and parturition have previously been reported for many domestic species including cow, ewe, pig, and goat (Smith et al., 1973; Chamley et al., 1973; Hunter et al., 1977; Thompson and Wagner, 1974; Baldwin and Stabenfeldt, 1975; Adams and Wagner, 1970). Basset and Thorburn (1969), reported a 3- to 6- fold increase in fetal plasma corticosteroid concentration during the periparturient period, but did not find any consistent changes in maternal corticosteroid concentration in the sheep. Scott et al. (1984), working with the rhesus macaque, reported similar stable-cortisol concentration in the maternal circulatory system before and during parturition. The llama appears to be similar to the ewe and rhesus monkey in that cortisol concentrations do not change dramatically during the periparturient period. This is in contrast to work in the ewe, sow, and cow where substantial increases in maternal corticosteroid concentrations occurred prior to parturition (Smith et al., 1973; Chamley et al., 1973; Adams and Wagner, 1970; Molokwu and Wagner, 1973; and Killian et al., 1973). One possible explanation for the absence of a dramatic periparturient increase in glucocorticoid concentrations in the llama may have been the relatively low sampling frequency during this period (3 samples per week). As a result, it is reasonable to speculate that a periparturient increase in cortisol could have been missed. There is no obvious explanation for the decline in

mean glucocorticoid concentrations observed during the 2 weeks immediately prepartum.

Changes in estrogen and estradiol-17β concentrations reported in this study are similar to those reported in the pig (Molokwu and Wagner, 1973; Guthrie, 1972), cow (Henriks, 1972), and ewe (Chamley et al., 1973). Estrogen concentrations have previously been reported to increase with gestation in other camelids. Agarwal (1987) working with dromedary camels, reported that estradiol-17β concentrations increased progressively during pregnancy from basal concentration of 20 pg/ml at 2 to 3 months of pregnancy to about 450 pg/ml during the final stage of gestation. Elias et al. (1984) reported that at 10 months of pregnancy, the $E_2\beta$ concentrations in the dromedary camel had increased dramatically from 338 pg/ml to a peak of 606 pg/ml at week 48 of gestation. In this study, a similar pattern for $E_2\beta$ concentrations occurred although the basal concentrations were lower, 10-46 pg/ml $E_2\beta$ during the majority of gestation before reaching a peak of 196 $\pm$ 10 pg/ml during the final trimester of pregnancy.

In camels, follicular development during early pregnancy has been reported by Elwishy (1981) in spite of the presence of the corpus luteum. High concentrations of estrogen in allantoic fluid on the day of parturition have also been demonstrated, suggesting the placenta as a probable source of estrogen (Elias et al., 1984). Thus, the rising concentrations of estrogen during pregnancy in the llama is possible from either a follicular or placental origin.

In the llama, T_3 concentrations were relatively unchanged during the periparturient period while T_4 hormone concentration decreased prior

to parturition, then increased to preparturient levels in the immediate postpartum period. The T_3 concentrations were similar to those previously reported for the pregnant llamas (Smith et al., 1989). T_4 concentrations in this study (58.1 $\pm$ 0.9 ng/ml) were in the lower end of the range previously reported for pregnant llamas (Smith et al., 1989). These concentrations are similar to those reported in the goat (Riss and Madsen, 1985). In the dromedary camel, T_3 and T_4 concentrations increased throughout pregnancy (Heshmat et al., 1984) while T_4 concentrations in the goat decreased 1 to 2 days prior to parturition (Riss and Madsen, 1985). The decline in T_4 concentrations in the goat was postulated to occur as a result of nutrient redistribution to the mammary gland in preparation for lactation (Riss and Madsen, 1985). A similar explanation for the T_4 changes in the llama may be applicable.

Fig. V-1 Mean (± SEM) progesterone, estradiol-17β, and total estrogens from day 0 (breeding day) to day 35 of pregnancy in the llama.

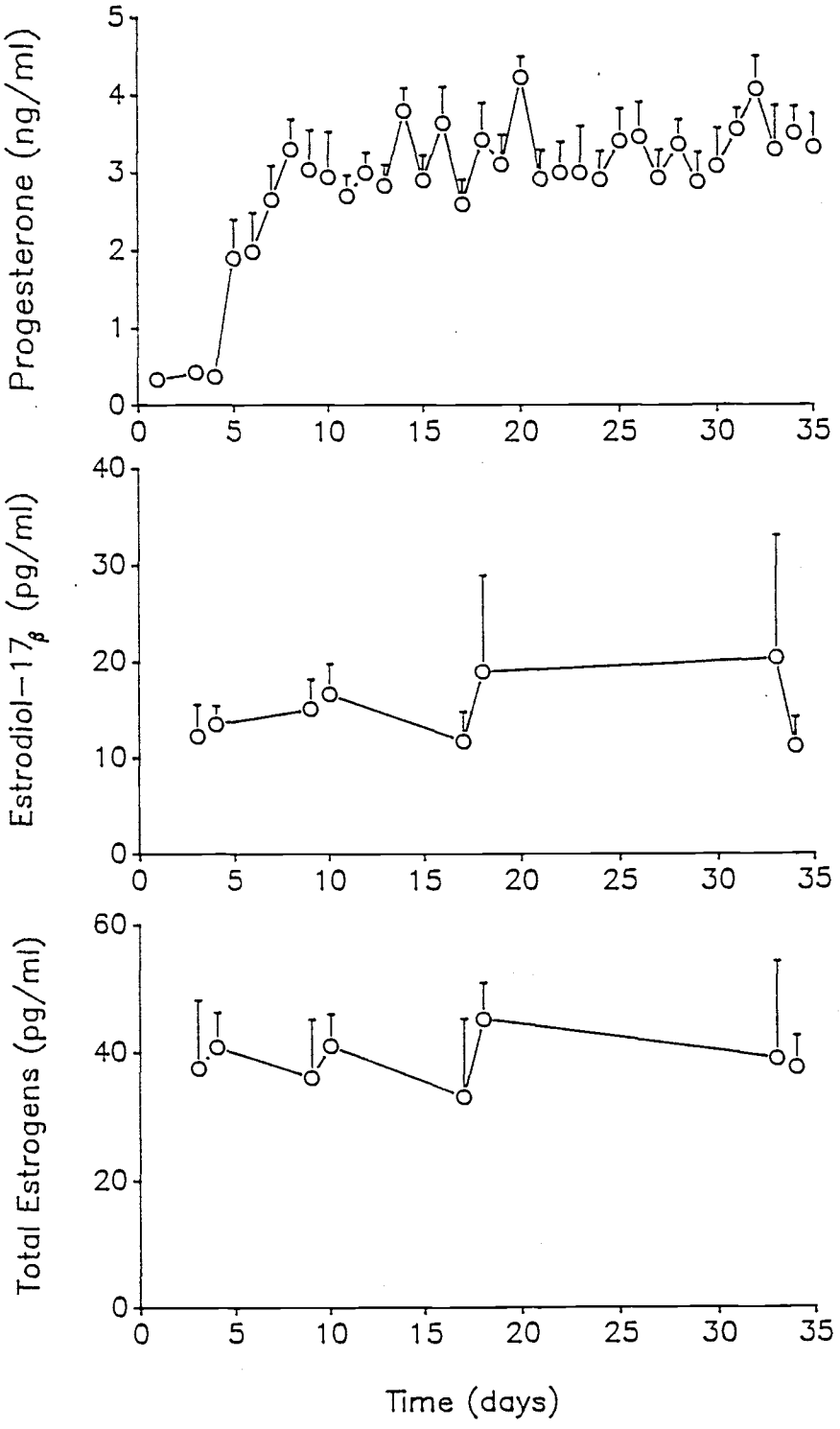


Fig. V-2 Mean (± SEM) progesterone, estradiol-17β, total estrogens, cortisol, T_3 and T_4 between conception and birth in the llama.

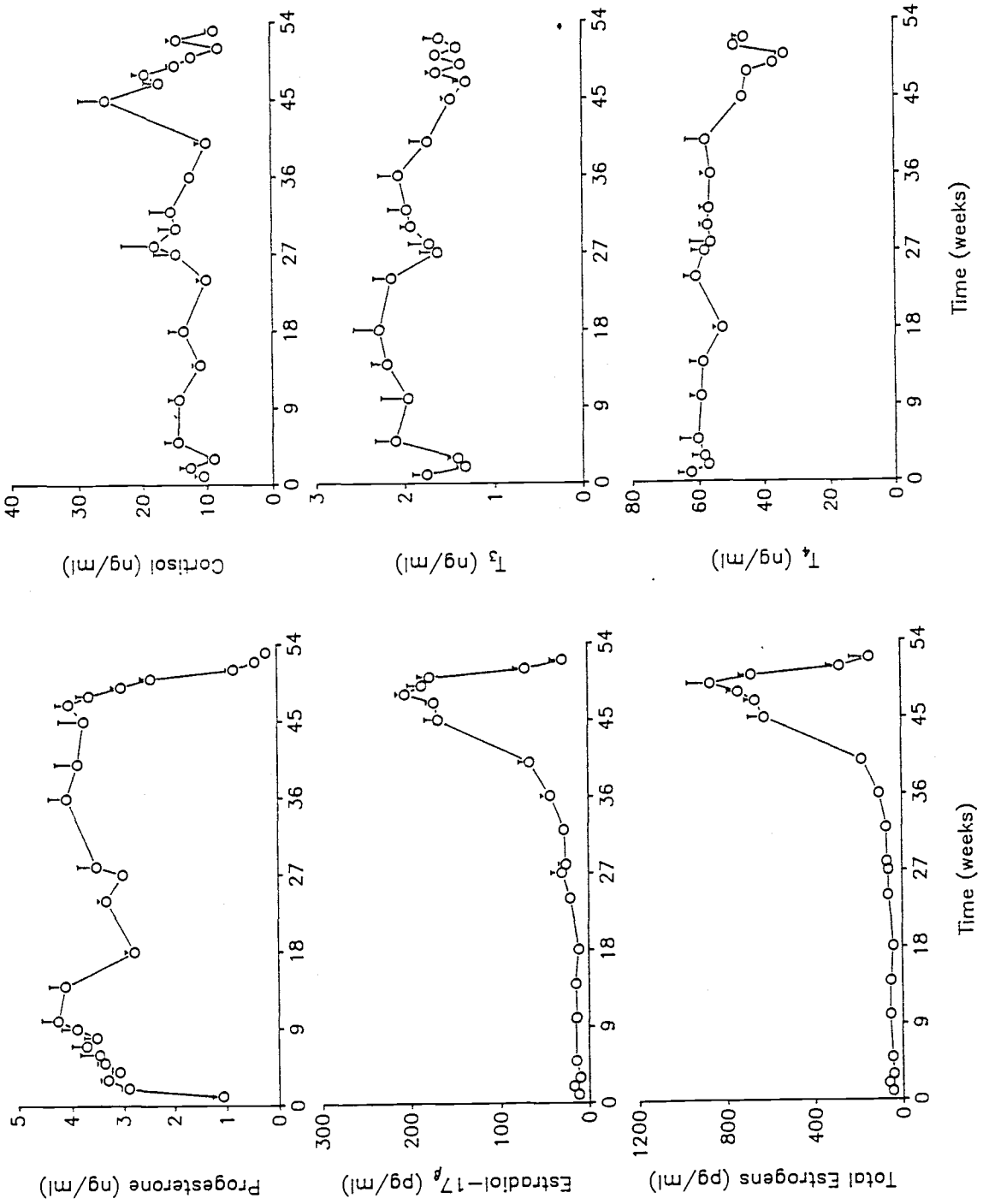
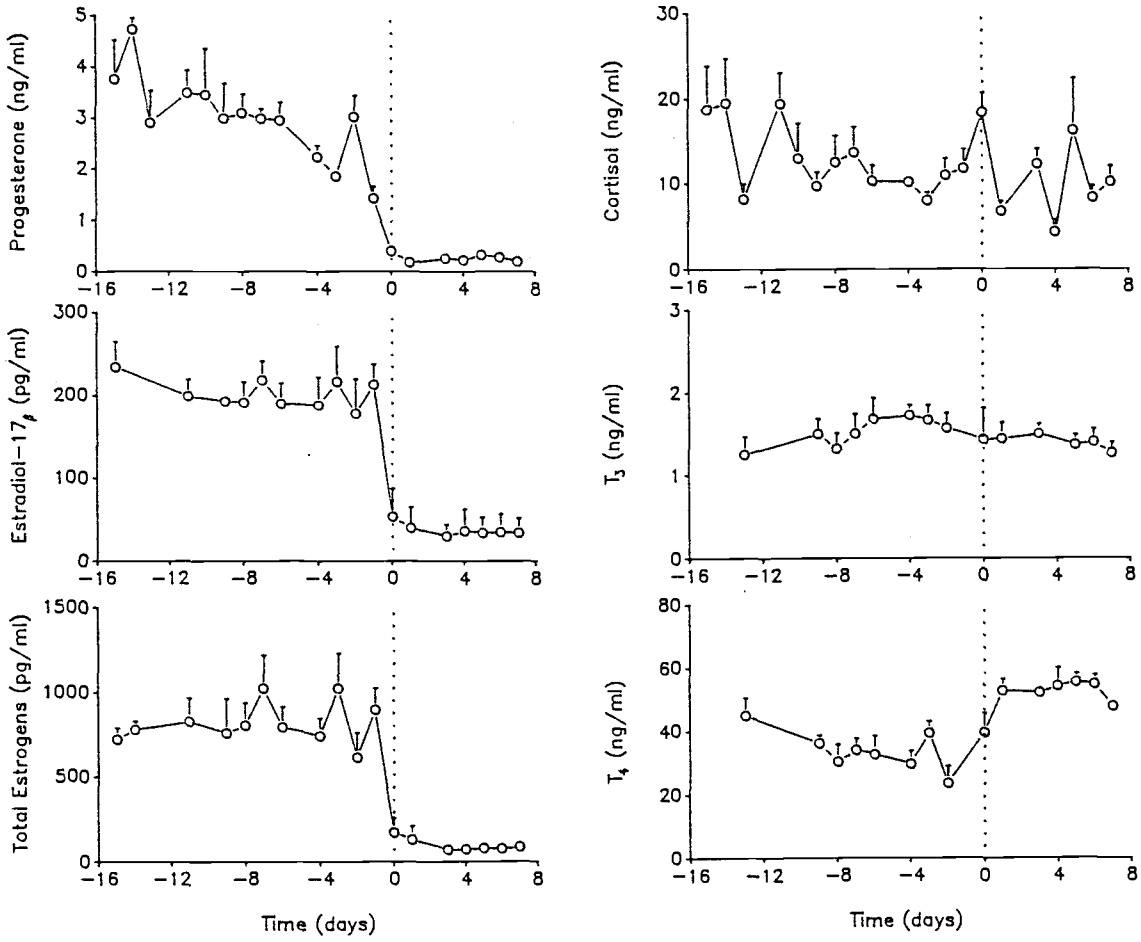


Fig. V-3 Mean (± SEM) progesterone, estradiol-17β, total estrogens, cortisol, T_3 and T_4 from -15 days before to 7 days after parturition in the llama. Day 0 (dotted vertical line) was the day of parturition.



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REFERENCES

Adams, W.M., and W.C. Wagner. 1970. The role of corticoids in parturition. **Biol. Reprod.** 3: 223-228.

Agarwal, S.P., N.D. Khanna, V.K. Agarwal, and P.K. Dwaraknath. 1987. Circulating levels of estrogen and progesterone in female camel (**Camelus dromedarius**) during pregnancy. **Theriogenology** 28: 849-858.

Ash, R.W. and R.B. Heap. 1975. Oestrogen, progesterone and corticosteroid concentrations in peripheral plasma of sows during pregnancy, parturition, lactation and after weaning. **J. Endocr.** 64: 141-154.

Baldwin, D.M and G.H. Stabenfeldt. 1975. Endocrine changes in the pig during late pregnancy, parturition and lactation. **Biol. Reprod.** 12: 508-515.

Basset, J.M., T.J. Oxborrow, I.D. Smith, and G.D. Thorburn. 1969. The concentration of progesterone in the peripheral plasma of the pregnant ewe. **J. Endocr.** 45: 449-457.

Bazer, F.W. and N.L. First. 1983. Pregnancy and parturition. **J. Anim. Sci.** 57: 425-460.

Bedford, C.A., J.R.G. Challis, F.A. Harrison, and R.B. Heap. 1972. The role of estrogens and progesterone in the onset of parturition in various species. **J. Reprod. Fert.** 16: 1-23.

Chamley, W.A., J.M. Buckmaster, M.E. Cerini, I.A. Cumming, J.R. Goding, J.M. Obst, A. Williams, and C. Winfield. 1973. Changes in the levels of progesterone, corticosteroids, estrone, estradiol-17B, luteinizing hormone, and prolactin in the peripheral plasma of the ewe during late pregnancy and at parturition. **Biol. Reprod.** 9: 30-35.

Csapo, A.I., E. Knobil, H.J. van der Molen and W.G. Wiest. 1971. Peripheral plasma progesterone levels during human pregnancy and labor. **Am. J. Obst. Gynec.** 110: 630-632.

Elias, E., E. Bedrak and R. Yagil. 1984. Estradiol Concentration in the serum of the one-humped camel (**Camelus dromedarius**) during the various reproductive stages. **Gen. Comp. Endocrinol.** 56: 258-264.

Elias, E., E. Bedrak and R. Yagil. 1984. Peripheral blood levels of progesterone in female camels during various reproductive stages. **Gen. Comp. Endocrinol.** 53: 235-240.

Evans, L.E. and W.C. Wagner. 1976. Bovine plasma estrogens, progesterone and glucocorticoids during dexamethasone induced parturition. **Acta Endoc.** 81: 385-397.

Fairclough, R.J., J.T. Hunter, R.A.S. Welch, and E. Payne. 1975. Plasma corticosteroid concentrations in the bovine foetus near term. **J. Endocr.** 65: 139-140.

Fairclough, R.J., J.T. Hunter and R.A.S. Welch. 1975. Peripheral plasma progesterone and utero-ovarian prostaglandin F concentrations in the cow around parturition. **Prostaglandins** 9: 901-914.

First, N.L. and M.J. Bosc. 1979. Proposed mechanisms controlling parturition and the induction of parturition in swine. **J. Anim. Sci.** 48: 1407-1421.

Guthrie, H.D., D.M. Henricks and D.L. Handlin. 1972. Plasma estrogen, progesterone and luteinizing hormone prior to estrus and during early pregnancy in pigs. **Endocrinol.** 91: 675-679.

Henricks, D.M., J.F. Dickey, J.R. Hill, and W.E. Johnston. 1972. Plasma estrogen and progesterone levels after mating, and during late pregnancy and postpartum in cows. **Endocrinology** 50: 1336-1342.

Hoffmann, B., W.C. Wagner, E. Ratterberger and J. Schmidt. 1977. Endocrine relationships during late gestation and parturition in the cow. Ciba Found. Symposium 47, pp. 107-122.

Hunter, J.T., R.J. Fairclough, A.J. Peterson and R.A.S. Welch. 1977. Foetal and maternal hormonal changes preceding normal bovine parturition. **Acta Endoc.** 84: 653-662.

Killian, D.B., H.A. Garverick and B.N. Day. 1973. Peripheral plasma progesterone and corticoid levels at parturition in the sow. **J. Anim. Sci.** 37: 1371-1375.

Llauro, J.L, B. Runnebaum and J. Zander. 1968. Progesterone in human peripheral blood before, during and after labor. **Am. J. Obstet. Gynecol.** 101: 867-873.

Molokwu, E.C.I. and W.C. Wagner. 1973. Endocrine physiology of the puerperal sow. **J. Anim. Sci.** 36: 1158-1163.

Peterson, A.J., J.T. Hunter, R.A.S. Welch and R.J. Fairclough. 1975. Oestrogens in bovine fetal and maternal plasma near term. **J. Reprod. Fert.** 43: 179-181.

Pope, G.S., S.K. Gupta and I.B. Munro. 1969. Progesterone levels in the systemic plasma of pregnant, cycling and ovariectomized cows. **J. Reprod. Fert.** 20: 369-381.

Robertson, H.A. and G.J. King. 1974. Plasma concentrations of progesterone, oestrone, oestradiol 17B and of oestrone sulphate in the pig at implantation, during pregnancy and at parturition. **J. Reprod. Fert.** 40: 133-141.

Smith, B.B., E.G. Pearsom and J. Leon. 1989. Thyroid function testing in the llama (**Lama glama**): an evaluation of normal triiodothyronine (T_3) and tetraiodothyronine (T_4) concentrations. **Am. J. Vet. Res.** (in press).

Smith, V.G., L.A. Edgerton, H.D. Hafs and E.M. Convey. 1973. Bovine serum estrogens, progestins and glucocorticoids during late pregnancy, parturition and early lactation. **J. Anim. Sci.** 36: 391-396.

Stabenfeldt, G.H., B.I. Osburn, and L.L. Ewing. 1970. Peripheral plasma progesterone levels in the cow during pregnancy and parturition. **Am. J. Physiol.** 218: 571-575.

Stabenfeldt, G.H., M. Drost, and C.E. Franti. 1972. Peripheral plasma progesterone levels in the ewe during pregnancy and parturition. **Endocrinology** 90: 144-150.

Thompson, F.N. and W.C. Wagner. 1974. Fetal-maternal corticosteroid relationships in sheep during late pregnancy. **J. Reprod. Fert.** 41:49-56.

