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REPRODUCTIVE HORMONE PATTERNS IN FEMALE PYGMY GOATS

by

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A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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DEDICATION

In The Memory Of

LUCY ASIIMWE

NYAMUHANGA AMUHUUMUZE

ABSTRACT

Reproductive Hormone Patterns in Female Pygmy Goats

Grace Richardson Engwe Kakusya

Blood samples collected from four female pygmy goats were assayed by radioimmunoassay (RIA) techniques to determine reproductive hormone profiles during various reproductive states (onset of puberty, anestrus, transtion from anestrus to breeding activity, behavioural estrus during the breeding season, pregnancy and parturition).

Ovarian cyclicity resumed (or started, in case of the prepubertal does) in mid-November and continued up to late May. The two prepubertal does reached puberty at an age of 248 and 251 days, respectively. Progesterone profiles suggest that all four animals resumed (or started) their breeding activity by exhibiting an ovulation that was not accompanied by overt estrus. The average length of the estrous cycle in the female pygmy was estimated to be 19.0 $\pm$ 1.2 days.

During the breeding season the nature of Luteinizing Hormone (LH) release was dependent on the reproductive state of the animal. The relationships between circulating progesterone and LH levels during the cycle, lend support to the thesis that during the breeding season progesterone exerts a dominant inhibitory effect on tonic LH release.

Luteinizing hormone peaks were less frequent but higher in magnitude during anestrus than during the breeding season.

Luteal regression, as indicated by falling progesterone levels occurred by day-3 to day-2 (with reference to the subsequent cycle) and was followed or accompanied by increases in estrogen, Follicle Stimulating Hormone (FSH) and LH secretion, all of which peaked at or around day 0 (first day of estrus) of the succeeding cycle.

During behavioural estrus, the onset of the preovulatory LH surge occurred on an average of 6.5 ± 0.7h after the onset of estrus and was followed by a FSH surge an average of 1.1 ± 0.4h later. LH secretion appeared to be episodic in nature as indicated by minor fluctuations, prior to the beginning of the preovulatory surge. The duration of the LH preovulatory surge was estimated to be 15.2 ± 0.5h, while the FSH preovulatory surge was found to be an average of 1.7 ± 0.7h shorter in duration than that of LH. However, these difference were not significant ($P>0.05$). During anestrus and the inter-estrous periods of the breeding season, the LH peaks were not accompanied by concurrent FSH peaks. Taking into consideration the interval from the onset of estrus to the beginning of the gonadotropin preovulatory surge and its duration, ovulation was estimated to occur on an average of 36h after the onset of estrus, and the most optimum time for insemination or mating would appear to be about 30h after the onset of estrus.

In this study, the mean gestation length of the pygmy goat was estimated to be 148.5 ± 1.4 days. During pregnancy, it was evident from the progesterone concentration profiles that there were two phases of increased progesterone secretion. The first phase was associated with the period from the 2nd to the 4th week of pregnancy; the second increase began in the 9th week of pregnancy. These increases were probably attributable to the activity of the corpus luteum as it became fully functional early in gestation, while the later increase in progesterone possibly could be related to a "rejuvenation" of the corpus luteum by luteotropic placental lactogen since it is reported to appear in the circulation at about day 60 of pregnancy.

Estrogen concentration increased steadily from the 10th week of pregnancy up to parturition. The stage of pregnancy affected progesterone and estrogen production significantly ($P<0.01$, and $P<0.05$, respectively). Although the type of pregnancy (single vs multiple) significantly ($P<0.01$) affected progesterone concentration, it failed to have similar effects on estrogen concentration.

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INTRODUCTION

The goat is a major constituent of the total world livestock population, making up to 15 percent of the world population of domesticated animals (FAO, 1977). It is estimated that, together with sheep, they contribute nearly 50 percent of the world production from indigenous animals. More than a third of the world human population relies on the goat rather than on cattle for milk and meat (Jeffrey, 1975). In addition to providing milk and meat, goats also provide fiber and skins and utilize forages that otherwise would be wasted and/or are perhaps noxious.

The world goat population is largely located in equatorial and tropical regions with more than two-thirds of the total lying within 30° of the equator. Biologically, their small size, large surface area relative to body weight, and limited subcutaneous fat covering adapt them poorly to cold climates, and make them relatively more adaptable to regions of high ambient temperatures (Shelton, 1977). Their small size in relation to the cow also makes them attractive to smallholder agricultural systems. Economically, this is the situation in many developing nations. Thus, the value of the goat and its contribution to human welfare is greater than is indicated by statistical figures because their products fill a greater need. In addition, new interest in dairy goats is rapidly gaining ground in the more developed and affluent societies because of the special health and nutritive value attached to goat milk and goat milk products. It is estimated that in the USA alone, 350 million kg of goat milk is produced annually (Haenlein, 1977). In other societies where religious beliefs (Jews, Muslims, and Hindus) do not allow for the consumption of pork, fat meat or beef, goat meat becomes a ready and equally nutritious substitute.

Although the goat was for a long time the least recognized of farm animals, there is now a growing tendency to acknowledge its desirable, good characteristics. It possesses great adaptability and has such relatively low nutritive requirements that it adjusts easily to a wide range of environmental conditions.

Goats differ in diet selection and gastrointestinal physiology from other domestic ruminants (cattle and sheep); being more similar to deer in some respects. Therefore, under environmental conditions unsatisfactory for other animals, the goat's requirements can easily be satisfied (Huston, 1978). Experimental evidence is now available showing that goats have greater digestive capacity (Cordova and Wallace, 1975) and that they are better able to produce milk more efficiently than cattle in relation to resource-availability and animal adaptability. It is this adaptability to harsh environments and their greater agility in search of food, together with their propensity for eating almost anything and everything that makes them thrive in mountainous and arid regions which the larger and more sedentary domestic animals cannot tolerate.

In addition, in the more recent past, the goat has emerged as a major animal model in the study of ruminant physiology and its use in investigations relating to cardio-vascular physiology in biomedical research is increasing (Hoversland, 1965; Shelton, 1977).

Reproduction is a major contributing factor to efficiency of goat production -- for whatever purpose. The understanding of various reproductive physiologic states vis-a-vis circulating hormone levels for many goat breeds, and under many environmental conditions to which they may be subjected during rearing is incomplete or totally lacking. Such information is not only useful in planning future breeding experiments and programmes per se but is also welcome as an addition to the general pool of knowledge relative to the many facets of endocrinology and their interaction in eliciting specific animal behaviour. Investigations were therefore carried out to find out the reproductive hormone patterns in anestrus, cycling, and pregnant female pygmy goats. Although these studies were conducted in the temperate latitudes of southern Canada, it was hoped that the observations would also be applicable to the more tropical regions previously referred to, where goats are a more numerous and important domestic species.

LITERATURE REVIEW

Introduction

Although it is generally recognized that the goat is a seasonal breeder in the temperate regions, very little is known abouts its endocrinology of reproduction throughout the year. Much of the information commonly used to explain its reproductive behaviour is "borrowed" from research that has been done on its closest relative -- the sheep. This, however, has the disadvantage that the information may not be necessarily so truly applicable as is usually assumed. For example, the two species differ in the way they synthesize progesterone to maintain pregnancy. Whereas sheep placenta is able to replace the corpus luteum as a major progesterone synthesizing tissue, the goat relies on the corpus luteum as the sole source of progesterone as long as the pregnancy is maintained. The removal of the corpus luteum without adequate hormone replacement therapy will result in abortion at any stage of pregnancy; whereas in the sheep a similar treatment will not result in abortion if it is done after day 50 of gestation. Therefore, caution must be exercised when trying to explain certain reproductive phenomena in the goat by extrapolation from sheep data.