Thorburn, G.D., D.H. Nicol, J.M. Bassett, D.A. Shutt, and R.I. Cox. 1972. Parturition in the goat and sheep: changes in corticosteroids, progesterone, oestrogens and prostaglandin F. **J. Reprod. Fert.** 16: 61-84.

Wagner, W.C., and S.L. Oxenreider. 1971. Endocrine physiology following parturition. **J. Anim. Sci.** 32: 1-16.

Wagner, W.C., F.N. Thompson, L.E. Evans and E.C.I. Molokwu. 1974. Hormonal mechanisms controlling parturition. **J. Anim. Sci.** 38: 39-57.

VI. GROWTH CHARACTERISTICS OF THE LLAMA (**LAMA GLAMA**) FROM BIRTH TO TWELVE MONTHS OF AGE

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ABSTRACT

The growth characteristics of the llama (**Lama glama**) have not been adequately described. This study characterized the growth patterns of this species from birth to twelve months of age. Body weight growth was described as a function of age. As a means of predicting body weight, algorithms were examined correlating body weight and specific body measurements. Regression analysis revealed a strong positive correlation between log-transformed measurements of thoracic circumference and height with body weight. Thoracic circumference was a good predictor of body weight with the equation: weight = $(8.7 * 10^{-4}$ kg) * circumference$^{2.46}$ ($r^2 = 0.91$).

INTRODUCTION

Normal growth characteristics of the llama (**Lama glama**) have not been adequately described previously making it difficult to clinically evaluate animals with suspected developmental problems. In addition, the wool on these animals makes the accurate estimation of body weight under field conditions difficult. To partially address these problems, the objectives of this study were to a) describe the normal growth characteristics of the llama during the first 12 months of life and b) develop algorithms to predict body weight based on specific body measurements.

Changes in body dimensions as a function of age have been well described in cattle (Ward, 1971; Touchberry, 1950, 1951; Vaccaro and Dillard, 1966; and Matthews et al., 1975), horses (Hickman and Colles, 1984; Carroll and Huntington, 1988; and Webb et al., 1979), and pigs (Phillips and Dawson, 1936). In these and other species, thoracic circumference is highly and positively correlated with body weight (Gruev and Machev, 1970; Yano and Ikeda, 1975). Although a positive correlation has been demonstrated between height, length, width, and body weight, the best correlation usually exists between thoracic circumference and body weight. As a result of these correlations, equations to predict body weight have been developed (Parekh et al., 1976). Due to differences in morphologic characteristics, it has not been possible, however, to develop a generalized equation applicable to all species, and growth curves have been developed for each species.

MATERIALS AND METHODS

Animals: Body measurements were taken in 1987 at approximately monthly intervals on 17 llamas in a commercial herd in the Willamette Valley of Oregon, from birth until 7 months of age. Monthly measurements on 8 of the animals were continued until 12 months of age. All animals were fed a combination of grass hay and given free access to pasture. Trace-mineral salt mix and water was available **ad lib** throughout the study. Crias were weaned at four months of age.

Measurements: The animals were weighed, then the following parameters were determined using a plastic tape measure (Fig. 1):

a) Body length: the distance on the dorsum, in a line parallel to the main axis of the body, from the base of the neck to the first moveable vertebra of the tail.

b) Height: the vertical distance from the highest point of the withers to the ground.

c) Circumference: the circumference of the thorax just caudal to the forelimb.

d) Width: the transverse width over the withers from the dorsal border of one scapula to the other.

Statistical Procedures

Simple linear regressions were used to evaluate the data. The relationship of age as the independent variable and weight as the dependent variable was examined; first, a simple linear form; second, with weight converted to natural logarithms; and third, as a second order equation. The remaining relationships with weight as the

independent variable and length, height, circumference, and width as dependent variables were examined in simple linear form and with log (base 10) normalized data. Residuals and correlation coefficients of the equations were examined to determine the best fit for the data. Analysis of the data was performed with the SAS version 6.0 and Sigmaplot version 3.1 for the IBM-XT.

RESULTS

The equation describing the relationship between weight and age was: weight(kg) = $(-0.38 * age^2) + (10.06 * age) + 14.28$ kg (r^2 = .929) (Fig. 2). The second order regression equation more closely described body-weight growth relative to age than did a simple linear equation or an equation using natural log-transformed weight data. The best fit for the linear measurements (e.g., circumference) related to weight occurred with the log (base 10) converted data. The resulting equations are shown in Table 1. Also, the relationship of thoracic circumference and body weight was converted so thoracic circumference was the independent variable. The resulting equation was: weight = $(8.7 * 10^{-4}$ kg) * circumference$^{2.46}$ (r^2 = 0.91).

DISCUSSION

Growth of the llama to 12 months of age can be described by the calculated algorithms. The equations can be used to predict normal weight for a certain age of animal, and weight can be predicted from measurement of thoracic circumference (within the size range studied). Of the parameters examined, thoracic circumference and body weight and

height and body weight had the highest correlation coefficients. The high correlation coefficients for the thoracic circumference and weight relationship and the height and weight relationship indicates that weight is a good predictor for both height and thoracic circumference. For ease of prediction of normal weight as a function of age, Figure 2 can be used. Figure 3 illustrates circumference as the independent variable and weight as the dependent variable and can be used to predict weight from a measured thoracic circumference.

The relationships between certain parameters have been well-documented in other species to function as good predictors of growth. The measurements with the best correlations were height (0.80) and thoracic circumference (0.86) with weight in pigs (Khokhlov, 1970; Yano and Ikeda, 1975). The correlations of length (0.66) and chest width (0.68) with weight were not as useful in the pig (Khokhlov, 1970; Yano and Ikeda, 1975). In the dairy cow, the best correlations existing were thoracic circumference (0.90) and length (0.87) with weight variable (Lazarevic, 1972). In another study of heifers at 6 months of age, correlations between thoracic circumference (0.68), length (0.49), and height (0.68) with weight were determined (Mafarrih, 1971). In the horse, a good correlation was found between thoracic circumference (0.90) and height (0.92) with weight (Henecke et al., 1983). In these studies, the best correlations were generally between thoracic circumference and weight and height and weight.

A group of growing llamas was studied to examine relationships between various growth parameters. More studies measuring these parameters in llamas should be done in the future to expand the numbers

of animals studied and to study animals from multiple farms. Future studies of crias, with a special emphasis on the critical first month of life, are also necessary.

TABLE VI-1. Equations describing the relationship of length, height, circumference, and width to body weight of llamas to 12 months of age.

	Equation	R^2
length	$= 9.97 \text{ cm} \times \text{weight}^{.410}$	.70
height	$= 30.41 \text{ cm} \times \text{weight}^{.230}$	.87
circumference	$= 15.50 \text{ cm} \times \text{weight}^{.367}$	.91
width	$= 7.91 \text{ cm} \times \text{weight}^{.231}$	.49

Fig. VI-1 Side view of the llama cria showing how the measurements were taken.

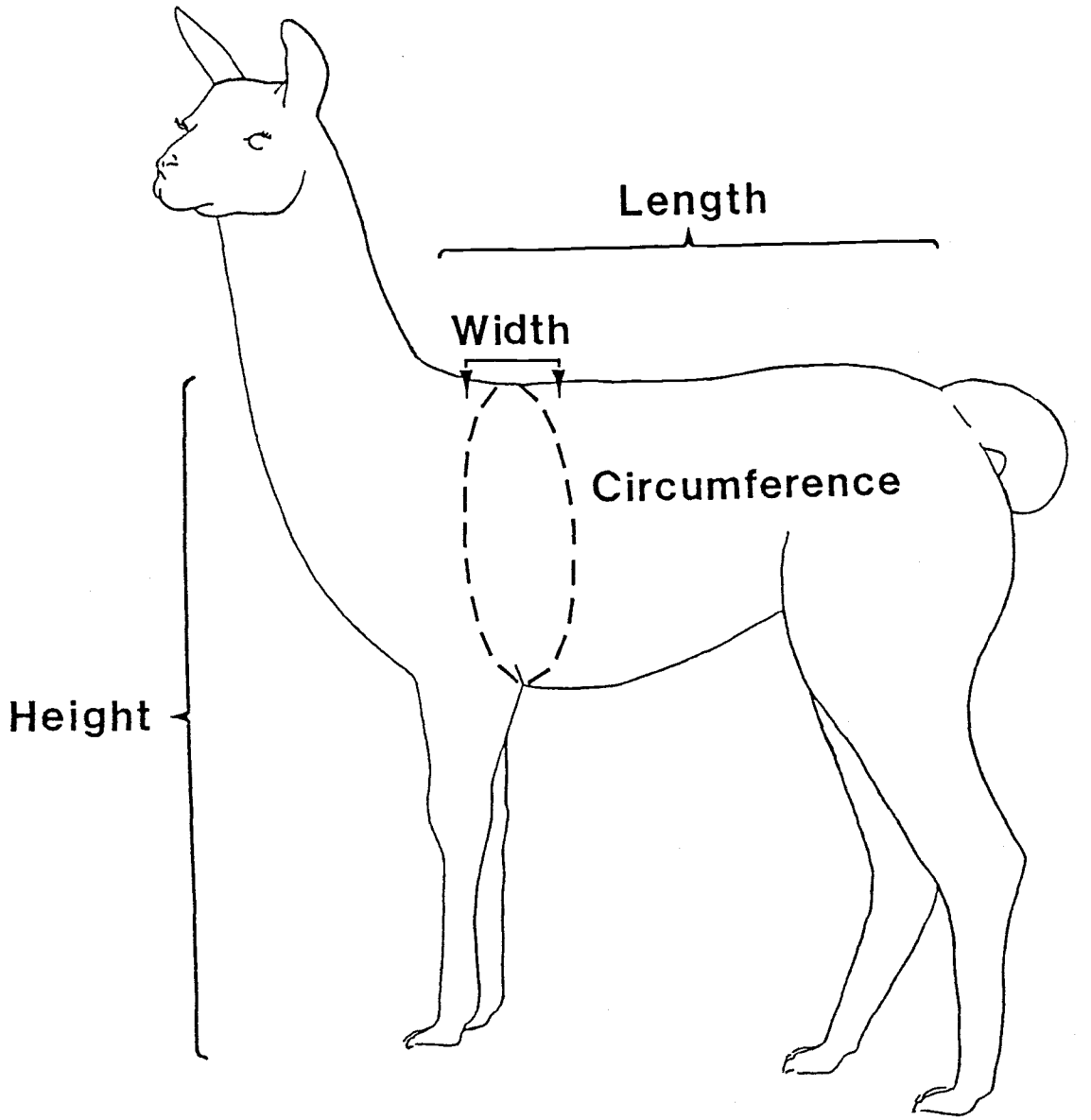


Fig. VI-2 Weight (kg) plotted as a function of age (months) of llamas from birth to twelve months.

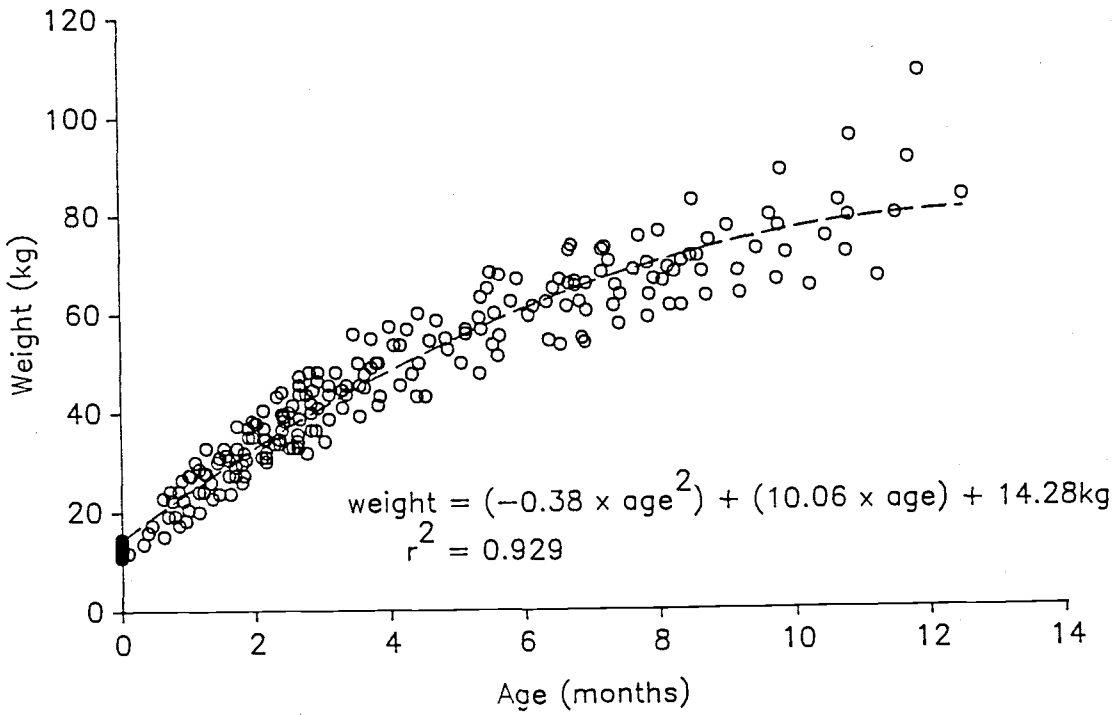
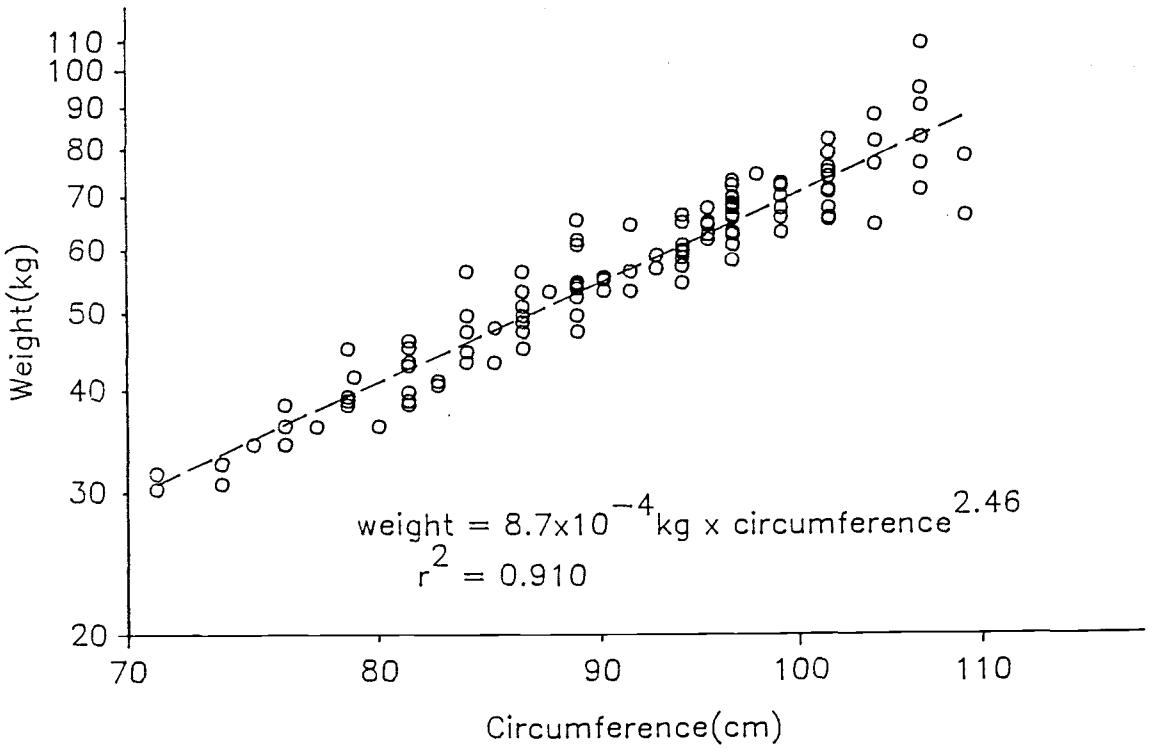


Fig. VI-3 Weight (kg) plotted as a function of thoracic circumference (cm) of llamas between 1 and 12 months of age.



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REFERENCES

Carroll, C.L., and P.J. Huntington. 1988. Body condition scoring and weight estimation of horses. **Equine Vet. J.** 20: 41-45.

Gruev, V., and M. Machev. 1970. Relationship between body weight and some body measurements in Bulgarian white pigs. **Anim. Breed.** Abs. 2089. 40: 326.

Henneke, D.R., G.D. Potter, J.L. Kreider, and B.F. Yeates. 1983. Relationship between condition score, physical measurements and body fat percentage in mares. **Equine Vet. J.** 15: 371-372.

Hickman, J., and C. Colles. 1984. Measurement of horses. **Vet. Rec.** 114: 491-493.

Khokhlov, A.M. 1970. Relationships between some characters of pigs during ontogenesis. **Anim. Breed.** Abs. 3526. 41: 395

Lazarevic, L. 1973. Correlations between body measurements and milk production of fattening performance in Danish red cattle. **Anim. Breed.** Abs. 587. 41: 60

Matthews, C.A., W.W. Swett, and R.E. McDowell. 1975. External form and internal anatomy of Holsteins and Jerseys. **J. Dairy Sci.** 58: 1453-1475.

Mufarrih, M.E. 1971. Relationship between live weights and body measurements in southern Darfur heifers from birth to 21 months age. **Sudan J. Vet. Sci. and Anim. Husbandry.** 12: 1-4.

Parekh, H.K.B., N.K. Dubey, and V.K. Taneja. 1976. Study on growth and body measurements in Tharparkar Friesian halfbreds. **Indian J. Dairy Sci.** 29: 278-282.

Phillips, R.W., and W.M. Dawson. 1936. A study of methods for obtaining measurements of swine. **Proc.** Am. Soc. Anim. Prod. 93-99.

Touchberry, R.W., and J.L. Lush. 1950. The accuracy of linear body measurements of dairy cattle. **J. Dairy Sci.** 32: 72-80.

Touchberry, R.W. 1951. Genetic correlations between five body measurements, weight, type and production in the same individual among Holstein cows. **J. Dairy Sci.** 33: 242-255.

Vaccaro, R., and E.U. Dillard. 1966. Relationship of dams's weight and weight changes of calf's growth rate in Hereford cattle. **J. Anim. Sci.** 25: 1063-1068.

Ward, J.K. 1971. Body measurements and calving difficulty. J. **Anim. Sci.** 33: 1164.

Webb, A.I., and B.M.Q. Weaver. 1979. Body composition of the horse. **Equine Vet. J.** 11: 39-47.

Yano, S.I., and T. Ikeda. 1975. Relationships between body measurements and meat production in live pigs. **Anim. Breed.** Abs. 2389. 45: 283.

VII. SUMMARY

Temporal changes in vaginal cytology were correlated with alterations in serum estradiol-17β and progesterone concentrations in the multiparous non-pregnant llama (**Lama glama**). The 2 * 2 factorial study examined the treatment effects of a) concurrent male exposure without copulation and b) collection of vaginal smears for cytologic examination on serum hormone concentrations. Exposure to the male did not produce significant changes in the relative numbers of cornified, intermediate, and parabasal cells. Mean estradiol-17β concentrations in the groups not examined for vaginal cytology increased over the 15-day sampling period, while the estrogen concentrations in the vaginal cytology study groups remained constant during the same period. Progesterone concentrations remained uniformly low during this time period in all groups. Repeated collection of vaginal samples for cytologic examination may adversely affect normal fertility by causing a relative decrease in serum estradiol-17β concentrations.

The life-span of the corpus luteum in the llama (**Lama glama**) has not been determined. The objective of this study was to determine the luteal life-span following hCG-induced ovulation and sterile or fertile breedings.

Peak plasma-progesterone concentrations of 8.5 $\pm$ 1.3 ng/ml (SEM) and 8.9 $\pm$ 1.8 ng/ml were observed 9.3 $\pm$ .3 and 9.8 $\pm$ .8 days following either sterile breeding or the intravenous administration of 5000 IU of hCG respectively in multiparous llamas (**Lama glama**). Luteal regression, began 10.3 $\pm$ .3 and 10.8 $\pm$ .8 days following sterile breeding or hCG administration, respectively, and was completed by day 12-13 post-

stimulation. Following a fertile breeding, progesterone increased significantly by 4 days post-breeding and remained above 2 ng/ml (2.6 ± .1, Range: 2.3 - 5.5 ng/ml) in all animals that subsequently delivered a full-term cria. Fertile breedings could be differentiated from sterile breedings or hCG induced ovulation by 15 days post stimulation. The results suggest that pregnancy can be confirmed as early as 15 days post breeding by monitoring plasma progesterone concentration.

The hormonal changes associated with pregnancy, parturition, and the postpartum period in the llama (**Lama glama**) have not been determined. The objective of this study was to characterized changes in plasma progesterone, estradiol-17β, total estrogens, T_3, T_4, and cortisol concentrations during pregnancy, parturition, and the early postpartum period in the llama.

Progesterone concentrations were significantly elevated by 5 days postbreeding and remained elevated (> 2.0 ng/ml) throughout pregnancy. Approximately 2 weeks prior to parturition, progesterone concentrations began to decline, dropped markedly during the final 24 hours prior to parturition, and returned to basal concentration (< 0.5 ng/ml) by the day of parturition. Total estrogen (TE) and estradiol-17β ($E_2\beta$) concentrations varied between 6-274 pg/ml and 4-114 pg/ml, respectively, during the first 9 months of pregnancy. Mean TE and $E_2\beta$ concentrations increased between 9 months and the end of pregnancy with peak mean concentrations of 827 ± 58 (SEM) pg/ml (TE) (Range: 64 - 1658) and 196 ± 10 pg/ml ($E_2\beta$) (31 - 294) observed during the last week of pregnancy. Total estrogen and estradiol-17β concentrations declined to concentrations of 87 ± 14 pg/ml (7 - 488) and 25 ± 5 pg/ml (2.5 -142),

respectively, during the first week postpartum. Cortisol concentrations varied between 2.6 and 51.9 ng/ml (14.0 ± 0.5 SEM) from conception until 2 weeks prior to parturition, when they began to decline. Only a slight increase in glucocorticoid concentrations were observed in association with parturition. T_3 concentrations varied between 0.5 and 4.5 ng/ml (1.9 ± 0.1 SEM) throughout pregnancy and the periparturient period. Thyroxine (T_4) concentrations varied between 21.3 and 91.5 ng/ml (56.5 ± 0.8 SEM) from conception until approximately 39 weeks of gestation. T_4 concentrations began to decline. T_4 concentration declined from 43.0 ± 5.3 SEM ng/ml 15 days prepartum to 23.5 ± 5.5 SEM ng/ml immediately prior to parturition. T_4 concentrations increased to 52.8 ± 3.9 SEM ng/ml by 1 day postpartum. The hormonal changes observed during pregnancy and the periparturient period are similar to those observed in other species. The absence of a significant periparturient increase in cortisol concentrations may be the result of the sampling frequency. Mean gestation length for the 14 animals in this study was 350 ± 4.5 days (SD).

The growth characteristics of the llama (**Lama glama**) have not been adequately described. This study characterized the growth patterns of this species from birth to twelve months of age. Body-weight growth was described as a function of age. As a means of predicting body weight, algorithms were examined correlating body weight and specific body measurements. Regression analysis revealed a strong positive correlation between log-transformed measurements of thoracic circumference and height with body weight. Thoracic circumference was a

good predictor of body weight with the equation: weight = ($8.7 * 10^{-4}$ kg) * circumference$^{2.46}$ ($r^2 = 0.91$).

VIII. BIBLIOGRAPHY

Adams, W.M., and W.C. Wagner. 1970. The role of corticoids in parturition. **Biol. Reprod.** 3: 223-228.

Agarwal, S.P., N.D. Khanna, V.K. Agarwal, and P.K. Dwaraknath. 1986. Thyroidal status of male camel during breeding and non-breeding seasons. **Indian J. Anim. Sci.** 56: 1036-1038.

Agarwal, S.P., N.D. Khanna, V.K. Agarwal, and P.K. Dwaraknath. 1987. Circulating levels of estrogen and progesterone in female camel (**Camelus dromedarius**) during pregnancy. **Theriogenology** 28: 849-858.

Agarwal, S.P., V.K. Agarwal, N.D. Khanna, and P.K. Dwaraknath. 1987. Profiles of steroid hormones in male camel. **Indian J. Anim. Sci.** 57: 659-661.

Ash, R.W., and R.B. Heap. 1975. Oestrogen, progesterone and corticosteroid concentrations in peripheral plasma of sows during pregnancy, parturition, lactation and after weaning. **J. Endocr.** 64: 141-154.

Baldwin, D.M., and G.H. Stabenfeldt. 1975. Endocrine changes in the pig during late pregnancy, parturition and lactation. **Biol. Reprod.** 12: 508-515.

Basset, J.M., T.J. Oxborrow, I.D. Smith, and G.D. Thorburn. 1969. The concentration of progesterone in the peripheral plasma of the pregnant ewe. **J. Endocr.** 45: 449-457.

Bazer, F.W., and N.L. First. 1983. Pregnancy and parturition. **J. Anim. Sci.** 57: 425-460.

Bedford, C.A., J.R.G. Challis, F.A. Harrison, and R.B. Heap. 1972. The role of estrogens and progesterone in the onset of parturition in various species. **J. Reprod. Fert.** 16: 1-23.

Caillot, M., C. Dauphin-Villemant, and L. Martinet. 1983. Oestrus behaviour and circulating progesterone and oestrogen levels during pseudopregnancy in the domestic rabbit. **J. Reprod. Fert.** 69: 179-186.

Calle-Escobar, R. 1984. Animal breeding and production of American camelids. pp. 21-22. Talleres Graficos de Abril. Lima. Peru.

Cardozo, A. 1981. Los camelidos de los andes altos. **World Rev. of Animal Prod.** 4: 15-20.

Carroll, C.L., and P.J. Huntington. 1988. Body condition scoring and weight estimation of horses. **Equine Vet. J.** 20: 41-45.

Challis, J.R.G., I.J. Davies, and K.J. Ryan. 1974. The concentrations of progesterone, estrone and estradiol-17β in the myometrium of the pregnant rabbit and their relationship to the peripheral plasma steroid concentrations. **Endocrinology** 95: 160-164.

Chamley, W.A., J.M. Buckmaster, M.E. Cerini, I.A. Cumming, J.R. Goding, J.M. Obst, A. Williams, and C. Winfield. 1973. Changes in the levels of progesterone, corticosteroids, estrone, estradiol-17β, luteinizing hormone, and prolactin in the peripheral plasma of the ewe during late pregnancy and at parturition. **Biol. Reprod.** 9: 30-35.

Chen, B.X., Z.X. Yuen, and G.W. Pan. 1985. Semen-induced ovulation in the Bactrian camel (**Camelus bactrianus**). **J. Reprod. Fert.** 73: 335-339.

Christie, D.W., J.B. Bailey, and E.T. Bell. 1972. Classification of cell types in vaginal smears during the canine oestrous cycle. **Br. Vet. J.** 128: 301-310.

Cole, H.H., and F.J. Saunders. 1935. The concentration of gonad-stimulating hormone in blood serum and of oestrin in the urine throughout pregnancy in the mare. **Endocrinology** 19: 199-208.

Concannon, P.W., W. Hansel, and W.J. Visek. 1975. The ovarian cycle of the bitch: plasma estrogen, LH, and progesterone. **Biol. Reprod.** 13: 112-121.

Concannon, P., B. Hodgson, and D. Lein. 1980. Reflex LH release in estrous cats following single and multiple copulations. **Biol. Reprod.** 23: 111.

Cristofori, P., G. Aria, E. Seren, G. Bono, A.Sh. Aaden, and H.M. Nur. 1986. Endocrinological aspects of reproduction in the female camel. **World Anim. Rev.** 57: 22-25.

Cross, B.A. 1973. Towards a neurophysiological basis for ovulation. **J. Reprod. Fertil.** (Suppl.20): 97.

Csapo, A.I., E. Knobil, H.J. van der Molen, and W.G. Wiest. 1971. Peripheral plasma progesterone levels during human pregnancy and labor. **Am. J. Obst. Gynec.** 110: 630-632.

D' Souza, F. 1978. The detection of oestrus. **Symp. zool. Soc. Lond.** 43: 175-193.

Dufy-Barbe, L., P. Franchimont, and J.M.A. Faure. 1973. Time-courses of LH and FSH release after mating in the female rabbit. **Endocrinology.** 92: 1318.

Elias, E., E. Bedrak, and R. Yagil. 1984. Estradiol concentration in the serum of the one-humped camel (**Camelus dromedarius**) during the various reproductive stages. **Gen. Comp. Endocrinol.** 56: 258-264.

Elias, E., E. Bedrak, and R. Yagil. 1984. Peripheral blood levels of progesterone in female camels during various reproductive stages. **Gen. Comp. Endocrinol.** 53: 235-240.

Elias, E., E. Bedrak, and D. Cohen. 1985. Induction of oestrus in the camel (**Camelus dromedarius**) during seasonal anoestrus. **J. Reprod. Fert.** 74: 519-525.

Elwishy, A.B., M.A. Omar, J.J. Parrish, and N.A. Homeida. 1983. The foetal thyroid of the dromedary: its relation to body weight and dimensions and to the weight of the dam's thyroid. **Vet. Res. Com.** 6: 289-296.

England, B.G., W.C. Foote, A.G. Cardozo, D.H. Matthews, and S. Riera. 1971. Oestrous and mating behaviour in the llama (**Lama glama**). **Anim. Behav.** 19: 722-726.

England, B.G., W.C. Foote, D.H. Matthews, A.G. Cardozo, and S. Riera. 1969. Ovulation and corpus luteum function in the llama (**Lama glama**). **J. Endocr.** 45: 505-513.

Evans, L.E., and W.C. Wagner. 1976. Bovine plalsma estrogens, progesterone and glucocorticoids during dexamethasone induced parturition. **Acta Endoc.** 81: 385-387.

Fairclough, R.J., J.T. Hunter, R.A.S. Welch, and E. Payne. 1975. Plasma corticosteroid concentrations in the bovine foetus near term. **J. Endocr.** 65: 139-140.

Fairclough, R.J., J. T. Hunter, and R.A.S. Welch. 1975. Peripheral plasma progesterone and utero-ovarian prostaglandin F concentrations in the cow around parturition. **Prostaglandins** 9: 901-914.

Fernandez Baca, S. 1971. La alpaca, reproduccion y crianza. Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA). Direccion de Investigacion Universidad Nacional Mayor de San Marcos. 7: 7-43.

Fernandez-Baca, S., and C. Novoa. 1968. Primer ensayo de inseminacion artificial de alpacas (Lama-pacos) con semen de vicuna (Vicugna-vicugna). Revista de la Facultad de Medicina Veterinaria, Universidad Nacional Mayor de San Marcos de Lima. Peru. Vol.22: 9-18.

Fernandez-Baca, S., W. Hansel, R. Saatman, J. Sumar, and C. Novoa. 1979. Differential luteolytic effects of right and left uterine horns in the alpaca. **Biol. Reprod.** 20: 586-595.

Fernandez-Baca, S. 1975. Alpaca raising in the high andes. Food and Agriculture Organization of the United Nations (FAO) World Animal Review. 14: 1-8.

Fernandez-Baca, S., D.H.L. Madden, and C. Novoa. 1970. Effect of different mating stimuli on induction of ovulation in the Alpaca. **J. Reprod. Fert.** 22: 261-267.

Fernandez-Baca, S., W. Hansel, and C. Novoa. 1970. Embryonic mortality in the alpaca. **Biol. Reprod.** 3: 243-251.

Fernandez-Baca, S., J. Sumar, C. Novoa, and V. Leyva. 1973. Relacion entre la ubicacion del cuerpo luteo y la localizacion del embrion en la alpaca. **Revista Invest. Pecu.** (IVITA) 2: 131-135.

First, N.L., and M.J. Bosc. 1979. Proposed mechanisms controlling parturition and the induction of parturition in swine. **J. Anim. Sci.** 48: 1407-1421.

Flamboe, E.E., and E.P. Reineke. 1959. Estimation of thyroid secretion rates in dairy goats and measurement of I-131 uptake and release with regard to age, pregnancy, lactation and season of year. **J. Anim. Sci.** 18: 1135-1148.

Foote, W.C., B.E. England, and M.E. Wilde. 1968. Llama reproduction. A South American problem. **Utah Science** :43-45.

Foote, W.C., and J.M. Huie. 1985. Pregnancy and postpartum levels of progesterone in the llama and their use in diagnosis of pregnancy. Paper presented at the V Internat. Convention on South American Cameloids, Cusco, Peru, June 16-21.

Franklin, W.L. 1982. Lama language. Modes of communication in the South American camelids. **Llama World.** Vol.1, number 2: 7-11.

Franklin, W.L. 1982. Contrasting socioecologies of South America's wild camelids: the vicuna and the guanaco. **Spec. Publ. Amer. Soc. Mamm.** 7: 573-629.

Franklin, W. 1974. El comportamiento social de las vicunas. Centro de Investigacion Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA). Universidad Nacional Mayor de San Marcos de Lima. Peru. Bol. 1: 1-32.

Franklin, W.L. 1981. Biology, ecology, and relationship to man of the South American camelids. Special Publication Series Pymatuning Laboratory of Ecology Universtiy of Pittsburgh. 6: 457-533.

Ganjam, V.K., and R.M. Kenney. 1975. Peripheral blood plasma levels and some unique metabolite aspects of progesterone in pregnant and non-pregnant mares. **Proc** Am Assoc Equine Pract. pp 263-276.

Ganong, W.F. 1983. Review of medical physiology. **Lange Med. Publ.** California. pp 258-271.

Ginter, O.J. 1974. Internal regulation of physiological processes through local venoarterial pathway: a review. **J. Anim. Sci.** 39: 550.

Goodman, A.L., and J.D. Neill. 1976. Ovarian regulation of postcoital gonadotrophin release in the rabbit: re-examination of a functional role for 20 alpha dihydroprogesterone. **Endocrinology** 99: 852.

Gruev, V., and M. Machev. 1970. Relationship between body weight and some body measurements in Bulgarian white pigs. **Anim. Breed.** Abs. 2089. 40: 326.

Guthrie, H.D., D.M. Henricks, and D.L. Handlin. 1972. Plasma estrogen, progesterone and luteinizing hormone prior to estrus and during early pregnancy in pigs. **Endocrinology** 91: 675-679.

Hamilton, W.J., and J.H. Gould. 1940. The normal oestrous cycle of the ferret: the correlation of the vagina smear and the histology of the genital tract, with notes on the distribution of glycogen, the incidence of growth, and the reaction to intravitam staining by trypan blue. **Trans. Roy. Soc.** Edin., 9: 87-104.

Hansel, W., P. W. Concannon, and J.H. Lukaszewska. 1973. Corporea lutea of the large domestic animals. **Biol. Reprod.** 8: 222.

Heap, R.B., and J. Hammond Jr. 1974. Plasma progesterone levels in pregnant and pseudopregnant ferrets. **J. Reprod. Fert.** 39: 149-152.

Heap, R. B., and A.P.F. Flint. 1984. Pregnancy. **Reproduction in mammals. Book 3,** 7: 153-194.

Henneke, D.R., G.D. Potter, J.L. Kreider, and B.F. Yeates. 1983. Relationship between condition score, physical measurements and body fat percentage in mares. **Equine Vet. J.** 15: 371-372.

Henneman, H.A., E.P. Reineke, and A. Griffin. 1955. The thyroid secretion rate of sheep as affected by season, age, breed, pregnancy and lactation. **J. Anim. Sci.** 14: 419-434.

Herrick, J.B. 1951. The cytological changes in the cervical mucosa of the cow (**Bos taurus**) throughout the estrous cycle. **Anim. J. Vet. Res.** 45: 276-281.

Henricks, D.M., J.F. Dickey, J.R. Hill, and W.E. Johnston. 1972. Plasma estrogen and progesterone levels after mating, and during late pregnancy and postpartum in cows. **Endocrinology** 50: 1336-1342.

Heshmat, H.A., A. Tha, A.A. Ismail, and M.B.A. Sami. 1984. Levels of thyroid hormones in the plasma of pregnant camels (**Camelus dromedarius**). **Indian J. Anim. Sci.** 54: 663-665.

Hickman, J., and C. Colles. 1984. Measurement of horses. **Vet. Rec.** 114: 491-493.

Hoffmann, B., W.C. Wagner, E. Ratterberger, and J. Schmidt. 1977. Endocrine relationships during late gestation and parturition in the cow. Ciba Found. Symposium 47, pp. 107-122.

Holtan, D.W., T.M. Nett, and V.L. Estergreen. 1975. Plasma progestins in pregnant, postpartum and cycling mares. **J. Anim. Sci.** 40: 251-260.

Homeida, A.M., M.G.R. Khalil, and A.A.M. Taha. 1988. Plasma concentrations of progesterone, oestrogens, testosterone and LH-like activity during the oestrous cycle of the camel (**Camelus dromedarius**). **J. Reprod. Fert.** 83: 593-598.

Hunter, J.T., R.J. Fairclough, A.J. Peterson, and R.A.S. Welch. 1977. Foetal and maternal hormonal changes preceding normal bovine parturition. **Acta Endoc.** 84: 653-662.

Ismail, S.T. 1987. A review of reproduction in the female camel (**Camelus dromedarus**). **Theriogenology** 28(3): 363-371.

Jochle, W. 1975. Current research in coitus-induced ovulation: a review. **J. Reprod. Fert.** Suppl. 22: 165-207.

Joshi, C.K., P.K. Pareek, and K.K. Vyas. 1980. Note on the sexual behaviour of she-camel during oestrus. **Indian J. Anim. Sci.** 50: 588.

Joshi, C.K., P.K. Pareek, and K.K. Vyas. 1981. Note on temperature and pulse and respiration rates in relation to oestrus in female camel (**Camelus dromedarius**). **Indian J. Anim. Sci.** 51: 245-247.

Joshi, C.K., K.K. Vyas, and P.K. Pareek. 1978. Studies on oestrus cycle in Bikaneri she-camel (**Camelus dromedarius**). **Indian J. Anim. Sci.** 48: 141-145.

Jungius, H. 1972. Bolivia and the vicuna. **Oryx** 11,5: 335-346.

Kanematsu, S., R.J. Scaramuzzi, J. Hilliard, and C.H. Sawyer. 1974. Patterns of ovulation-inducing LH release following coitus, electrical stimulation and exogenous LH-RH in the rabbit. **Endocrinology** 95: 247.

Killian, D.B., H.A. Garverick, and B.N. Day. 1973. Peripheral plasma progesterone and corticoid levels at parturition in the sow. **J. Anim. Sci.** 37: 1371-1375.

Koford, C.B. 1957. The vicuna and the puna. **Ecological Monographs.** 27: 153-219.

Khokhlov, A.M. 1970. Relationships between some characters of pigs during ontogenesis. **Anim. Breed.** Abs. 3526. 41: 395.

Lazarevic, L. 1973. Correlations between body measurements and milk production of fattening performance in Danish red cattle. **Anim. Breed.** Abs. 587. 41: 60.

Leon, J., and B.B. Smith. 1989. Endocrine changes during pregnancy, parturition, and early post-partum in the llama (**Lama glama**). (Submitted to **J. Reprod. Fert.**).

Llauro, J.L., B. Runnebaum, and J. Zander. 1968. Progesterone in human peripheral blood before, during and after labor. **Am. J. Obstet. Gynecol.** 101: 867-873.

Lofstedt, R.M. 1982. The estrous cycle of the domestic cat. **Continuing Education** 4: 52-58.

Lush, J.L., and O.C. Copeland. 1930. A study of the accuracy of measurements of dairy cattle. **J. Agr. Res.** 41: 37-49.

Magdub, A.B., and H.D. Johnson. 1978. Plasma and milk thyroxine of lactating cows. **J. Dairy Sci.** 61: 156.

Marie, M. and A. Anouassi. 1987. Induction of luteal activity and progesterone secretion in the nonpregnant one-humped camel (**Camelus dromedarius**). **J. Reprod. Fert.** 80: 183-192.

Marie, M., and A. Anouassi. 1986. Mating-induced luteinizing hormone surge and ovulation in the female camel (**Camelus dromedarius**). **Biol. Reprod.** 35: 792-798.

Marshall, A.J. 1984. **Marshall's Physiology of Reproduction.** Churchill Livingstone. Broadway, New York.

Matthews, C.A., W.W. Swett, and R.E. McDowell. 1975. External form and internal anatomy of Holsteins and Jerseys. **J. Dairy Sci.** 58: 1453-1475.

McDonald, L.E. 1980. **Veterinary Endocrinology and Reproduction.** Lea and Febiger, Philadelphia. pp. 438-445.

Mehta, V.S., A.H.A. Prakash, and M. Singh. 1962. Gestation period in camels. **Indian Vet. J.** 39: 387-389.

Milligan, S.R. 1982. Induced ovulation in mammals. **Oxford Reviews of Reprod. Biol.** 1: 46.

Moller, M.O. 1973. The progesterone concentrations in the peripheral plasma of the mink (**Mustela vison**) during pregnancy. **J. Endocr.** 56: 121-132.

Molokwu, E.C.I., and W.C. Wagner. 1973. Endocrine physiology of the puerperal sow. **J. Anim. Sci.** 36: 1158-1163.

Morton, W.R.M. 1961. Observations on the full-term foetal membranes of three members of the camelidae (**Camelus Dromedarius L., Camelus Bactrianus L. and Lama Glama L.**) **J. Anat.** 95: 200-209.

Mufarrih, M.E. 1971. Relation between liveweights and body measurements in southern Darfur heifers from birth to 21 months age. **Sudan J. Vet. Sci. and Anim. Husbandry.** 12: 1-4.

Musa, B.E., and M.E. Abusineina. 1978. The oestrous cycle of the camel (**Camelus dromedarius**). **Vet. Rec.** 103: 556-557.

Musa, B.E., and M.E. Abusineina. 1978. Clinical pregnancy diagnosis in the camel and a comparison with bovine pregnancy. **Vet. Rec.** 102: 7-10.

Neely, D.P., I.K.M. Liu, and R.B. Hillman. 1983. Equine reproduction. Hoffman-La Roche Inc. Nutley, New Jersey. pp 58-69.

Nett, T.M., D.W. Holton, and V.L. Estergreen. 1975. Oestrogens, LH, PMSG, and prolactin in serum of pregnant mares. **J. Reprod. Fertil.** 23: 457-462.

Novoa, C. 1970. Review of reproduction in camelidae. **J. Reprod. Fertil.** 22: 3.

Novoa, C., S. Fernandez-Baca, J. Sumar, and V. Leyva. 1972. Pubertad en la alpaca. Rev. Inv. Pec. (IVITA), Univ. Nac. San Marcos 1: 29-35.