Seasonal Effects on Breeding Activity in the Goat

Like the sheep, goats are seasonally polyestrous in the temperate regions. Their sexual activity is suggested to be controlled by three environmental factors: photoperiod, temperature and relative humidity. Of the three factors, the changing pattern of daylength is the principal environmental cue which is thought to control the timing of the onset of reproductive activity and ovarian cyclicity in sheep and goats (Bissonnette, 1941; Hafez, 1952; Shelton, 1960; Godley et al., 1966; Thimonier and Mauleon, 1969; Palmer et al., 1972; Dyrmundson, 1973; Ortavant, 1977; Schanbacher and Lunstra, 1977; Lincoln et al., 1977; Lincoln, 1978; Sanford et al., 1978; Muduuli, 1978; Turek and Campbell, 1979).

Temporal Hormonal Relationships During Transition from Anestrus to Breeding Activity

Whereas a fair amount of information has been accumulated in relation to the interplay of various hormones in the ewe, during the breeding season vis-a-vis the non-breeding season, such information is still unavailable with regard to the doe. It has been suggested that a change from long to short days results in increases in levels of circulating gonadotropins. This observation is suggested to be the result of the reduced sensitivity of the hypothalamus-pituitary system toward the ovarian-hormonal feedback system and culminates in the resumption of cyclic sexual activity in the sheep and goat (Pelletier and Ortavant, 1964; Pelletier, 1973; Rawlings et al., 1977).

Luteinizing Hormone (LH) secretion in domestic animals studied so far is episodic in fashion (Foster et al., 1975; Ravault, 1976; Katongole et al., 1974; Davies et al., 1977; Lincoln et al., 1977; Sanford et al., 1977; Muduuli, 1978). Lincoln et al., (1977) and Sanford et al (1977) found that in the ram, LH peaks increase in number but decrease in magnitude during the breeding (short day) season. Thereafter episodic LH releases increase in magnitude but decrease in number during the non-breeding (long day) season. The target organs (the testes in this case) are therefore subjected to lower but more constant circulating levels of gonadotropins during the breeding season. There also exists in the ram and buck a circadian rhythm during which plasma levels of LH, testerone (T) and to a lesser extent Follicle-Stimulating Hormone (FSH) increase during the dark phases of the 24-h cycle (Lincoln et al., 1977; Lincoln and Peet, 1977; Muduuli, 1978). Earlier work by Falvo et al. (1975) had, however, failed to reveal such rhythmicity. The discrepancy in these observations may be attributed to the frequency of sampling.

During a 12 month period, Muduuli (1978) found that plasma LH concentrations in the buck displayed one large peak in September and October; a second smaller peak was detected in February and May. Associated with the smaller peak was an extremely high animal-to-animal variation. During the September-October peak, plasma LH mean concentrations ranged from 0.9 to 3.1 ng/ml, while those of the lowest month (November) varied between a maximum of 0.5 ng/ml to non-detectable levels.

Temporal relationships between the various hormones involved in reproduction during the transition from anestrus to breeding activity in the female goat have not been reported. However, in the ewe Yuthasastrakosol et al. (1975) and Walton et al. (1977) found that LH levels fluctuated throughout most of the anestrus period. Day to day fluctuations in FSH levels were also observed with no overall change in circulating levels except for some high values that were associated with high LH levels. The short-term relationships between peaks of plasma LH and FSH suggest and support the notion that a single hypothalamic hormone Gonadotropin-Releasing Hormone (GnRH) regulates the secretion of both gonadotropins (Burgus et al., 1972; Guillemin and Burgus, 1972; Reeves et al., 1974; Donovan and ter Haar, 1977; Simaraks, 1978; Reichlin, 1978).

Although brief minor rises in progesterone were reported

(Yuthasastrakosol, 1975), circulating levels of this hormone remained consistently low for most of the anestrus period. As shown by the profile of circulating progesterone, the first ovulation was not accompanied by estrus.