Novoa, C. 1980. La conservacion de especies nativas en america latina. FAO. Roma.

Novoa, C. 1981. La conservacion de especies nativas en america latina. Animal Genetic Resources, Conservation and Management. Food and Agriculture Organization of the United Nations (FAO). Chapter 26: 349-361.

Novoa, C. 1984. Reproduction of llamas and alpacas. Presentation at the camelid medicine workshop. Santa Cruz, California, June 23-24. 1984.

Novoa, C., and J.C. Wheeler. 1984. **Lama and Alpaca. Evolution of Domesticated Animals.** Edited by Ian L. Mason. Longman London and New York:116-128.

Olson, P.N., P.W. Husted, T.A. Allen, and T.M. Nett. 1984. Reproductive endocrinology and physiology of the bitch and queen. **Vet. Clin. North Am.** 14: 927-946.

Parekh, H.K.B., N.K. Dubey, and V.K. Taneja. 1976. Study on growth and body measurements in Tharparkar Friesian halfbreds. **Indian J. Dairy Sci.** 29: 278-282.

Pearson, O.P. 1940. The status of the vicuna in southern Peru. **J. of Mammalogy.** 24: 97.

Pearson, O.P. 1951. Mammmals in the highlands of southern Peru. **Bull. Mus. Comp. Zool.** 106(3): 116-174.

Peterson, A.J., J.T. Hunter, R.A.S. Welch, and R.J. Fairclough. 1975. Oestrogens in bovine fetal and maternal plasma near term. **J. Reprod. Fert.** 43: 179-181.

Phillips, R.W., and W.M. Dawson. 1936. A study of methods for obtaining measurements of swine. **Proc. Am. Soc. Anim. Prod.** 93-99.

Pope, G.S., S.K. Gupta, and I.B. Munro. 1969. Progesterone levels in the systemic plasma of pregnant, cycling and ovariectomized cows. **J. Reprod. Fert.** 20: 369-381.

Refsal, K.R., R.F. Nachreiner, and C.R. Anderson. 1984. Relationship of season, herd, lactation, age, and pregnancy with serum thyroxine and triiodothyronine in Holstein cows. **Domest. Anim. Endocr.** 1: 225-234.

Riis, P.M., and A. Madsen. 1985. Thyroxine concentrations and secretion rates in relation to pregnancy, lactation and energy balance in goats. **J. Endocr.** 107: 421-427.

Robertson, H.A. and G.J. King. 1974. Plasma concentrations of progesterone, oestrone, oestradiol-17β and of oestrone sulphate in the pig at implantation, during pregnancy and at parturition. **J. Reprod. Fert.** 40: 133-141.

Rosenstrauch, A., E. Bedrak, and M. Friedlander. 1978. Testosterone production by testicular tissue of the camel (**Camelus dromedarius**) during the breeding season. **J. Steroid Biochem.** 9: 821.

Rothchild, I. 1965. Interrelations between progesterone and the ovary, pituitary and central nervous system in the control of ovulation and the regulation of progesterone secretion. **Vitam. Horm.** 23: 209-327.

Rothchild, I. 1981. The regulation of the mammalian corpus luteum. **Recent Prog. Horm. Res.** 37: 183-298.

Rotzel, J.F. 1975. Genital cytology of the bitch. **Vet. Scope** 19: 2-15.

Sanger, V.L., P.H. Engle, and D.S. Bell. 1958. The vaginal cytology of the ewe during the estrous cycle. **Anim. J. Vet. Res.** 19: 283-287.

San Martin, M. 1961. Fisiologia de la reproduccion de las alpacas. Simposium sobre problemas ganaderos. Lima. Peru.

San Martin, M., M. Copaira, J. Zuniga, R. Rodriguez, G. Bustinza, and L. Acosta. 1968. Aspects of reproduction in the alpaca. **J. Reprod. Fertil.** 16: 395-399.

Schutte, A.P. 1967. Canine vaginal cytology. I. Technique and cytological morphology. **J. Small Anin. Pract.** 8: 301-306.

Scott, W.W., F.Z. Stanczyk, and M.J. Novy. 1984. Daily hormonal changes in the maternal, fetal, and amniotic fluid compartments before parturition in a primate species. **J. Clin. Edocr. Metabol.** 58: 629-639.

Shalash, M.R., and M. Nawito. 1964. **Proc.** 5th Int. Congr. Anim. Reprod. and A.I. (Trento), 2: 263.

Shalash, M.R. 1965. Some reproductive aspects in the female camel. **World Rev. Anim. Prod.** 4: 103-108.

Shalash, M.R. 1980. Reproduction in camels. 9th International congress on Animal Reproduction and A. I. Madrid. pp. 559-564.

Shimada, M., and I. Shimada. 1985. Prehistoric llama breeding and herding on the north coast of Peru. **Amer. Antiquity,** 50(1): 3-26.

Short, R.V. 1985. Oestrous and menstrual cycles. **Hormonal Control of Reproduction.** pp 125-129. Cambridge University Press.

Simpson, G.G. 1941. Vernacular names of South American mammals. **J. of Mammalogy** 22: 1-17.

Singh, V., and A. Prakash. 1964. Mating behavior in camel. **Indian Vet. Journal** 23: 475-476.

Soliman, F.A., H. Nasr, and K. Zaki. 1963. Levels of thyroid and thyrotrophic hormones in the blood of Friesian cows at various reproductive stages. **J. Reprod. Fertil.** 6: 335-340.

Squires, E.L., M.C. Garcia, and O.J. Ginther. 1974. Effects of pregnancy and hysterectomy on the ovaries of pony mares. **J. Anim. Sci.** 38: 330-338.

Smith, V.G., L.A. Edgerton, H.D. Hafs, and E.M. Convey. 1973. Bovine serum estrogens, progestins and glucocorticoids during late pregnancy, parturition and early lactation. **J. Anim. Sci.** 36: 391-396.

Smith, B.B., E.G. Pearson, and J. Leon. 1989. Thyroid function testing in the llama (**Lama glama**): an evaluation of normal triiodothyronine (T_3) and tetraiodothyronine (T_4) concentrations. **Am. J. Vet. Res.** (in press).

Stabenfeldt, G.H., E.L. Akins, L.L. Ewing, and M.C. Morrissette. 1969. Peripheral plasma progesterone levels in pigs during the oestrus cycle. **J. Reprod. Fertil.** 20: 443.

Stabenfeldt, G.H., B.I. Osburn, and L.L. Ewing. 1970. Peripheral plasma progesterone levels in the cow during pregnancy and parturition. **Am. J. Physiol.** 218: 571-575.

Stabenfeldt, G.H., M. Drost, and C.E. Franti. 1972. Peripheral plasma progesterone levels in the ewe during pregnancy and parturition. **Endocrinology** 90: 144-150.

Stenson, G.B. 1988. Oestrus and the vaginal smear cycle of the river otter, **Lutra canadensis. J. Reprod. Fert.** 83: 605-610.

Strbak, V., F. Tomsik, and I. Hlozanek. 1976. Thyroid hormone in serum of fetal calf and pregnant cow during the last trimester of pregnancy. **Experientia** 32: 1215-1216.

Sumar, J. 1980. Gestacion gemelar en la alpaca. Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA) Universidad Nacional Mayor de San Marcos de Lima, Peru. Vol. 5(1): 58-60.

Sumar, J. 1983. Studies on reproductive pathology in alpacas. Thesis, Master of Veterinary Science. Dept. of Obstetrics and Gynaecology, Faculty of Veterinary Medicine, Swedish University of Agricultural Sciences and Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA), Universidad Nacional Mayor de San Marcos, Lima, Peru.

Terqui, M., and E. Palmer. 1979. Oestrogen pattern during early pregnancy in the mare. **J. Reprod. Fert.** 27: 441-446.

Thompson, F.N. 1973. Feto-placental steroids and parturition in the ewe. Ph.D. Thesis, Iowa State Univ. Ames.

Thompson, F.N., and W.C. Wagner. 1974. Fetal-maternal corticosteroid relationships in sheep during late pregnancy. **J. Reprod. Fert.** 41: 49-56.

Thorburn, G.D., D.H. Nicol, J.M. Basset, D.A. Shutt, and R.I. Cox. 1972. Parturition in the goat and sheep: changes in corticosteroids, progesterone, oestrogens and prostaglandin F. **J. Reprod. Fert.** 16: 61-84.

Tingari, M.D., K.A. Moniem, and E. Kunzel. 1979. Observation on the fine structure of the testicular interstitial cells in the camel (**Camelus dromedarius**). **Q. J. Exp. Physiol.** 64: 39-45.

Touchberry, R.W., and J.L. Lush. 1950. The accuracy of linear body measurements of dairy cattle. **J. Dairy Sci.** 32: 72-80.

Touchberry, R.W. 1951. Genetic correlations between five body measurements, weight, type and production in the same individual among Holstein cows. **J. Dairy Sci.** 33: 242-255.

Travis, H.F., T.E. Pilbeam, W.J. Gardner, and R.S. Cole. 1978. Relationship of vulvar swelling to estrus in mink. **J. Anim. Sci.** 46: 219-224.

Vaccaro, R., and E.U. Dillard. 1966. Relationship of dams's weight and weight changes of calf's growth rate in Hereford cattle. **J. Anim. Sci.** 25: 1063-1068.

Verhage, H.G., N.B. Beamer, and R.M. Brenner. 1976. Plasma levels of estradiol and progesterone in the cat during polyestrus, pregnancy and pseudopregnancy. **Biol. Reprod.** 14: 579-585.

Wagner, W.C., and S.L. Oxenreider. 1971. Endocrine physiology following parturition. **J. Anim. Sci.** 32: 1-16.

Wagner, W.C., F.N. Thompson, L.E. Evans, and E.C.I. Molokwu. 1974. Hormonal mechanisms controlling parturition. **J. Anim. Sci.** 38: 39i-57.

Ward, J.K. 1971. Body measurements and calving difficulty. **J. Anim. Sci.** 33: 1164.

Webb, A.I., and B.M.W. Weaver. 1979. Body composition of the horse. **Equine Vet.** J. 11: 39-47.

Wheeler, J.C. 1983. La domesticacion de la alpaca (**Lama Pacos L.**) y la llama (**Lama Glama L.**) y el desarrollo temprano de la ganaderia autoctona en los Andes Centrales. Paper presented at the IX Congreso Latinoamericano de Zoologia (CLAZ), Arequipa, Peru. 9-15 Octubre 1983.

Wheeler, J. C. 1984. On the origin and early development of camelid pastoralism in the Andes. **BAR Internat. Series** 202: 395-410.

Wheeler, J.C. 1988. Origin and evolution of the South American camelidae. 60th Western Veterinary Conference. Las Vegas.

Wheeler, J.C. 1988. An introduction to llamas and alpacas. 60th Western Veterinary Conference. Las Vegas.

Wheeler, J.C. 1988. Llamas and alpacas of South America. 60th Western Veterinary Conference. Las Vegas.

Wildt, D.E., S.W.J. Seager, and P.K. Chakraborty. 1980. Effect of copulatory stimuli on incidence of ovulation and on serum luteinizing hormone in the cat. **Endocrinology** 107: 1212.

Williamson, G., and W.J.A. Payne. 1988. **An Introduction to Animal Husbandry in the Tropics.** pp. 484-498. Longmans. London.

Xu, Y.S., H.Y. Wang, G.Q. Zeng, G.T. Jiang, and Y.H. Gao. 1985. Hormone concentrations before and after semen-induced ovulation in the Bactrian camel (**Camelus bactrianus**). **J. Reprod. Fert.** 74: 341-346.

Yagil, R., Z. Etzion, and J. Ganani. 1978. Camel thyroid metabolism: effect of season and dehydration. **J. Appl. Physiol.** 45: 540-544.

Yagil, R., and Z. Etzion. 1980. Hormonal and behavioural patterns in the male camel (**Camelus dromedarius**). **J. Reprod. Fert.** 58: 61-65.

Yagil, R., and Z. Etzion. 1984. Enhanced reproduction in camels (**Camelus dromedarius**). **Comp. Biochem. Physiol.** 79A: 201-204.

Yagil, R. 1986. The camel self-sufficiency in animal protein in drought-stricken areas. **World Animal Review** 57: 2-10.

Yano, S.I., and T. Ikeda. 1975. Relationships between body measurements and meat production in live pigs. **Anim. Breed.** Abs. 2389. 45: 283.

Zirkin, B.R., L.L. Ewing, N. Kromann, and R.C. Cochran. 1980. Testosterone secretion by the rat, rabbit, guinea pig, dog and hamster testes perfused **in vitro**: correlation with Leydig cell ultra structure. **Endocrinology** 107: 1867-1874.

APPENDIX

Table A.1 -- Cytology Study. Progesterone Concentrations

Progesterone (ng/ml)

No Cytology / No Exposure to Male

Time (days)	Llama # L:139	L:158	L:163	L:189	L:172	#	mean (ng/ml)	sd (n-1)	sem	Pooled #	mean (ng/ml)	sd (n-1)	sem
					nt usd								
1	.3	.4	.2	.3	.2	4	.30	.08	.04	18	.18	.10	.02
2	.3	.5	.1	.2	.2	4	.28	.17	.09	19	.21	.14	.03
3	.5	.3	.2	.2	.2	4	.30	.14	.07	19	.23	.16	.04
4	.2	.3	.1	.2	.3	4	.20	.08	.04	19	.23	.18	.04
5	.2	.2	.1	.2	.4	4	.18	.05	.03	19	.21	.22	.05
6	.2	.3	.1	.1	.3	4	.18	.10	.05	19	.20	.23	.05
7	.3	.3	.1	.1	.5	4	.20	.12	.06	19	.21	.18	.04
8	.2	.3	.1	.1	1	4	.18	.10	.05	19	.18	.08	.02
9	.1	.2	.2	.1	2.1	4	.15	.06	.03	19	.18	.08	.02
10	.2	.5	.1	.1	2.6	4	.23	.19	.09	19	.17	.10	.02
11	.2	.1	.2	.1	2.7	4	.15	.06	.03	19	.15	.07	.02
12	.1	.2	.2	.1	2.4	4	.15	.06	.03	18	.17	.08	.02
13	.2	.3	.2	.1	.2	4	.20	.08	.04	19	.17	.09	.02
14	.2	.2	.1	.1	.2	4	.15	.06	.03	19	.14	.08	.02
15	.1	.3	.2	.1	.2	4	.18	.10	.05	19	.14	.09	.02

No Cytology / Exposure to Male

Time (days)	Llama # L:154	L:167	L:169	L:185	L:197	#	mean (ng/ml)	sd (n-1)	sem
1	.3	.1	.1	.1	.1	5	.14	.09	.04
2	.2	.2	.2	.2	.1	5	.18	.04	.02
3	.2	.2	.2	.2	.1	5	.18	.04	.02
4	.2	.2	.2	.4	.2	5	.24	.09	.04
5	.2	.1	.1	.5	.2	5	.22	.16	.07
6	.2	.1	.1	.3	.2	5	.18	.08	.04
7	.3	.1	.4	.3	.2	5	.26	.11	.05
8	.2	.3	.3	.1	.2	5	.22	.08	.04
9	.2	.2	.4	.2	.2	5	.24	.09	.04
10	.2	.2	.3	.1	.2	5	.20	.07	.03
11	.3	.2	.2	.2	.1	5	.20	.07	.03
12	.3	.2	.3	.1	.2	5	.22	.08	.04
13	.3	.3	.2	.3	.1	5	.24	.09	.04
14	.2	.2	.2	.2	.1	5	.18	.04	.02
15	.2	.3	.2	.2	.2	5	.22	.04	.02

Cytology / No Exposure to Male

Time (days)	Llama # L:026	L:027	L:130	L:140	L:156	#	mean (ng/ml)	sd (n-1)	sem
1	.1		.1	.3	.1	4	.15	.10	.05
2	.1	.3	.1	.2	.1	5	.16	.09	.04
3	.1	.3	.1	.4	.1	5	.20	.14	.06
4	.1	.5	.1	.2	.1	5	.20	.17	.08
5	.1	.4	.1	.2	.1	5	.18	.13	.06
6	.1	.2	.2	.2	.1	5	.16	.05	.02
7	.1	.1	.1	.5	.1	5	.18	.18	.08
8	.2	.2	.1	.3	.1	5	.18	.08	.04
9	.2	.2	.1	.3	.1	5	.18	.08	.04
10	.1	.2	.1	.2	.1	5	.14	.05	.02
11	.1	.2	.1	.1	.1	5	.12	.04	.02
12	.1	.3	.1	.2	.2	5	.18	.08	.04
13	.1	.2	.2	.2	.1	5	.16	.05	.02
14	.1	.2	.1	.3	.1	5	.16	.09	.04
15	.1	.1	.1	.2	.1	5	.12	.04	.02

Cytology / Exposure to Male

Time (days)	Llama # L:028	L:132	L:143	L:148	L:198	#	mean (ng/ml)	sd (n-1)	sem
1	.1	.1	.2	.1	.2	5	.14	.05	.02
2	.1	.3	.1	.1	.6	5	.24	.22	.10
3	.2	.2	.1	0	.7	5	.24	.27	.12
4	.2	0	.5	0	.7	5	.28	.31	.14
5	.1	.1	.1	0	1	5	.26	.42	.19
6	.1	.1	.1	0	1.1	5	.28	.46	.21
7	.1	.1	.1	0	.7	5	.20	.28	.13
8	.1	.1	.3	.1	.2	5	.16	.09	.04
9	.2	.1	.2	.1	.1	5	.14	.05	.02
10	.1	.1	.2	.1	.1	5	.12	.04	.02
11	.1	.1	.2	0	.2	5	.12	.08	.04
12	.1	.1	.2		0	4	.10	.08	.04
13	.1	.1	.1	0	.1	5	.08	.04	.02
14	0	.1	.2	0	0	5	.06	.09	.04
15	0	.1	.1	0	0	5	.04	.05	.02

Table A.2 -- Cytology Study. Estradiol-17β Concentrations

Estradiol-17B (pg/ml)

No Cytology / No Exposure to Male

Time (days)	Llama # L:139	L:158	L:163	L:189	L:172 nt usd	#	mean (pg/ml)	sd (n-1)	sem	Pooled No Cytology #	mean (pg/ml)	sd (n-1)	sem
1	.0	4.9	6.1	11.2	14.0	4	5.55	4.60	2.30	9	7.17	5.13	1.71
3	5.0	9.7	8.4	18.6	13.3	4	10.42	5.78	2.89	9	10.65	3.94	1.31
5	6.9	7.8	8.5	9.7	10.9	4	8.25	1.20	.60	9	8.13	3.21	1.07
7	11.4	11.2	8.2	18.5	14.5	4	12.32	4.36	2.18	9	14.64	4.97	1.66
9	2.1	14.5	6.2	19.6	12.5	4	10.59	7.93	3.97	9	11.72	7.60	2.53
11	1.4	11.3	8.7	26.1	10.7	4	11.86	10.38	5.19	9	14.10	7.55	2.52
13	3.9	10.8	10.3	25.1	17.5	4	12.54	8.96	4.48	9	13.57	8.21	2.74
15	5.4	8.4	11.0	37.2	16.4	4	15.51	14.65	7.32	9	14.80	10.50	3.50

No Cytology / Exposure to Male

Time (days)	Llama # L:169	L:154	L:167	L:185	L:197	#	mean (pg/ml)	sd (n-1)	sem
1	.2	7.3	9.4	16.0	9.3	5	8.47	5.66	2.53
3	7.9	10.2	9.3	13.0	13.7	5	10.83	2.44	1.09
5	7.7	6.0	9.0	2.7	14.7	5	8.03	4.42	1.98
7	9.8	14.9	15.7	23.5	18.6	5	16.49	5.05	2.26
9	11.3	.0	17.0	13.0	21.8	5	12.62	8.13	3.64
11	9.8	21.8	17.2	18.7	11.9	5	15.90	4.93	2.21
13	.0	15.8	18.6	22.3	15.3	5	14.39	8.52	3.81
15	2.7	11.8	17.0	23.3	16.4	5	14.24	7.65	3.42

Cytology / No Exposure to Male

Time (days)	Llama # L:026	L:027	L:130	L:140	L:156	#	mean (pg/ml)	sd (n-1)	sem	Pooled Cytology #	mean (pg/ml)	sd (n-1)	sem
1	16.1	13.2	7.4	6.1	4.0	5	9.37	5.08	2.27	10	7.34	4.51	1.43
3	20.5	8.9	7.8	9.6	5.5	5	10.46	5.81	2.60	10	8.03	5.28	1.67
5	16.3	9.0	2.1	4.1	1.2	5	6.55	6.25	2.80	10	6.82	5.07	1.60
7	14.7	14.8	3.0	3.3	9.2	5	8.99	5.77	2.58	10	8.74	5.87	1.86
9	22.3	10.6	6.6	3.2	2.4	5	9.03	8.10	3.62	10	7.81	5.81	1.84
11	12.0	9.3	13.5	5.6	6.1	5	9.31	3.47	1.55	10	7.71	3.38	1.07
13	17.5	15.1	6.4	3.2	6.6	5	9.76	6.18	2.76	10	7.84	5.47	1.73
15	12.7	15.3	2.4		12.0	4	10.59	5.66	2.83	9	6.35	5.45	1.82

Cytology / Exposure to Male

Time (days)	Llama # L:028	L:132	L:143	L:148	L:198	#	mean (pg/ml)	sd (n-1)	sem
1	6.3	3.4	8.1	7.8	.8	5	5.30	3.10	1.39
3	3.8	9.6	8.9	.4	5.4	5	5.60	3.77	1.68
5	9.4	3.4	12.9	2.4	7.4	5	7.09	4.30	1.92
7	19.5	2.1	9.2	5.3	6.3	5	8.49	6.65	2.97
9	10.2	6.0	3.1	7.6	6.1	5	6.58	2.59	1.16
11	10.1	5.0	7.4	3.4	4.5	5	6.10	2.69	1.21
13	1.2	6.2	13.2	4.2	4.8	5	5.91	4.46	1.99
15	3.1	4.6	.9	1.4	4.7	5	2.96	1.75	.78

Table A.3 -- Cytology Study. Percent of Cell Type

	Percent of Cell Type Present									Percent of Cell Type Present										Pooled			
	Not Exposed to Male / Cornified Cells									Exposed to Male / Cornified Cells													
	Llama #									Llama #													
Time (days)	1:026	1:140	1:027	1:130	1:156	#	mean (%)	sd (n-1)	sem	1:148	1:132	1:028	1:143	1:158	#	mean (%)	sd (n-1)	sem	#	mean (%)	sd (n-1)	sem
1	88	76		27	90	4	70.3	28.5	14.7	76	68	62	57	33	5	59.6	16.8	7.5	9	64.3	22.3	7.4
2	77	82	82	53	60	5	70.6	13.4	6.0	60	18	81	27	28	5	43.0	26.5	11.9	10	56.9	24.6	7.8
3	68	69	70	84	70	5	72.4	6.5	2.9	73	34	46	52	91	5	59.6	22.3	10.0	10	66.1	15.9	5.3
4	83	35	65	25	86	5	60.8	24.9	11.1	72	42	81	80	74	5	69.8	16.0	7.2	10	65.3	20.3	6.4
5	71	58	58	38	70	5	59.2	13.3	5.9		88	92	84	65	4	87.3	3.6	1.8	9	71.7	17.7	5.9
6	83	37	73	54	75	5	64.4	18.6	8.3	83	72	88	67	83	5	82.6	6.3	2.8	10	73.5	16.3	5.1
7	80	86	71		82	4	80.3	7.0	3.5	82	77	88	74	80	5	80.2	5.3	2.4	9	80.2	5.7	1.9
8	76	19	78	58	87	5	64.2	27.4	12.3	68	82	87	61	90	5	77.6	12.5	5.6	10	70.9	21.3	6.7
9	80	70	85	82	76	5	78.6	5.8	2.6	91	90	77	69	82	5	78.8	11.3	5.1	10	78.3	8.5	2.7
10	86	85	72	33	85	5	75.4	25.2	11.3	76	27	73	89	92	5	71.8	25.2	11.7	10	73.6	24.3	7.7
11	92	82	85	71	88	5	83.6	8.0	3.6	91	62	67	83	87	5	80.0	15.1	6.8	10	81.8	11.5	3.6
12	75	87	88	91	98	5	87.8	8.3	3.7	82	84	87	91	93	5	87.4	4.6	2.1	10	87.6	6.4	2.0
13	74	56	84	70	91	5	75.0	13.5	6.0	72	87	75	56	73	5	74.6	11.7	5.2	10	74.8	11.9	3.8
14	80	88	80	65	83	5	79.2	8.6	3.8	82	66	90	83	77	5	83.6	4.8	2.2	10	81.4	7.0	2.2
15	68	92	91	84	92	5	85.6	9.9	4.4	84	68	95	84	93	5	83.0	9.2	4.1	10	84.3	9.1	2.9

	Not Exposed to Male / Intermediate Cells									Exposed to Male / Intermediate Cells										Pooled			
	Llama #									Llama #													
Time (days)	1:026	1:140	1:027	1:130	1:156	#	mean (%)	sd (n-1)	sem	1:148	1:132	1:028	1:143	1:158	#	mean (%)	sd (n-1)	sem	#	mean (%)	sd (n-1)	sem
1	9	19		71	3	4	25.5	31.0	15.5	12	15	19	22	7	5	15.0	5.9	2.6	9	18.7	20.2	6.7
2	15	15	14	41	27	5	22.8	11.4	5.1	25	62	15	60	65	5	45.4	23.5	10.5	10	34.1	21.1	6.7
3	15	27	28	4	24	5	19.6	10.1	4.5	9	61	45	38	7	5	32.0	23.5	10.5	10	25.8	18.2	5.8
4	25	64	26	64	13	5	38.4	23.9	10.7	22	46	19	10	21	5	22.4	14.2	6.3	10	30.4	20.4	6.4
5	20	38	38	60	19	5	35.0	16.8	7.5		8	8	9	12	4	9.3	1.9	.9	9	23.6	18.1	6.0
6	24	60	24	37	21	5	33.2	16.2	7.2	15	25	10	14	13	5	15.8	6.1	2.7	10	24.4	14.8	4.7
7	16	12	28		13	4	17.3	7.4	3.7	17	12	7	18	17	5	14.2	4.7	2.1	9	15.6	5.8	1.9
8	19	45	17	27	9	5	23.4	13.7	6.1	21	9	9	14	8	5	12.4	5.3	2.4	10	17.9	11.4	3.6
9	13	30	14	12	14	5	16.6	7.5	3.4	5	6	21	18	10	5	12.4	6.8	3.0	10	14.5	7.1	2.3
10	5	4	26	64	7	5	21.2	25.6	11.4	7	51	21	5	5	5	17.8	19.7	8.8	10	19.5	22.6	6.8
11	4	16	9	25	10	5	12.8	8.0	3.6	6	22	23	13	3	5	13.4	8.1	4.1	10	13.1	8.1	2.6
12	19	13	9	9	1	5	10.2	6.6	2.9	12	6	8	6	5	5	7.4	2.8	1.2	10	8.8	5.0	1.6
13	13	37	8	15	6	5	16.0	12.4	5.5	11	9	8	31	14	5	14.6	9.4	4.2	10	15.3	10.4	3.3
14	8	8	10	26	8	5	12.0	7.9	3.5	15	8	7	13	14	5	11.4	3.6	1.6	10	11.7	5.8	1.8
15	25	7	8	11	6	5	11.4	7.8	3.5	7	21	5	18	8	5	12.2	6.3	2.8	10	10.8	6.7	2.1

	Not Exposed to Male / Parabasal Cells									Exposed to Male / Parabasal Cells									Pooled			
	Llama #									Llama #												
Time (days)	L:026	L:140	L:027	L:130	L:156	#	mean (%)	sd (n-1)	sem	L:148	L:132	L:028	L:143	L:158	#	mean (%)	sd (n-1)	sem	#	mean (%)	sd (n-1)	sem
1	3	5		2	7	4	4.3	2.2	1.1	10	18	19	21	23	5	18.2	5.0	2.2	9	12.0	8.3	2.8
2	7	2	4	6	13	5	6.4	4.2	1.9	15	21	4	13	7	5	12.0	6.7	3.0	10	9.2	6.0	1.9
3	15	4	2	12	6	5	8.0	5.8	2.6	15	7	6	10	2	5	8.0	4.8	2.2	10	8.0	5.1	1.6
4	2	1	9	1	1	5	2.8	3.5	1.6	6	13	6	10	5	5	8.0	3.4	1.5	10	5.4	4.2	1.3
5	9	4	3	2	11	5	5.8	4.0	1.8		4	0	7	3	4	3.5	2.9	1.4	9	4.8	3.5	1.2
6	0	3	3	6	5	5	4.0	3.3	1.5	2	2	2	6	0	5	2.8	3.0	1.4	10	3.4	3.1	1.0
7	4	0	1		5	4	2.5	2.4	1.2	1	11	5	8	3	5	5.6	4.0	1.8	9	4.2	3.6	1.2
8	2	35	5	14	4	5	12.2	14.1	6.3	11	6	4	25	1	5	10.0	9.3	4.1	10	11.1	11.3	3.6
9	7	0	1	6	10	5	4.8	4.2	1.9	4	12	2	22	8	5	9.6	7.9	3.5	10	7.2	6.5	2.1
10	7	1	2	3	4	5	3.4	2.3	1.0	15	22	6	6	3	5	10.4	7.9	3.5	10	6.9	6.6	2.1
11	4	2	6	4	2	5	3.6	1.7	.7	3	16	10	4	0	5	6.6	6.4	2.9	10	5.1	4.7	1.5
12	6	0	3	0	1	5	2.0	2.5	1.1	6	10	5	3	2	5	5.2	3.1	1.4	10	3.6	3.2	1.0
13	13	7	8	14	3	5	9.0	4.5	2.0	17	4	13	13	7	5	10.8	5.2	2.3	10	9.9	4.7	1.5
14	12	4	10	9	9	5	8.6	2.9	1.3	3	6	3	4	9	5	5.0	2.5	1.1	10	6.9	3.3	1.0
15	6	2	1	5	2	5	3.2	2.2	1.0	9	10	0	6	9	5	6.8	4.1	1.8	10	5.0	3.6	1.1

Table A.4 -- Cytology Study. Sexual Receptivity Behavior

Time to Submission (sec)

No Cytology Performed

Time (days)	Llama # L:154	L:167	L:169	L:185	L:197	#	mean (sec)	sd (n-1)	sem
2	41	36	67	111	20	5	55.0	35.6	15.9
3	79	29	14	108	33	5	52.6	39.4	17.6
4	62	23	18	110	58	5	54.2	37.0	16.5
5		36	43		28	3	35.7	7.5	4.3
6	85	100			39	3	74.7	31.8	18.4
7	128		28		53	3	69.7	52.0	30.0
8	67	72	31	113	49	5	66.4	30.7	13.7
9	146	109	61	46	55	5	83.4	42.7	19.1
10	114	108	76	71	105	5	94.8	19.8	8.9
11	135	65	124		45	4	92.3	44.0	22.0
12	109		25		74	3	69.3	42.2	24.4
13	68		83			2	75.5	10.6	7.5
14	138	75				2	106.5		
15			75			1	75.0		

Cytology and No Cytology

#	mean (sec)	sd (n-1)	sem
9	53.2	34.9	11.6
9	39.6	32.3	10.8
8	45.1	31.6	11.2
7	31.0	16.3	6.2
6	49.3	34.7	14.2
6	46.3	41.7	17.0
10	57.9	31.2	9.9
10	78.4	42.8	13.5
10	86.9	37.4	11.8
6	80.3	39.4	16.1
6	74.2	36.4	14.8
4	97.0	39.3	19.6
4	113.0	42.6	21.3
3	63.7	24.1	13.9

Cytology Performed

Time (days)	Llama # L:028	L:132	L:143	L:148	L:198	#	mean (sec)	sd (n-1)	sem
2	109	31	23	41		4	51.0	39.4	19.7
3	20	36	22	15		4	23.3	9.0	4.5
4	28		45	17		3	30.0	14.1	8.1
5	24	6	57	23		4	27.5	21.3	10.7
6	14	28		30		3	24.0	8.7	5.0
7	21	26		22		3	23.0	2.6	1.5
8	38	103	38	16	52	5	49.4	32.6	14.6
9	52	101	142	26	46	5	73.4	47.2	21.1
10	10	103	130	41	111	5	79.0	51.0	22.8
11	68			45		2	56.5	16.3	11.5
12	59	123		55		3	79.0	38.2	22.0
13	155			82		2	118.5	51.6	36.5
14	160			79		2	119.5	57.3	40.5
15	80			36		2	58.0	31.1	22.0

Frequency of Occurance

Time (days)	Aggressive spits	kicks	stance	h/h	Submissive angle	recum
2	2	1	0	1	7	9
3	1	1	2	1	0	9
4	2	1	2	0	2	8
5	1	0	3	0	5	7
6	2	0	3	2	2	6
7	1	0	2	2	1	6
8	0	0	1	0	1	10
9	0	0	0	0	1	10
10	0	0	0	0	0	10
11	2	0	0	0	0	6
12	1	3	0	0	0	6
13	1	2	1	0	0	4
14	0	1	1	0	0	4
15	0	1	0	0	0	3

Table A.5 -- Corpus Luteum Life Span. Progesterone Response Following Sterile Breeding

Time (days)	Progesterone (ng/ml) Llama # L:162	L:199	L:621	L:625	L:612 nt usd	L:631 nt usd	#	mean (ng/ml)	sd (n-1)	sem
1	.2	.8	.4	.1	5.3	.8	4	.38	.30	.15
2	.2	.7	.6	.1	2.7	1.1	4	.42	.29	.15
3	.2	1.1	.4	.2	8.1	3.1	4	.47	.43	.21
4	.3	1.1	.5	.4	8.2	3.5	4	.56	.37	.18
5	.9	1.3	1.0	.9	7.8	3.7	4	1.01	.20	.10
6	1.6	2.2	1.1	1.4	6.3	5.3	4	1.57	.46	.23
7	2.3	3.0					2	2.65	.49	.35
8	3.4	6.4	3.9	13.6	4.5	6.7	4	6.82	4.71	2.35
9	4.5	9.5	5.5	9.2	7.0	6.2	4	7.17	2.55	1.27
10	4.9	8.3	5.3	9.2	4.0	5.3	4	6.91	2.16	1.08
11	6.3	5.0	6.1	3.8	4.7	2.4	4	5.30	1.15	.58
12	4.8	1.6	3.8	1.8	6.9	1.6	4	3.00	1.56	.78
13	1.2	1.3	1.0	1.2	5.1	.8	4	1.18	.13	.06
14	.5	1.0	.7	1.0	9.3	.7	4	.80	.24	.12
15	.5	.9	.5	.6	6.4	.5	4	.63	.19	.09

Table A.6 -- Corpus Luteum Life Span. Progesterone Response Following hCG Stimulation

Time (days)	Progesterone (ng/ml) Llama # L:036	L:155	L:159	L:176	L:130 nt usd	L:179 nt usd	#	mean (ng/ml)	sd (n-1)	sem
1	.4	.1	.2	.4	.2	.2	4	.28	.15	.08
2	.3	.1	.1	.3	.1	.3	4	.20	.12	.06
3	.8	.1	.1	.1	.0	.3	4	.28	.35	.18
4	.9	.3	.3	.6	.1	.4	4	.53	.29	.14
5	1.8	.5	.5	1.4	.2	.3	4	1.05	.66	.33
6	2.1	1.3	1.4	2.1	.2	.5	4	1.73	.43	.22
7	6.6	3.3	3.0	4.3	.1	.5	4	4.30	1.63	.82
8	6.1	4.2	3.9	6.6	.2	.5	4	5.20	1.35	.67
9	11.6	3.7	5.9	9.5	.1	.1	4	7.68	3.54	1.77
10	7.4	6.9	5.1	7.2	.1	.1	4	6.65	1.05	.53
11	.5	6.0	.7	1.9	.1	.4	4	2.28	2.56	1.28
12	.2	.4	.0	.7	.0	.3	4	.33	.29	.14
13	.2	.2	.2	.3	.1	.1	4	.23	.05	.03
14	.0	.2	.1	.2	.1	.0	4	.14	.08	.04
15	.0	.0	.1	.1	.0	.0	4	.06	.05	.02

Table A.7 -- Corpus Luteum Life Span. Progesterone Response Following Fertile Breeding

Progesterone (ng/ml)

Time (days)	L:026	L:028	L:128	L:132	L:139	L:140	L:143	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	L:197	#	mean (ng/ml)	sd (n-1)	sem
1							.2		.6								.2	3	.33	.23	.13
2				.2														1	.20		
3					.5		1.2	.1	.4				.1	.3		.7	.1	8	.43	.38	.13
4	.3	.5		.9		.3				.1	.3				.2			7	.37	.26	.10
5					2.2		3.8	1.7	.6				.2	2.4		3.8	.5	8	1.90	1.42	.50
6	2.4	3.6		3.6		.4				.5	1.5				1.9			7	1.99	1.31	.50
7			1.4		5.5		2.8	1.3	2.2			1.5	1.8	4.3		3.6	2.1	10	2.65	1.40	.44
8	4.7	3.8		4.4		2.6				2.8	1.8				3			7	3.30	1.04	.39
9			.1		3.4		5	1.8	5.1			1.6	4	4.2		3	2.2	10	3.04	1.61	.51
10	.1	4		2.9		3.2				4.9	2				3.5			7	2.94	1.54	.58
11			3.9		2.5		2.5	1.7	3			1.5	3.6	3.7		3	1.6	10	2.70	.89	.28
12	3.7	3.7		2.3		3				3	1.9				3.4			7	3.00	.69	.26
13			3.9		2.9		2.2	1.8	3.9			1.8	3.3	3.7		3	1.8	10	2.83	.87	.28
14	4.4	3		3.6		4.2				4.9	2.7				3.8			7	3.80	.78	.29
15			5		3.4		2.7	1.8	2.5			1.4	3.8	2.8		3.3	2.3	10	2.90	1.04	.33

Table A.8 -- Pregnancy and Parturition Study. Progesterone Concentrations During Early Pregnancy

P4 (ng/ml)

Time (days)	Llama # L:026	L:028	L:128	L:132	L:139	L:140	L:143	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	L:197	#	mean (ng/ml)	sd (n-1)	sem
1							.2		.6								.2	3	.33	.23	.13
2				.2														1	.20		
3					.5		1.2	.1	.4				.1	.3		.7	.1	8	.43	.38	.13
4	.3	.5		.9		.3				.1	.3				.2			7	.37	.26	.10
5					2.2		3.8	1.7	.6				.2	2.4		3.8	.5	8	1.90	1.42	.50
6	2.4	3.6		3.6		.4				.5	1.5				1.9			7	1.99	1.31	.50
7			1.4		5.5		2.8	1.3	2.2			1.5	1.8	4.3		3.6	2.1	10	2.65	1.40	.44
8	4.7	3.8		4.4		2.6				2.8	1.8				3			7	3.30	1.04	.39
9			.1		3.4		5	1.8	5.1			1.6	4	4.2		3	2.2	10	3.04	1.61	.51
10	.1	4		2.9		3.2				4.9	2				3.5			7	2.94	1.54	.58
11			3.9		2.5		2.5	1.7	3			1.5	3.6	3.7		3	1.6	10	2.70	.89	.28
12	3.7	3.7		2.3		3				3	1.9				3.4			7	3.00	.69	.26
13			3.9		2.9		2.2	1.8	3.9			1.8	3.3	3.7		3	1.8	10	2.83	.87	.28
14	4.4	3		3.6		4.2				4.9	2.7				3.8			7	3.80	.78	.29
15			5		3.4		2.7	1.8	2.5			1.4	3.8	2.8		3.3	2.3	10	2.90	1.04	.33
16	5.3	3.4		2.9		3				3.4	2.1				5.4			7	3.64	1.24	.47
17			4.5		2.1		3	1.1	2.5			2	2.2	3.2		3.7	1.7	10	2.60	1.01	.32
18	4.3	3.5		5		2.1				3.3	1.5				4.3			7	3.43	1.26	.48
19			3.7		3.1		3.3	1.6	2.3			1.4	4.4	3.5		5.3	2.5	10	3.11	1.21	.38
20	5.1	3.6		4.6		3.8				3.7	3.6				5.2			7	4.23	.72	.27
21			4.8		2.3			1.3	3.8			1.6	3.6	2.6		3.5	2.8	9	2.92	1.12	.37
22	3.5	2.3				2.5				3.4	1.8				4.5			6	3.00	.98	.40
23			6.2		2.8			1.5				2.1	3.8	1.8		2.8		7	3.00	1.61	.61
24	4	3				1.7				3	2.1				3.7			6	2.92	.89	.36
25			4.9		3.5			1.6				2.7	4	3		4.2		7	3.41	1.09	.41
26	4.1	3.9				2.2				3.3	2.3				5			6	3.47	1.09	.44
27			3		2.7		3.3	1.8				2.4	2.6	2.5		5.2		8	2.94	1.01	.36
28	3.7	3.9		3.3		2.2				3.5	2.4				4.6			7	3.37	.84	.32
29			3.7		2.6			1.2	2.6			2.2	4.7	2		4.5	2.4	9	2.88	1.18	.39
30	4.6	4.2				1.7				2.5	2				3.5			6	3.08	1.20	.49
31			3.4		3.4			2.3				3.5	4.7	3.8		3.8		7	3.56	.71	.27
32	5.5	5				3.1				4.3	2.9				3.9			6	4.12	1.03	.42
33			5.2		3			1.4				2.2	5.5	2.7		3.1		7	3.30	1.51	.57
34	3.5	4.3				2.2				4.3	2.9				3.9			6	3.52	.84	.34
35			3.3				4.1					2.6						3	3.33	.75	.43

Table A.9 -- Pregnancy and Parturition Study. Estradiol-17β Concentrations During Early Pregnancy

	Estraiol-17B (pg/ml)																	
							Llama #											
Time (days)	L026	L028	L128	L139	L140	L148	L158	L163	L167	L168	L169	L172	L185	L189	#	mean (pg/ml)	sd (n-1)	sem
1															0			
2															0			
3				12.8		25.0					8.1	6.8		8.3	5	12.20	7.50	3.36
4	7.3	13.6			16.8			7.8	11.4				10.5		6	11.23	3.59	1.46
5							10.5								1	10.51		
6	7.3														1	7.30		
7			9.5							63.3					2	36.43	38.05	26.90
8	5.3														1	5.30		
9				12.6		27.2					12.2	9.5		13.8	5	15.09	6.96	3.11
10	13.3	12.4			8.2			25.2	16.0				10.8		6	14.32	5.92	2.42
11															0			
12	34.3														1	34.30		
13			11.0							9.8					2	10.38	.89	.63
14	11.3														1	11.30		
15															0			
16	9.3														1	9.30		
17						20.5					11.7	8.2		6.5	4	11.72	6.25	3.13
18	45.3				7.8			9.6	9.2				9.2		5	16.23	16.26	7.27
19				9.8											1	9.75		
20	12.3														1	12.30		
21							14.0			113.5					2	63.78	70.34	49.74
22	9.3														1	9.30		
23			10.3												1	10.27		
24	7.3														1	7.30		
25															0			
26	7.3														1	7.30		
27															0			
28	8.3														1	8.30		
30	7.3														1	7.30		
31															0			
32	8.3														1	8.30		
33				7.0		71.0					8.0	9.0		7.0	5	20.40	28.30	12.66
34	10.3	14.0			12.0			5.0	3.0				9.0		6	8.88	4.19	1.71
35															0			

Table A.10 -- Pregnancy and Parturition Study. Total Estrogen Concentrations During Early Pregnancy

	Total Estrogens (pg/ml)																
							Llama #										
Time (days)	L:026	L:028	L:128	L:139	L:140	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	n	mean (pg/ml)	sd (n-1)	sem
1															0			
2															0			
3				55.3		62.4					20.1	5.5		44.0	5	37.45	23.97	10.72
4	19.0	39.4			56.4			36.4	53.7				39.8		6	40.79	13.48	5.51
5							53.4								1	53.37		
6	24.0														1	24.00		
7										108.9					1	108.86		
8	11.0														1	11.00		
9				37.5		64.7					21.8	11.8		44.3	5	36.03	20.47	9.16
10	19.0	37.1			47.3			42.7	54.9				45.3		6	41.04	12.28	5.01
11															0			
12	24.0														1	24.00		
13			78.6							47.9					2	63.25	21.76	15.39
14	10.0														1	10.00		
15															0			
16	19.0														1	19.00		
17						65.9					24.6	7.6		34.4	4	33.12	24.49	12.24
18	58.0				53.4			24.5	44.4				45.8		5	45.23	12.84	5.74
19				32.6											1	32.64		
20	26.0														1	26.00		
21							107.0			120.6					2	113.80	9.65	6.83
22	22.0														1	22.00		
23			70.3												1	70.34		
24	23.0														1	23.00		
25															0			
26	17.0														1	17.00		
27															0			
28	18.0														1	18.00		
29															0			
30	19.0														1	19.00		
31															0			
32	20.0														1	20.00		
33				29.0		94.7					7.0	18.0		46.0	5	38.93	34.32	15.35
34	21.0	45.0			54.0			39.0	27.0				40.0		6	37.67	11.99	4.90
35															0			

Table A.11 -- Pregnancy and Parturition Study. Cortisol Concentrations During Early Pregnancy

	Corsisol (ng/ml)																			
									Llama #											
time (days)	L:026	L:028	L:128	L:132	L:139	L:140	L:143	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	L:197	#	mean (ng/ml)	sd (n-1)	sem
1																		0			
2																		0			
3						11.5		12.1	5.4					20.3	10.0		5.3	6	10.77	5.52	2.25
4		9.6	5.8		21.8		15.0				5.1	9.3				7.0		7	10.51	5.97	2.26
5										9.0								1	9.00		
6																		0			
7				17.5									19.5					2	18.50	1.41	1.00
8																		0			
9						13.6			19.6					9.1	6.0		7.3	5	11.12	5.54	2.48
10		19.0	10.1				13.0				1.7	4.2				6.0		6	9.00	6.36	2.60
11																		0			
12																		0			
13				22.8									18.6					2	20.70	2.97	2.10
14																		0			
15																		0			
16																		0			
17						5.0			6.6					8.1	11.0		4.0	5	6.94	2.75	1.23
18		8.1	6.6				8.0				13.8	6.9				6.0		6	8.23	2.85	1.16
19								13.3										1	13.30		
20					18.0													1	18.00		
21				3.9						11.1			4.0					3	6.33	4.13	2.38
22																		0			
23																		0			
24																		0			
25																		0			
26																		0			
27																		0			
28																		0			
29																		0			
30																		0			

Table A.12 -- Pregnancy and Parturition Study. Triiodothyronine (T_3) Concentrations During Early Pregnancy

	T3 (ng/ml)																				
	Llama #																				
Time (days)	L:026	L:028	L:128	L:132	L:139	L:140	L:143	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	L:197	#	mean (ng/ml)	sd (n-1)	sem
1																		0			
2															3.0			1	3.00		
3					2.5		1.5	1.7					1.3	1.8		2.2		6	1.83	.45	.18
4	1.7	2.3		1.3		1.1				2.0	.9							6	1.55	.54	.22
5									1.3								1.1	2	1.20	.14	.10
6																		0			
7			1.1									1.4						2	1.25	.21	.15
8																		0			
9					1.3			.5					1.2	1.7		1.4		5	1.22	.44	.20
10	1.2	1.7				1.3				1.1	1.4				1.5			6	1.37	.22	.09
11																		0			
12																		0			
13			.9									2.2						2	1.55	.92	.65
14																		0			
15																		0			
16																		0			
17					1.7			1.4					1.0	1.5		1.2		5	1.36	.27	.12
18	1.8	1.9				.8				1.2	.8				1.2			6	1.28	.48	.19
19							2.1											1	2.10		
20				1.7														1	1.70		
21			.9						2.6			1.3					1.2	4	1.50	.75	.38
22																		0			
23																		0			
24																		0			
25																		0			
26																		0			
27																		0			
28																		0			
29																		0			
30																					

Table A.13 -- Pregnancy and Parturition Study. Tetraiodotyronine (T_4) Concentrations During Early Pregnancy

T4 (ng/ml)

Time (days)	L:026	L:028	L:128	L:132	L:139	L:140	L:143	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	L:197	#	mean (ng/ml)	sd (n-1)	sem
1																		0			
2																		0			
3					71.3		66.3	77.1					58.0	61.6		75.1		6	68.23	7.58	3.10
4	40.0	66.0		47.2		43.0			53.5	82.5	46.7				85.0		62.3	7	58.63	19.08	7.21
5																		2	57.90	6.22	4.40
6																		0			
7			53.1									51.0						2	52.05	1.48	1.05
8																		0			
9					58.8			50.7					63.1	57.2		70.0		5	60.36	7.44	3.33
10	57.3	73.4				46.2				60.5	45.7				66.0			6	58.18	10.94	4.47
11																		0			
12																		0			
13			52.4									48.0						2	50.20	3.11	2.20
14																		0			
15																		0			
16																		0			
17					63.2			88.2					51.4	60.8		44.0		5	61.52	16.77	7.50
18	64.9	67.6				37.4				54.7	39.6				69.0			6	55.53	14.13	5.77
19							65.0											1	65.00		
20				51.0														1	51.00		
21			51.7						70.4			51.0					58.0	4	57.78	8.99	4.49
22																		0			
23																		0			
24																		0			
25																		0			
26																		0			
27																		0			
28																		0			
29																		0			
30																		0			

Table A.14 -- Pregnancy and Parturition Study. Progesterone Concentrations During the Entire Pregnancy

P4 (ng/ml)

Time (weeks)	Llama # L:026	L:028	L:128	L:132	L:139	L:140	L:143	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	L:197	#	mean (ng/ml)	sd (n-1)	sem
1	.3	.5		.2	.5	.3	.2	.1	.6	.1	.3		.1	.3	.2	.7	.2	34	1.07	1.19	.20
	2.4	3.6		.9	2.2	.4	1.2	1.7	.4	.5	1.5		.2	2.4	1.9	3.8	.1				
				3.6			3.8		.6								.5				
2	4.7	3.8	1.4	4.4	5.5	2.6	2.8	1.3	2.2	2.8	1.8	1.5	1.8	4.3	3.0	3.6	2.1	61	2.90	1.16	.15
	.1	4.0	.1	2.9	3.4	3.2	5.0	1.8	5.1	4.9	2.0	1.6	4.0	4.2	3.5	3.0	2.2				
	3.7	3.7	3.9	2.3	2.5	3.0	2.5	1.7	3.0	3.0	1.9	1.5	3.6	3.7	3.4	3.0	1.6				
			3.9		2.9		2.2	1.8	3.9			1.8	3.3	3.7		3.0	1.8				
3	4.4	3.0	5.0	3.6	3.4	4.2	2.7	1.8	2.5	4.9	2.7	1.4	3.8	2.8	3.8	3.3	2.3	58	3.31	1.13	.15
	5.3	3.4	4.5	2.9	2.1	3.0	3.0	1.1	2.5	3.4	2.1	2.0	2.2	3.2	5.4	3.7	1.7				
	4.3	3.5	3.7	5.0	3.1	2.1	3.3	1.6	2.3	3.3	1.5	1.4	4.4	3.5	4.3	5.3	2.5				
	5.1	3.6		4.6		3.8				3.7	3.6				5.2						
4	3.5	2.3	4.8		2.3	2.5	3.3	1.3	3.8	3.4	1.8	1.6	3.6	2.6	4.5	3.5	2.8	49	3.08	1.09	.16
	4.0	3.0	6.2		2.8	1.7		1.5		3.0	2.1	2.1	3.8	1.8	3.7	2.8					
	4.1	3.9	4.9		3.5	2.2		1.6		3.3	2.3	2.7	4.0	3.0	5.0	4.2					
			3.0		2.7			1.8				2.4	2.6	2.5		5.2					
5	3.7	3.9	3.7	3.3	2.6	2.2		1.2	2.6	3.5	2.4	2.2	4.7	2.0	4.6	4.5	2.4	48	3.37	1.08	.16
	4.6	4.2	3.4		3.4	1.7		2.3		2.5	2.0	3.5	4.7	3.8	3.5	3.8					
	5.5	5.0	5.2		3.0	3.1		1.4		3.6	2.9	2.2	5.5	2.7	4.4	3.1					
	3.5	4.3				2.2				4.3	2.9				3.9						
6			3.3	4.3	3.5		4.1	2.6	1.6			2.6	4.6	2.4		3.2	1.8	13	3.47	1.35	.37
			6.5									4.6									
7	3.6	4.5	4.3	4.3		2.3	4.4		2.7	5.6	3.0	2.7			4.0		3.2	12	3.72	.97	.28
8	3.1	4.1	4.6	4.4	4.7	3.9	5.6	1.7	3.1	3.2	3.2	2.3	2.4	2.5	4.7	3.2	3.1	17	3.52	1.04	.25
9	4.1	2.9	3.1		2.9	4.3		2.2		3.1	4.4	5.3	3.4	4.7	6.0	4.2		13	3.89	1.08	.30
10	5.6	5.7	4.0		4.1	3.7	3.0	2.2		6.2	3.1	4.8	3.1	4.6	4.8	4.6		14	4.25	1.16	.31
12				4.3					3.1								2.7	3	3.37	.83	.48
14	3.8	4.9	4.0		3.0	3.3		2.2		5.1	3.6	6.3	2.9	4.9	5.0	4.5		13	4.12	1.13	.31
16				2.2			2.7											2	2.45	.35	.25
17									2.3								2.3	2	2.30	.00	.00
18	3.3	2.5			2.0	2.4		2.1		2.6	3.1		2.2	4.0	3.4	2.9		11	2.77	.63	.19
19			2.9									3.3						2	3.10	.28	.20
22				5.8			3.1		3.3								3.2	4	3.85	1.30	.65
24	3.3	4.6	3.9		3.3	2.8		2.9		3.5	3.0	2.9	2.6	2.8	4.3	3.4		13	3.33	.61	.17
25							4.1											1	4.10		
26				2.5					3.5								2.8	3	2.93	.51	.30

27					3.1			2.6					2.8	3.2		3.3		5	3.00	.29	.13
28	2.8	3.4	3.2			5.7				3.9	2.6	2.6			3.9			8	3.51	1.03	.36
30				2.8			3.6		3.1								3.3	4	3.20	.34	.17
32	4.2	3.6	3.5		3.9	2.5		2.4		2.8	3.6	3.7	4.0	3.2	5.1	3.5		13	3.54	.72	.20
34				4.9			3.4		3.2								3.1	4	3.65	.84	.42
35	4.8	4.7				5.7				4.7								4	4.98	.49	.24
36			4.4		4.2			3.0			4.4	3.6	3.0	3.7	6.5	3.9		9	4.08	1.05	.35
38				5.2			3.6											2	4.40	1.13	.80
39									2.5								2.9	2	2.70	.28	.20
40	4.8	4.5			6.7	3.2		2.9		5.0	1.6		4.7	2.8	3.5	2.8		11	3.86	1.42	.43
41			4.8									2.8						2	3.80	1.41	1.00
43				2.9			4.1		2.9								3.0	4	3.23	.59	.29
45	2.6	2.7	4.2	5.3	3.3	1.2	9.9	2.3	5.3	2.6	4.8	2.8	3.2	4.2	2.7	4.0	2.5	17	3.74	1.95	.47
46				4.9			5.7											2	5.30	.57	.40
47	2.8	5.7	5.2	4.9	3.9	2.7	3.5	3.8	3.9	6.5	3.8	2.9	5.0	3.0	4.1	7.2	2.9	25	4.04	1.24	.25
				3.5			5.1		3.9								2.2				
				3.1			4.8		3.5								3.0				
48	4.4	4.4		4.0	4.1	3.5	3.1	3.0	3.9	4.9	4.0		6.7	5.3	2.8	4.4	2.1	24	3.65	1.17	.24
				3.1			3.0		2.9								1.9				
				2.6			3.3		5.3								2.7				
									2.1												
49	1.7	1.9	4.4	9.0	2.7	3.0	3.3	1.5	2.0	2.4	2.7	2.4	2.6	3.9	1.6	3.6	2.5	50	3.02	1.39	.20
	4.0	4.0	4.9	2.1	4.1	2.3	1.5	2.7	2.9	5.3	2.8	1.5	4.9	4.6	3.1	4.4	1.0				
	2.6	4.8	4.3	2.3	3.4	3.4	2.9	1.5		2.4	1.4	2.5	3.0	3.3	1.5	2.9	1.4				
50	3.4	3.4	2.1	3.0	3.4	3.8	4.1	1.6	2.1	4.1	2.6	1.3	3.5	2.3	1.9	3.7	.8	51	2.43	1.54	.22
	.6	2.3	6.8	1.3	3.4	3.6	2.6	1.4	4.0	3.2	.2	4.3	2.8	1.9	2.1	4.6	2.7				
	.3	5.3	2.2	1.8	2.8	1.9	1.5	.2	.3	1.8	.2	.4	1.1	.5	.9	6.2	1.6				
51	.1	3.8	1.7	1.1	1.9	.1	2.6	.1	.2	2.3	.1	.2	.2	.2	.1	2.8	1.1	45	.85	1.03	.15
	.1	2.3	2.7		.5	.1		.1	.3	.2	.1	.2	.2	.3	.1	2.5	1.8				
		2.1	2.1		.5	.3		.1	.4	.2	.1	.1	.2	.2	.1	1.8					
52	.2	.9	.4		.9	.4		.2	.3	.7	.3	.2	.4	.7	.4	3.6		39	.42	.57	.09
	.1	.3	.5		.3	.1		.2	.3	.5	.1	.6	.1	.1	.1	.2					
		.3	.2		.2	.2			.5	.9		.1	.2	.2	.1	.4					
53		.3	.2		.2	.2				.2						.2		13	.22	.06	.02
		.3	.3		.2											.2					
		.2	.2													.1					
54		.2														.2		3	.20	.00	.00
																.2					

Table A.15 -- Pregnancy and Parturition Study. Estradiol-17β Concentrations During the Entire Pregnancy

	Estradiol-17B (pg/ml)																	
							Llama #											
Time (weeks)	L:026	L:028	L:128	L:139	L:140	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	#	mean (pg/ml)	sd (n-1)	sem
1	20.7	13.6		12.8	16.8	25.0	10.5	7.8	11.4		8.1	6.8	10.5	8.3	12	12.69	5.59	1.61
2	31.2	12.4	9.5	12.6	8.2	27.2		25.2	16.0	63.3	12.2	9.5	10.8	13.8	15	18.19	14.36	3.71
			11.0							9.8								
3	33.3			9.8	7.8	20.5		9.6	9.2		11.7	8.2	9.2	6.5	10	12.58	8.24	2.61
4	21.5		10.3				14.0			113.5					4	39.84	49.35	24.67
5	22.3	13.6		6.9	11.8	71.4		4.8	3.5		8.2	8.8	8.9	6.6	11	15.17	19.35	5.83
6			9.2							77.4					2	43.29	48.27	34.13
7							8.1								1	8.07		
10	22.5	11.1	5.8	7.2	13.4	6.4		10.1	7.0	75.8	5.6	11.9	10.9	4.1	13	14.75	18.95	5.25
12							8.7								1	8.74		
14	27.2	4.4	10.3	8.3	5.2	14.3		21.5	5.6	84.6	6.7	6.6	5.4	6.4	13	15.89	21.79	6.04
17							10.3								1	10.27		
18	24.0	9.3		11.6	19.9	17.0		16.7	3.8		7.9	11.2	8.9	6.7	11	12.46	6.17	1.86
19			9.9							75.0					2	42.46	46.00	32.52
22							14.9								1	14.90		
24	29.1	15.4	8.7	9.0	7.6	32.6		20.0	15.9	91.7	14.0	10.2	9.9	12.1	13	21.25	22.55	6.25
26							9.5								1	9.50		
27				19.5		79.6					20.2	18.6		10.9	5	29.76	28.13	12.58
28	28.1	22.3	12.8		14.8			17.4	19.8	74.8			13.2		8	25.40	20.59	7.28
30							22.1								1	22.10		
32	28.8	8.5	13.7	29.4	12.2	91.3		15.1	18.3	82.8	22.0	14.1	6.8	11.0	13	27.23	27.49	7.62
36	43.4		26.1	37.8	18.2	93.3		21.3	23.4	102.8	42.6	19.0			10	42.78	30.66	9.70
39							48.1								1	48.11		
40	99.0	42.7		63.5	69.7	156.8		49.4	59.9		113.6	47.5	33.8	31.7	11	69.80	38.57	11.63
41			60.0							114.8					2	87.36	38.75	27.40
43							160.0								1	160.04		
45	154.0	212.3	125.9	185.3	86.3	281.3	190.6	165.7	170.0	200.8	222.2	114.6	106.5	126.8	14	167.31	53.05	14.18
47	104.9	219.9	144.3	240.5	87.1	173.4	246.1	129.2	190.4	234.3	167.0	128.9	188.4	164.7	24	168.87	41.11	8.39
	180.4				129.1	165.1			167.5	185.3	185.8	120.1						
	144.7					172.0			183.6									
48	116.6	235.6		247.6	104.1	251.8	220.5		197.9	241.0	199.1	142.7	207.3	133.6	22	201.33	51.02	10.88
					236.1	227.8			191.6	321.0	177.5	218.2	187.2					
						186.5			145.9	239.8								
49	159.5		139.4	216.3	117.0	248.6	199.8	168.3	9.3	222.4	208.3	215.8	185.7		16	184.60	60.22	15.06
							202.2	174.7										
							260.2	226.2										
50	123.5	311.7	194.6	181.9	127.4	251.3	245.0	168.2	140.6	294.1	259.4	161.5	137.7	140.5	40	169.63	84.67	13.39
	74.8	218.9	182.0	270.9	104.5	237.9	226.9	196.0	9.7	282.1	244.5	111.7	160.7	141.6				
	22.4		149.9	277.2	116.4	79.9	16.0	255.6	7.0	198.0	247.5	15.0	192.7					
51	27.1	269.9	137.5	182.1	10.8	57.7	18.7	206.4	.0	85.3	17.8	10.0	142.0	199.1	40	68.48	76.84	12.15
	29.7	220.5	129.0	22.5	11.9	85.1	17.5	11.9	2.0	66.4	16.4	7.7	9.4	186.8				
	51.3	182.4	17.4	10.9	10.6		24.4	5.8		81.4	14.1	11.8	6.4	141.5				
52	25.6	212.1	14.8	20.2				13.6					7.0	30.7	16	29.34	49.89	12.47
	48.6	9.0	13.0	15.1									8.1	18.5				
		8.8	7.1											17.4				
53		13.7												16.4	4	16.53	2.31	1.16
		16.6												19.4				

Table A.16 -- Pregnancy and Parturition Study. Total Estrogen Concentrations During the Entire Pregnancy

	Total Estrogens (pg/ml)																	
							Llama #											
Time (weeks)	L:026	L:028	L:128	L:139	L:140	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	#	mean (pg/ml)	sd (n-1)	sem
1	21.7	39.4		55.3	56.4	118.7	53.4	36.4	53.7		20.1	5.5	39.8	44.0	12	45.37	28.07	8.10
2	18.0	37.1		37.5	47.3	122.7		42.7	54.9	195.5	21.8	11.8	45.3	44.3	14	60.75	49.02	13.10
			78.6							92.9								
3	28.1			32.6	53.4	124.9		24.5	44.4		24.6	7.6	45.8	34.4	10	42.03	31.89	10.09
4	20.4		70.3				107.0			213.5					4	102.80	81.92	40.96
5	19.3	45.1		28.9	54.2	173.1		38.6	27.4		7.1	17.6	40.4	45.6	11	45.20	44.70	13.48
6			73.3							207.1					2	140.21	94.63	66.92
7							99.1								1	99.07		
10	11.3	50.7	50.7	24.8	45.9	100.3		39.9	51.5	213.9	8.3	15.3	47.1	40.5	13	53.86	53.61	14.87
12							64.2								1	64.21		
14	24.9	54.4	56.2	31.5	41.4	83.9		36.6	42.0	218.7	7.8	8.4	36.1	33.2	13	51.93	53.94	14.96
17							108.8								1	108.79		
18	21.7	47.4		37.2	57.9	115.7		46.1	32.4	0		17.5	34.9	30.8	10	44.16	27.87	8.81
19			74.9							238.7					2	156.78	115.80	81.88
22							146.5								1	146.51		
24	23.7	48.7	51.4	36.9	46.2	132.5		54.4	73.9	207.0	17.5	24.7	42.1	48.9	13	62.14	52.25	14.49
26							113.4								1	113.42		
27				43.1		168.9					22.1	35.3		46.2	5	63.13	59.84	26.76
28	9.7	51.8	66.7		38.4			54.6	62.0	169.5			48.3		8	62.62	46.63	16.48
30							91.6								1	91.60		
32	30.4	39.9	82.8	46.8	47.7	254.3		34.3	57.3	191.6	26.0	15.3	35.3	43.4	13	69.64	71.11	19.72
36	43.1		89.9	72.2	67.4	273.8		70.3	64.1	207.3	73.3	28.6			10	99.00	78.07	24.69
39							217.6								1	217.58		
40	89.7	152.1		197.4	171.5	437.9		133.8	128.2		275.8	101.3	124.6	121.0	11	175.76	101.18	30.51
41			189.8							309.7					2	249.75	84.78	59.95
43							1086.5								1	1086.49		
45	378.0	875.8	430.3	754.8	371.0	1116.1	1070.8	479.8	487.6	580.3	791.1	423.7	398.8	316.1	14	606.74	267.14	71.40
47	202.4	897.1	493.9	658.1	447.0	887.9	1419.1	468.6	660.7	812.6	559.9	486.6	569.8	463.5	24	606.95	266.27	54.35
	130.5				578.4	746.4			737.2	638.6	542.7	378.6						
	253.3					802.7			731.2									
48	226.9	975.6		813.6	460.4	996.3	1187.9		800.9	901.4	597.8	437.4	596.8	324.3	24	681.97	279.39	57.03
	222.4				601.3	861.3			729.5	1236.5	526.1	702.8	621.4					
	303.2					832.2			530.6	880.5								
49	340.9		568.7	902.3	541.9	1056.7	1453.8	735.4	40.9	821.4	876.2	927.3	576.8		16	838.80	412.67	103.17
							1367.1	650.0										
							1658.1	903.4										
50	170.2	957.5	714.4	674.9	591.0	1093.3	992.5	708.5	463.1	962.6	934.0	574.2	460.9	428.5	40	638.32	371.85	58.79
	99.8	1090.1	519.6	1258.6	452.8	1081.6	1053.5	813.5	98.3	859.0	650.7	402.5	571.3	546.4				
	30.8		661.9	1278.0	546.7	207.7	71.5	1403.5	54.1	688.4	892.6	13.0	481.3					
51	20.0	1282.5	510.1	815.5	50.7	189.7	76.7	1041.0	1.2	203.5	30.4	.0	448.3	485.0	40	262.18	359.23	56.80
	56.9	1131.8	424.6	100.1	49.6	242.2	64.5	37.6	19.3	211.7	21.3	.0	37.4	570.6				
	31.4	1165.0	139.1	34.7	43.3		141.5	20.3		250.4	18.1	9.7	36.4	475.5				
52	28.0	1315.2	88.6	52.7				35.4					35.9	64.0	16	132.97	315.76	78.94
	32.5	47.8	89.8	54.6									47.4	56.9				
		58.1	72.0											48.8				
53		65.3												59.4	4	57.64	10.88	5.44
		64.1												41.8				

Table A.17 -- Pregnancy and Parturition Study. Cortisol Concentrations During the Entire Pregnancy

	Cortisol (ng/ml)																				
									Llama #												
Time (weeks)	L:026	L:028	L:128	L:132	L:139	L:140	L:143	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	L:197	#	mean (ng/ml)	sd (n-1)	sem
1	9.6	5.8		21.8	11.5	15.0	12.1	5.4	9.0	5.1	9.3		20.3	10.0	7.0	5.3	4.0	15	10.08	5.40	1.39
2	19.0	10.1	17.5		13.6	13.0		19.6			4.2	19.5	9.1	6.0	6.0	7.3		14	13.31	6.20	1.66
			22.8									18.6									
3	8.1	6.6		18.0	5.0	8.0	13.3	6.6		13.8	6.9		8.1	11.0	6.0	4.0		13	8.88	4.03	1.12
4			3.9						11.1			4.0					17.0	4	9.00	6.31	3.15
5	8.3	12.1			7.4	20.0		15.9		8.4	9.8		26.4	12.0	11.2	27.0		11	14.41	7.08	2.13
6			16.6									12.0						2	14.30	3.25	2.30
8				14.5			21.1		7.7								16.0	4	14.83	5.53	2.76
10	19.5	11.4	24.8		11.2	26.0		16.5		12.1	9.3	6.1	15.4	9.0	14.0	10.0		13	14.25	6.07	1.68
12				11.4			12.8		5.1								10.0	4	9.83	3.35	1.68
14	5.0	15.0	13.7		4.3	15.3		9.1		13.3	6.0	6.4	18.0	11.0	15.0	10.0		13	10.93	4.51	1.25
16				5.5			13.6											2	9.55	5.73	4.05
17									7.4								22.0	2	14.70	10.32	7.30
18	14.6	6.2			21.2	30.2		17.0		11.2	4.8		4.0	13.4	15.0	11.0		11	13.51	7.65	2.31
19			28.5									7.3						2	17.90	14.99	10.60
22				32.3			13.8		7.9								18.1	4	18.03	10.39	5.20
24	10.7	2.6	17.5		20.8	6.1		9.7		8.5	9.3	5.1	8.0	17.0	9.0	5.0		13	9.95	5.39	1.50
25							21.4											1	21.40		
26				10.7					11.2								19.0	3	13.63	4.65	2.69
27					27.8			12.0					10.0	9.0		16.4		5	14.64	7.64	3.42
28	13.7	15.9	24.0			20.0				8.1		5.7			6.0			7	13.34	7.12	2.69
30				11.2			20.1		10.9								8.4	4	12.65	5.12	2.56
32	29.1	11.7	33.7		40.5	17.0		16.8		5.3	7.3	5.8	15.1	6.0	9.2	5.0		13	15.42	11.93	3.31
34				29.5			15.3		6.0								8.3	4	15.03	10.61	5.31
36	5.8	13.7	19.0		8.9	12.0		14.0		14.5	11.7	8.6	17.3	9.1	11.6	15.0		13	12.37	3.73	1.04
38				6.3			12.5											2	9.40	4.38	3.10
39									7.6								17.3	2	12.45	6.86	4.85
40	5.2	4.0			12.4	7.8		6.8		11.8	8.4		13.9	23.9	9.6	4.1					
41			9.3									5.7						2	7.50	2.55	1.80
43				21.6			31.7		10.9									3	21.40	10.40	6.01
40	5.2	4.0			12.4	7.8		6.8		11.8	8.4		13.9	23.9	9.6	4.1					
45	15.1	9.0	18.2		43.7	12.0		16.1		9.8	18.2	51.9	37.4	38.6	21.3	41.7		13	25.62	14.79	4.10
46				35.0			15.0											2	25.00	14.14	10.00
47				11.4			11.5		24.9								8.7	10	16.25	7.38	2.33
				28.6			16.0		5.1												
				21.9			16.3		18.1												
48	10.3	10.5		20.9	33.0	28.9	24.5	31.0	6.1	13.5	22.9		30.0	32.6	21.2	21.2	13.0	23	18.24	8.58	1.79
				17.7			18.2		8.3								8.7				
				14.3			12.8		8.9								11.0				
49	10.7	6.1	15.3	7.5	8.7	12.4	29.8	9.0	7.1	5.2	8.1	28.3	6.6	6.3	3.4	7.8	13.0	51	14.23	8.66	1.21
	24.7	21.2	16.0	10.1	31.3	38.8	15.7	26.1	4.5	7.4	12.7	9.4	32.0	24.1	26.8	26.8	7.6				
	9.8	11.3	15.3	11.4	11.0	15.3	17.4	11.0	7.3	13.8	10.1	27.8	13.6	7.1	6.9	10.7	5.2				
50	14.6	8.3	10.6	11.4	16.0	11.1	11.7	10.7	6.8	6.4	10.6	10.7	15.1	12.2	12.9	12.8	2.3	51	11.96	5.13	.72
	27.7	11.8	14.3	6.6	9.6	9.1	14.8	15.6	13.1	5.4	18.6	5.9	10.5	7.9	10.6	9.3	21.5				
	18.6	4.8	15.6	8.5	13.3	14.6	16.7	10.1	16.0	7.0	20.1	25.9	8.2	7.3	13.5	5.5	8.2				
51	8.2	6.4	10.6	10.5	4.0	7.1	8.8	4.7	16.6	2.1	5.4	9.2	4.5	7.9	8.0	4.9	9.1	46	7.92	3.79	.56
	8.1	6.8	8.8		15.8	10.2		7.2	7.6	4.2	19.3	5.2	5.5	6.9	3.5	3.7	7.8				
	7.9	6.4	14.0		17.8	13.8		8.5	3.4	4.3	3.4	6.2	4.9	6.3	5.9	10.0					
52	5.4	16.6	14.6		49.2	26.0		18.4	6.1	7.5	13.7	4.6	15.8	37.7	19.4	19.7		39	14.31	9.27	1.48
	8.6	10.2	27.4		14.3	3.8		18.9	8.0	10.3	9.4	16.7	19.8	9.5	4.9	21.3					
					10.4				6.3				23.2	11.7		15.8					
		1.9	8.2			11.8				9.8		14.0			9.1						
53		10.8	19.0		10.6	4.0				5.2						10.3		13	8.64	4.28	1.19
		5.9	9.0		7.7											8.6					
		6.5	12.4													2.3					
54		10.8														5.8		3	8.90	2.71	1.56
																10.1					

Table A.18 -- Pregnancy and Parturition Study. Triiodotyronine (T_3) Concentrations During the Entire Pregnancy

	T_3 (ng/ml)									Llama #											
Time (weeks)	L:026	L:028	L:128	L:132	L:139	L:140	L:143	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	L:197	#	Mean (ng/ml)	sd (n-1)	sem
1	1.7	2.3		1.3	2.5	1.1	1.5	1.7	1.3	2.0	.9		1.3	1.8	3.0	2.2	1.1	15	1.71	.59	.15
2	1.2	1.7	1.1		1.3	1.3		.5		1.1	1.4	1.4	1.2	1.7	1.5	1.4		15	1.33	.39	.10
			.9									2.2									
3	1.8	1.9		1.7	1.7	.8	2.1	1.4		1.2	.8		1.0	1.5	1.2	1.2		13	1.41	.42	.12
4			.9						2.6			1.3					1.2	4	1.50	.75	.38
5	2.8	3.2			3.2	1.0		2.0		2.7	2.0		1.2	1.8	1.8	1.4		11	2.10	.77	.23
6			1.6									2.0						2	1.80	.28	.20
8				2.0			2.8		2.3								1.0	4	2.03	.76	.38
10	2.4	3.9	1.5		4.4	.8		1.6		1.4	1.2	2.8	1.3	1.1	1.8	1.3		13	1.96	1.11	.31
12				2.3			3.0		2.4								1.4	4	2.28	.66	.33
14	3.2	2.3	1.6		2.9	1.0		2.1		2.0	2.1	2.9	1.3	2.0	2.3	2.8		13	2.19	.65	.18
16				2.7			3.6											2	3.15	.64	.45
17									3.7								1.7	2	2.70	1.41	1.00
18	2.7	3.9			3.7	2.5		2.4		2.9	1.0		1.6	1.2	1.5	1.7		11	2.28	.37	.29
19			1.1									2.1						2	1.60	.71	.50
22				3.3			3.3		1.9								1.3	4	2.45	1.01	.51
24	2.3	2.9	1.6		3.9	1.2		2.3		1.7	2.0	2.4	1.4	2.0	2.6	1.6		13	2.15	.72	.20
25							2.4											1	2.40		
26				1.9					2.6								1.4	3	1.97	.50	.35
27					1.8			2.3					1.2	1.5		1.3		5	1.62	.44	.20
28	1.9	2.3	1.1			.6				2.0	2.0	1.3			2.5			8	1.71	.65	.23
30				2.1			2.4		1.5								1.3	4	1.83	.51	.26
32	2.5	2.8	.9		2.1	1.4		1.7		1.5	1.9	3.8	1.7	1.9	2.1	1.3		13	1.97	.74	.21
34				2.0			1.9		2.8								1.3	4	2.00	.62	.31
36	2	2.5	1.4		2.6	.9		3.6		1.6	3.3	2.7	1.4	1.8	1.7	1.5		13	2.06	.79	.22
38				2.5			1.4											2	1.95	.78	.55
39									1.6								2.0	2	1.80	.28	.20
40	2.7	2.7			2.0	1.1		1.9		1.0	.6		1.6	1.7	2.1	1.6		11	1.73	.66	.20
41			1.2									2.8						2	2.00	1.13	.80
43				1.5			1.2		1.8								1.4	4	1.48	.25	.13
45	1.4	2.3	1.1		1.6	1.0		2.0		1.5	1.0	1.3	1.4	1.5	1.6	1.4		13	1.47	.37	.10
47				1.6			1.3		.9								1.7	6	1.37	.32	.13
				1.1	.		1.6														
48				2.0			2.0		1.3								2.3	10	1.77	.37	.12
				1.6			1.6		1.3								1.7				
									1.6								2.3				
49	1.7	2.1	.8	1.3	1.3	.9	1.9	1.3	1.2	1.2	.7	1.4	.9	1.0	1.8	1.7	1.4	34	1.36	.41	.07
	1.3	1.1		1.3	1.6	.9	1.7	1.2	1.1	2.3	1.3		.9	2.3	1.7	.9	1.4				
				1.4			1.2														
50	2.2	1.2	1.2	2.3	2.3	1.2	1.8	1.9	1.8	1.3	2.0	1.8	1.1	1.4	2.5	1.6	1.5	34	1.62	.45	.08
	1.6	1.4	1.5		1.8	1.9		1.9	1.3	1.6	.9	1.6	1.8	1.3	2.4	2.1	1.3				
			1.0									.6									
51	1.6	1.8	1.1		1.3	1.3		1.9		1.2	1.2	1.3	1.2	1.4	1.9	1.7		37	1.40	.35	.06
	1.8	2.0	1.3		.7	1.3		1.7		.9	.9	1.2	1.2	1.3	1.9	1.3					
	2.2	1.8			1.6	1.3		1.2		1.2	1.0		1.0	1.1	1.6	1.5					
52	1.5	1.9	1.5		1.5	1.1		1.3		1.6	1.0	1.2	1.7	1.9	1.9	3.6		15	1.59	.64	.16
			1.1									1.1									

Table A.19 -- Pregnancy and Parturition Study. Tetraiodothyronine (T_4) Concentrations During the Entire Pregnancy

	T4 (ng/ml)								Llama #											
Time (weeks)	L:026	L:028	L:128	L:132	L:139	L:140	L:143	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	L:197	#	mean (ng/ml)	sd (n-1)	sem
1	40.0	66.0		47.2	71.3	43.0	66.3	77.1	53.5	82.5	46.7		58.0	61.6	85.0	75.1	62.3	15	62.37	14.28	3.69
2	57.3	73.4	53.1		58.8	46.2		50.7		60.5	45.7	51.0	65.1	57.2	66.0	70.0		15	57.03	8.61	2.22
			52.4									48.0									
3	64.9	67.6		51.0	63.2	37.4	65.0	88.2		54.7	39.6		51.4	60.8	69.0	44.0		13	58.22	13.90	3.86
4			51.7						70.4			51.0					58.0	4	57.78	8.99	4.49
5	59.0	75.2			87.8	33.3		86.1		47.0	44.4		51.3	54.9	75.1	48.0		11	60.19	18.12	5.46
6			47.9									55.1						2	51.50	5.09	3.60
8				56.3			66.0		74.1								58.0	4	63.60	8.18	4.09
10	60.4	63.3	42.3		66.7	41.0	58.8	91.5		59.7	43.0	49.0	62.0	53.7	71.0	66.0		14	59.17	13.37	3.57
12				45.3					62.1								53.0	3	53.47	8.41	4.86
14	55.4	69.7	42.3		56.5	42.7		91.4		44.2	37.2	57.0	65.7	57.8	70.1	71.0		13	58.56	15.10	4.19
16				59.4			61.0											2	60.20	1.13	.80
17									67.4								59.0	2	63.20	5.94	4.20
18	53.5	53.0			62.7	35.8		61.8		51.7	36.0		62.1	45.0	60.2	58.0		11	52.71	9.90	2.99
19			45.1									56.0						2	50.55	7.71	5.45
22				64.4			60.0		66.8								70.0	4	65.30	4.22	2.11
24	53.8	77.5	49.0		61.7	44.5		66.8		54.0	42.0	58.0	70.6	56.5	88.0	67.0		13	60.72	13.13	3.64
25							54.6											1	54.60		
26				58.2					69.1								60.0	3	55.77	5.84	3.37
27					49.0			63.6					56.0	51.0		70.2		5	57.56	8.86	3.96
28	54.1	74.1	45.7			42.3				41.0	39.4	62.7			89.3			8	56.08	18.04	6.38
30				53.4			53.2		54.1								62.1	4	55.70	4.28	2.14
32	69.2	66.2	46.4		60.5	42.8		54.1		51.6	54.4	51.5	54.2	69.1	80.5	57.0		13	56.73	10.23	2.84
34				52.1			55.6		64.8								58.0	4	57.63	5.36	2.68
36	56.0	55.2	44.2		53.4			60.8		51.0	71.2	52.4	49.0	55.6	72.3	72.4		12	56.13	10.58	3.05
38				58.6			58.2											2	58.40	.28	.20
39									46.3								67.0	2	56.65	14.64	10.35
40	58.0	83.8			54.7			65.2		39.6	21.3		62.7	63.0		71.0		9	57.70	18.13	6.04
41			53.3									60.0						2	56.65	4.74	3.35
43				53.0			51.0		39.0								50.0	4	48.25	6.29	3.15
45	42.0	58.0	46.0		38.0			49.0		50.0	42.0	51.0	45.0	35.0	51.0	50.0		12	46.42	6.40	1.85
47				50.7					35.7								43.5	4	42.70	6.24	3.12
				40.9																	
48				44.8					43.4								39.5	8	42.61	4.00	1.42
				47.4					45.0								34.4				
									43.6								42.8				
49	35.2	45.6	32.2	48.1	47.2			36.1	41.5	37.7	25.7	41.0	34.1	35.9	56.4	35.0	42.1	29	37.22	11.04	2.05
	16.0	38.6		49.7	38.6			50.3	37.7	38.0	12.3		13.0	24.2	40.6	29.5	44.8				
				52.4																	
50	17.3	48.2	29.5	47.3	41.4			44.8	41.1	34.2	14.0	20.8	11.0	27.2	41.2	32.6	34.3	31	33.50	13.30	2.39
	30.3	59.7	28.8		41.2			42.3	66.9	42.4	17.0	14.4	17.8	32.1	39.6	39.3	35.2				
			25.9									20.8									
52	53.9	41.2	45.3		42.2			65.8		44.2	31.8	61.0	51.5	47.2	61.8	39.8		35	48.87	8.62	1.46
	53.3	40.3	29.8		38.4			60.8		53.2	45.9	49.0	47.2	47.6	55.4	41.0					
	58.0	41.3	33.4		58.7			58.6		49.4	50.1		49.8	46.7	59.2	37.5					
52	57.0	53.1	50.1		47.0			70.1		48.7	23.4	47.8	29.2	39.5	46.8	57.4		14	45.79	12.90	3.45
			45.3									25.6									

Table A.20 -- Pregnancy and Parturition Study. Progesterone Concentrations During Late Pregnancy

	Progesterone (ng/ml)																	
	Llama #																	
Time (days)	L:026	L:028	L:128	L:139	L:140	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	#	mean (ng/ml)	sd (n-1)	sem
-15		3.4			3.5			2.4			6.7		2.8		5	3.76	1.70	.76
-14			4.3	4.1			5.3					5.3		4.6	5	4.72	.56	.25
-13		2.3			3.0			5.3			2.3		1.6		5	2.90	1.43	.64
-12						3.0						3.9			2	3.45	.64	.45
-11	4.4		2.1	3.4	2.3		2.1		4.0	2.4	4.9		3.1	6.2	10	3.49	1.38	.44
-10		5.3				1.5		2.4				4.6			4	3.45	1.79	.90
-9	1.7		6.8	3.4			2.0		2.7	1.5				2.8	7	2.99	1.81	.68
-8		3.8			3.4	2.7		4.1			3.0		1.5		6	3.08	.93	.38
-7	4.0		2.2	3.4			2.9		2.8	2.5		3.3		2.7	8	2.98	.57	.20
-6		2.3			3.8			3.2			3.5		1.9		5	2.94	.81	.36
-5						1.5						2.3			2	1.90	.57	.40
-4	2.6		1.7	2.8	3.6		2.1		1.4	1.3	2.8		2.1	1.8	10	2.22	.72	.23
-3		2.1				1.6		1.8				1.9			4	1.85	.21	.10
-2	3.4		1.2	1.9			4.0		2.6	4.3				3.6	7	3.00	1.14	.43
-1		.9			1.9	1.4		2.3			1.1		.9		6	1.42	.57	.23
0	.6		.5	.5			.3		.2	.4		.5		.2	8	.40	.15	.05
1		.3			.1			.2			.2		.1		5	.18	.08	.04
2						.2						.2			2	.20	.00	.00
3	.3		.4	.5	.1		.2		.2	.2	.2		.1	.4	10	.26	.13	.04
4		.3				.1		.2				.3			4	.23	.10	.05
5	.1		.5	.9			.3		.1	.2				.2	7	.33	.29	.11
6		.3			.3	.1		.7			.2		.1		6	.28	.22	.09
7	.1		.2	.3			.4		.1	.1		.2		.2	8	.20	.11	.04
8		.3			.4			.5			.4		.4		5	.40	.07	.03
9						.1						.7			2	.40	.42	.30
10	.0		.2	.2	.1		.3		.1	.2	.1		.1	.1	10	.14	.08	.03
11		.2				.2		.9				.1			4	.35	.37	.18
12	.2		.2	.2			.3		.3	.6				.2	7	.29	.15	.06
13		.2			.2	.2		.2			.2		.1		6	.18	.04	.02
14	.1		.3	.2			.5		.1	.1		.2		.2	8	.21	.14	.05
15					.2										1	.20		

Table A.21 -- Pregnancy and Parturition Study. Estradiol-17β Concentrations During Late Pregnancy

	Estradiol-17B (pg/ml)																	
	Llama #																	
Time (days)	L:026	L:028	L:128	L:139	L:160	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	#	mean (ng/ml)	sd (n-1)	sem
-15	141	312			236	228		163			178		187		7	206.4	57.5	21.7
-14									192	240		218			3	216.7	24.0	13.9
-13								175							1	175.0		
-12	117					186									2	151.3	49.1	34.7
-11			195	216			200		146	222				142	6	186.8	34.7	14.1
-10		219						226							2	222.5	4.9	3.5
-9			182	182			202							199	4	191.3	10.8	5.4
-8		270			117			168			208		186		5	189.8	56.0	25.1
-7			150	271			260					216		187	5	216.8	50.4	22.5
-6		221			127			196			259		138		5	188.2	55.7	24.9
-5	160					249						161			3	189.8	51.2	29.6
-4			138	277	104		245			294	244		161	142	8	200.6	72.4	25.6
-3	124	182				251		256				112			5	184.9	68.0	30.4
-2			129	182			227		141	282				31	6	165.3	86.8	35.4
-1	75	212			116	238		206			248		193		7	184.0	64.4	24.4
0			17	23			16		10	198		15		18	7	42.4	68.7	26.0
1		9			11			12			18	- -	142		5	38.4	58.0	25.9
2	22					80						10			3	37.5	37.3	21.6
3			15	11	12		19		7	85	16		9	17	9	21.2	24.2	8.1
4	27	9				58		6				8			5	21.6	22.0	9.9
5			13	20			18		0	66				16	6	22.2	22.6	9.2
6	30	14			11	85		14			14		6		7	24.8	27.5	10.4
7			7	15			24		2	81		12		19	7	22.9	26.7	10.1
8		17											7		2	12.0	7.1	5.0
9	51														1	51.3		
10													8		1	8.0		
11	26														1	25.6		
12															0			
13															0			
14	49														1	48.6		
15															0			

Table A.22 -- Pregnancy and Parturition Study. Total Estrogen Concentrations During Late Pregnancy

Total Estrogen (pg/ml)

Time (days)	Llama # L:026	L:028	L:128	L:139	L:140	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	#	mean (pg/ml)	sd (n-1)	sem
-15	222	957			601	861		735			554		621		7	650.2	238.5	90.1
-14									730	881		730			3	780.3	87.2	50.3
-13								650							1	650.0		
-12	303					832									2	567.6	373.9	
-11			714	902			1454		531	821				546	6	828.0	340.0	138.8
-10		1090						903							2	996.5	132.2	93.5
-9			520	657			1367							485	4	757.3	413.2	206.6
-8		1282			542			708			904		577		5	802.6	303.3	135.6
-7			662	1259			1658					955		571	5	1021.0	446.7	199.8
-6		1132			591			813			961		461		5	791.6	271.4	121.4
-5	341					1057						602			3	666.6	362.4	209.2
-4			510	1278	453		993			963	678		571	475	8	740.1	302.6	107.0
-3	170	1165				1093		1404				430			5	852.4	525.3	234.9
-2			425	816			1053		463	859				64	6	613.3	361.8	147.7
-1	100	1315			547	1062		1041			920		481		7	780.8	420.3	158.9
0			139	100			72		98	688		40		57	7	170.6	230.4	87.1
1		48			51			38			58		448		5	128.6	178.7	79.9
2	31					208						26			3	88.3	103.7	59.9
3			89	35	50		77		54	204	49		37	49	9	71.6	52.7	17.6
4	20	58				190		20				24			5	62.4	73.1	32.7
5			90	53			64			212				59	5	95.6	66.6	29.8
6	57	65			43	242		35			45		36		7	74.7	74.6	28.2
7			72	55			142		19	250		37		42	7	88.1	81.6	30.9
8		64											36		2	50.0	19.8	14.0
9	31														1	31.4		
10													47		1	47.0		
11	28														1	28.0		
12															0			
13	33														1	32.5		
14															0			
15															0			

Table A.23 -- Pregnancy and Parturition Study. Cortisol Concentrations During Late Pregnancy

	Cortisol (ng/ml)																	
								Llama #										
Time (days)	L:026	L:028	L:128	L:139	L:140	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	#	mean (ng/ml)	sd (n-1)	sem
-15		8.3			28.9			5.2			30.0		21.2		5	18.72	11.49	5.14
-14			15.3	31.3			8.9					32.6		9.3	5	19.48	11.67	5.22
-13		11.8			12.4			7.4			6.6		2.4		5	8.12	4.11	1.84
-12						31.0						6.3			2	18.65	17.47	12.35
-11	10.3		10.6	11.0	38.8		7.1		22.9	28.3	32.0		26.8	5.5	10	19.33	11.82	3.74
-10		4.8				9.0		13.8				24.1			4	12.93	8.31	4.15
-9	10.7		14.3	16.0			4.5		8.1	9.4				4.9	7	9.70	4.37	1.65
-8		6.4			15.3	26.1		6.4			13.6		6.9		6	12.45	7.74	3.16
-7	24.7		15.6	9.6			7.3		12.7	27.8		7.1		3.7	8	13.56	8.67	3.06
-6		6.8			11.1			5.4			15.1		12.9		5	10.26	4.08	1.83
-5						11.0						12.2			2	11.60	.85	.60
-4	9.8		10.6	13.3	9.1		6.8		10.1	10.7	10.5		10.6	10.0	10	10.15	1.61	.51
-3		6.4				10.7		7.0				7.9			4	8.00	1.90	.95
-2	14.6		8.8	4.0			13.1		10.6	5.9				19.4	7	10.91	5.29	2.00
-1		16.6			14.6	15.4		2.1			8.2		13.5		6	11.73	5.55	2.26
0	27.7		14.0	15.8			16.0		18.6	25.9		7.3		21.3	8	18.33	6.61	2.34
1		10.2			7.1			4.2			4.5		8.0		5	6.80	2.51	1.12
2						10.2						7.9			2	9.05	1.63	1.15
3	18.6		14.6	17.8	10.2	4.7	14.6		20.1	9.2	5.5		3.5	15.8	11	12.24	5.91	1.78
4		1.9						4.3				6.9			3	4.37	2.50	1.44
5	8.2		27.4	49.2			7.6		5.4	5.2				10.3	7	16.19	16.46	6.22
6		10.8			13.8	7.2		7.5			4.9		5.9		6	8.35	3.34	1.36
7			8.2	14.3			8.4		19.3	6.2		6.3		8.6	7	10.19	4.84	1.83
8	8.1	5.9			24.0			10.3			15.8		19.4		6	13.92	7.02	2.87
9						8.5						37.7			2	23.10	20.65	14.60
10	7.9		19.0	10.4	3.8		6.1		3.4	4.6	19.8		4.9	2.3	10	8.22	6.34	2.00
11		6.5				18.4		9.8				9.5			4	11.05	5.12	2.56
12	5.4		9.0	10.6			8.0		13.7	16.7				5.8	7	9.89	4.14	1.56
13		10.8			11.8	18.9		5.2			23.2		9.1		6	13.17	6.65	2.71
14	8.6		12.4	7.7			6.3		9.4	14.0		11.7		10.1	8	10.03	2.56	.91
15					4.0										1	4.00		

Table A.24 -- Pregnancy and Parturition Study. Triiodothyronine (T_3) Concentrations During Late Pregnancy

	T3 (ng/ml)																	
	Llama #																	
Time (days)	L:026	L:028	L:128	L:139	L:140	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	#	mean (ng/ml)	sd (n-1)	sem
-15		1.2						1.2							2	1.20	.00	.00
-14							1.6							2.1	2	1.85	.35	.25
-13		1.4			.9						.9		1.8		4	1.25	.44	.22
-12												1.0			1	1.00		
-11			1.2	1.6											2	1.40	.28	.20
-10						1.3		2.3							2	1.80	.71	.50
-9	1.7		1.5	2.3			1.2		.7	1.4				1.7	7	1.50	.49	.19
-8		1.8			.9			1.3			.9		1.7		5	1.32	.43	.19
-7			1.0	1.8			1.1					2.3		1.3	5	1.50	.54	.24
-6		2.0			1.2			1.6			1.1		2.5		5	1.68	.58	.26
-5						1.2						1.4			2	1.30	.14	.10
-4	1.3				1.9		1.8		1.3	1.8	1.8		2.4	1.5	8	1.73	.36	.13
-3		1.8				1.9						1.3			3	1.67	.32	.19
-2	2.2		1.1	1.3				1.2	2.0	1.6					6	1.57	.45	.18
-1						1.9									1	1.90		
0	1.6		1.3	.7			1.3		.9	.6				3.6	7	1.43	1.02	.39
1		1.9			1.3			.9			1.2		1.9		5	1.44	.44	.20
2												1.4			1	1.40		
3			1.5	1.6	1.3						1.2		1.9		5	1.50	.27	.12
4						1.9						1.3			2	1.60	.42	.30
5	1.6								1.2	1.3					3	1.37	.21	.12
6					1.3	1.7					1.0		1.6		4	1.40	.32	.16
7	1.8		1.1	1.5					.9	1.2		1.1			6	1.27	.33	.13
8								1.6							1	1.60		
9						1.2									1	1.20		
10	2.2				1.1				1.0	1.2	1.7		1.9		6	1.52	.49	.20
11												1.9			1	1.90		
12															0			
13						1.3									1	1.30		
14	1.5								1.0	1.1					3	1.20	.26	.15
15															0			

Table A.25 -- Pregnancy and Parturition Study. Tetraiodothyronine (T_4) Concentrations During Late Pregnancy

	T4 (ng/ml)					Llama #											
Time (days)	L:026	L:028	L:128	L:139	L:140	L:148	L:158	L:163	L:167	L:168	L:169	L:172	L:185	L:189	n	Mean (ng/ml)	sd (n-1)	sem
-15		48.2						37.7							2	42.95	7.42	5.25
-14														39.3	1	39.30		
-13		59.7			31.2		43.6				34.1		56.4		5	45.00	12.82	5.73
-12												35.9			1	35.90		
-11			29.5	38.6											2	34.05	6.43	4.55
-10						36.1		38.0							2	37.05	1.34	.95
-9	35.2		28.1	41.4			41.5		25.7	41.0				39.8	7	36.10	6.68	2.53
-8		41.2			23.1			34.2			13.0		40.6		5	30.42	12.16	5.44
-7			25.9	41.2			37.7					24.2		41.0	5	34.00	8.31	3.72
-6		40.3			28.7			42.4			11.0		41.2		5	32.72	13.33	5.96
-5						50.3						27.2			2	38.75	16.33	11.55
-4	16.0		45.3		36.2		41.1		12.3	20.8	17.8		39.6	37.5	9	29.62	12.68	4.23
-3		41.3				44.8						32.1			3	39.40	6.56	3.79
-2	17.3		29.8	42.2					14.0	14.4					5	23.54	12.26	5.48
-1						42.3		44.2							2	43.25	1.34	.95
0	30.3		33.4	38.4			66.9		17.0	20.8	51.5			57.4	8	39.46	17.70	6.26
1		53.1			42.9			53.2					61.8		4	52.75	7.73	3.86
2												47.2			1	47.20		
3			50.1	58.7	49.7						47.2		55.4		5	52.22	4.69	2.10
4						65.8		49.4				47.6			3	54.27	10.03	5.79
5	53.9								51.8	61.0					3	55.57	4.82	2.78
6					49.5	60.8					49.8		59.2		4	54.83	6.01	3.01
7	53.3		45.3	47.0					45.9	49.0		46.7			6	47.87	2.95	1.20
8								48.7							1	48.70		
9						58.6									1	58.60		
10	58.0				42.3				50.1	47.8	29.2		46.8		6	45.70	9.59	3.92
11												39.5			1	39.50		
12															0			
13						70.1									1	70.10		
14	57.0								23.4	25.6					3	35.33	18.80	10.85
15															0			

Table A.26 -- Growth Study. Crias Body Measurements

Age (mth)	Age (day)	Weight (kg)	Height (cm)	Width (cm)	Circ. (cm)	Length (cm)
L:711						
.0	0	12				
2.0	61	38	81			
2.1	63			20		
2.2	65				79	56
2.4	72	40				
2.9	86	45				
3.5	106	50				
3.8	114	50	88	25	89	66
4.1	122	54	91	25	90	70
5.6	167	60	95	25	94	71
6.8	203	65	97	25	95	74
8.1	242	66	99	25	99	76
8.6	257	71	102	25	102	79
9.9	296	72	102	28	102	79
L:713						
.0	0	11				
1.8	54	26	81			
1.9	56			20		
1.9	58				69	56
2.2	65	30				
2.6	79	34				
3.3	99	41				
3.6	107	39	84	22	79	66
3.8	115	41	86	22	83	66
5.3	160	48	91	22	89	69
6.5	196	54	93	23	91	69
7.8	235	59	94	24	94	69
8.3	250	61	94	24	97	76

Age (mth)	Age (day)	Weight (kg)	Height (cm)	Width (cm)	Circ. (cm)	Length (cm)
L:712						
.0	0	15				
2.0	59	38	84			
2.0	61			20		
2.1	63				79	74
2.3	70	43				
2.8	84	48				
3.5	104	56				
3.7	112	55	88	24	89	74
4.0	120	57	89	24	93	74
5.5	165	68	90	24	95	74
6.7	201	74	91	25	97	84
8.0	240	76	94	25	102	89
8.5	255	83	97	25	102	89
9.8	294	89	102	25	104	94
10.8	325	95	102	25	107	102
11.9	356	109	104	28	107	107
L:714						
.0	0	14				
1.8	54	30	83			
1.9	56			18		
1.9	58				74	51
2.2	65	32				
2.6	79	35				
3.3	99	45				
3.6	107	45	88	23	81	64
3.8	115	50	93	23	86	65
5.3	160	59	97	23	94	69
6.5	196	67	97	23	94	69
7.8	235	70	97	23	97	70
8.3	250	70	102	25	99	74
9.6	289	80	102	25	102	79
10.7	320	82	104	28	104	86
11.7	351	91	107	28	107	94

L:715

.0	0	13				
1.3	40	26	76			
1.4	42			18		
1.5	44				71	64
1.7	51	29				
2.2	65	31				
2.8	85	40				
3.1	93	39	81	22	81	64
3.4	101	44	86	22	84	66
4.9	146	53	94	22	89	69
6.1	182	60	94	23	93	72
7.4	221	65	94	23	94	76
7.9	236	64	97	23	97	76
9.2	275	68	97	23	97	79

L:716

.0	0	13				
1.6	48	27	79			
1.7	50			19		
1.7	52				71	50
2.0	59	35				
2.4	73	38				
3.1	93	44				
3.4	101	45	84	25	81	64
3.6	109	48	86	25	86	66
5.1	154	57	89	25	91	71
6.3	190	62	91	25	95	71
7.6	229	69	94	25	97	76
8.1	244	69	97	25	97	76
9.4	283	73	99	25	97	81
10.5	314	75	99	25	98	84
11.5	345	80	102	28	102	89
12.5	375	83	109	33	107	94

L:717

.0	0	12				
1.2	35	29	79			
1.2	37			23		
1.3	39				71	56
1.5	46	33				
2.0	60	38				
2.7	80	47				
2.9	88	46	81	24	81	64
3.2	96	48	91	24	85	64
4.7	141	59	94	25	97	66
5.9	177	67	94	25	97	70
7.2	216	73	94	25	99	71
7.7	231	75	97	25	102	79
9.0	270	77	102	25	107	79

L:718

.0	0	11				
1.0	31	27				
1.1	32		12			
1.1	34			3		
1.2	36				11	8
1.4	43	30				
1.9	57	35				
2.6	77	41				
2.8	85	42	86	23	79	58
3.1	93	45				
4.6	138	55				
5.8	174	62				

L:719

.0	0	11				
1.0	29	18				
1.0	30		66			
1.1	32			18		
1.1	34				64	48
1.4	41	23				
1.8	55	27				
2.5	75	33				
2.8	83	32	76	20	71	66
3.0	91	34				
4.5	136	43				

L:720

.0	0	13				
.9	27	26	72			
1.0	29			19		
1.0	31				69	46
1.3	38	28				
1.7	52	33				
2.4	72	40				
2.7	80	39	84	22	79	64
2.9	88	41	84	22	83	64
4.4	133	50	84	23	86	64
5.6	169	55	91	23	90	67

L:721

.0	0	15				
.9	26	24				
.9	27		81			
1.0	29			20		
1.0	31				71	58
1.3	38	33				
1.7	52	37				
2.4	72	44				
2.7	80	45	86	25	86	71
2.9	88	48				
4.4	133	60				
5.6	169	68				

L:722

.0	0	11				
.9	26	17	74			
.9	28			18		
1.0	30				66	51
1.2	37	24				
1.7	51	27				
2.4	71	34				
2.6	79	33	79	20	74	61
2.9	87	36	83	22	77	65
4.4	132	43	84	23	81	66
5.6	168	51	86	23	86	67
6.9	207	54	89	23	89	69
7.4	222	58	94	23	94	74
8.7	261	63	102	23	97	74
9.7	292	66	104	25	102	81
10.8	323	72	107	30	107	89

L:723

.0	0	13				
.8	24	19	75			
.9	26			18		
.9	28				64	51
1.2	35	20				
1.6	49	24				
2.3	69	34				
2.6	77	33	76	22	74	64
2.8	85	36	81	23	80	64
4.3	130	48	86	23	84	64
5.5	166	54	95	24	88	67
6.8	205	62	91	24	89	69
7.3	220	61	94	24	89	81
8.6	259	68	99	25	97	81

L:724

.0	0	12				
.7	22	24	74			
.8	24			20		
.9	26				66	51
1.1	33	30				
1.6	47	31				
2.5	75	40	86	24	81	64
2.8	83	44	91	24	85	66
4.3	128	57	94	25	86	69
5.5	164	65	94	25	95	71
6.8	203	66	94	25	97	71
7.3	218	70	102	25	97	89

L:725

.0	0	13				
.6	19	23	76			
.7	21			18		
.8	23				66	51
1.0	30	27				
1.5	44	31				
2.1	64	40				
2.4	72	40	86	23	79	64
2.7	80	44	89	23	81	64
4.2	125	54	91	25	86	66
5.4	161	63	98	25	95	84
6.7	200	73	99	25	99	89
7.2	215	73	102	25	99	89

L:726

.0	0	13				
.4	12	16	72			
.5	14			17		
.5	16				61	51
.8	23	22				
1.2	37	28				
1.9	57	37				
2.2	65	35	81	24	76	61
2.4	73	39	84	25	81	61
3.7	112	49	89	25	86	61
5.1	154	56	91	25	90	69
6.4	193	65	91	25	91	71
6.9	208	66	94	25	102	79
8.2	247	68	99	25	102	79

L:728

.0	0	12				
.3	10	14	69			
.4	12			15		
.5	14				56	46
.7	21	19				
1.2	35	24				
1.8	55	32				
2.1	63	31	79	22	74	64
2.4	71	35	79	23	76	66
3.9	116	43	84	23	81	71
5.1	152	50	84	23	84	71
6.4	191	55	84	23	89	71
6.9	206	55	91	23	94	76
8.2	245	61	91	23	94	76
9.2	276	64	97	28	99	84
10.2	307	65	99	28	104	89
11.2	337	67	107	33	109	94

L:729

.0	0	14				
.6	19	15	67			
.7	21			17		
.7	21				56	46
1.0	30	20				
1.5	44	24				
2.1	64	37				
2.4	72	36	81	20	76	61
2.7	80	39	85	22	76	61
4.2	125	45	89	23	79	61
5.4	161	57	89	23	84	64
6.7	200	66	91	23	89	64
7.2	215	68	99	23	99	66
8.5	254	71	99	23	102	71

L:730

.0	0	11				
.1	3	12	69			
.2	5			17		
.2	7				56	48
.5	14	17				
.9	28	22				
1.6	48	30				
1.9	56	30	76	18	71	56
2.1	64	35	84	19	75	58
3.6	109	45	89	23	84	61
4.8	145	55	89	23	89	67
6.1	184	61	94	23	97	69
6.6	199	61	94	23	97	71
7.9	238	67	94	23	97	74