In the ewe, all the components of the hypothalamo-hypophyseal-ovarian axis are capable of functioning during the entire period of anestrus (Roche et al., 1970; Karsh et al., 1978). Experiments by Goding et al. (1969); Beck and Reeves (1973); and Reeves et al. (1974b) demonstrated that the administration of estradiol-17β or GnRH stimulated the release of LH during anestrus. It was also reported (Yuthasastrakosol et al., 1975; Karsch and Foster, 1975; Scaramuzzi and Baird, 1977; Karsch et al., 1978) that both positive and negative feedback effects of the gonadal steroids are readily demonstratable on the hypothalamo-hypophyseal axis during anestrus.

Recent investigations by Legan et al. (1977); Hauger et al., (1977); Karsch et al. (1977); Rawlings et al. (1977); and Karsch et al. (1978), have led to certain speculations on the possible mechanisms involved in the onset of the anestrus condition and the consequent resumption of ovarian cyclicity in the breeding season in the ewe. It is possible that similar mechanisms are operative at the onset of seasonal anestrus and resumption of breeding activity in the goat.

In one such all-year-round experiment using ovariectomised ewes implanted with silastic capsules that maintained physiologic levels (3-7pg/ml) of circulating estradiol, Karsch et al. (1978) observed a striking biannual change in circulating LH. The pattern of biannual changes in serum LH concentration was coincident with the transition between breeding and anestrus periods in intact ewes; elevated LH levels being associated with the breeding season while undetectable LH levels occurred during the anestrus period. It was hypothesized by Karsch et al. (1978) that in the ewe there occurs a profound seasonal change in the sensitivity of the system which governs tonic LH secretion in response to the "feedback" action of estradiol. Estradiol was found to be a potent negative-feedback hormone during anestrus but was ineffective in this regard during the breeding season. The mechanism as proposed by Karsch et al. (1978) and Legan and Karsch (1979) is as follows: During the follicular phase of the estrous cycle during the breeding season the regression of the corpus luteum (CL) is followed by progesterone withdrawal; this effects a major opening in the negative-feedback loop which controls LH secretion. This is followed by a progressive increase in circulating LH which in turn causes an increase in estradiol production by the follicles. The estradiol secretion is sustained until it reaches a threshold for triggering the pre-ovulatory LH surge. As observed in a normal cycle, concurrent sustained increase in both LH and estradiol can occur because physiologic levels of estradiol alone cannot inhibit LH secretion during the breeding season. During the transition period into anestrus, the system governing tonic LH release gains response to the negative-feedback action of estradiol. As the CL of the last cycle regresses, both LH and estradiol begin to rise in the same manner as described earlier. However, the response to the negative-feedback action of estradiol is now higher and so terminates the progressive increase in tonic LH release; an increase that is necessary for sustained estradiol production. As a result estradiol levels begin to fall before reaching the threshold required for the initiation of the pre-ovulatory LH surge. Hence, without the pre-ovulatory surge, ovulation does not occur and ovarian acyclicity sets in. At the onset of the next breeding season, the system which governs LH secretion again becomes unresponsive to the negative-feedback effect of estradiol. Concurrent increases occur in circulating estradiol and the LH and estrous cycles and ovarian cyclicity are reinitiated.

Presumably, environmental photoperiodicity lends its control of reproductive activity by somehow changing the responsiveness of the hypothalamo-hypophyseal axis to the negative-feedback effect of estradiol. In essence, the sustained preovulatory increase in LH release is the suggested pivotal step and its interruption or completion dictates the seasonal reproductive state. In this way, estradiol becomes the major organizer of the seasonal reproductive cycle. The sequence of events leading to ovulation and to another cycle is permitted when the negative response on the hypothalamus is low; it is, however, interrupted and actively inhibited when the negative response to estradiol is high.

Hormonal Changes During the Estrous Cycle

Little is known about the interplay of the hormones originating from the hypothalamus, pituitary, ovary and the adrenals in the goat during the estrous cycle. Using protein-binding assay techniques, Thorburn and Schneider (1972) found that progesterone concentrations in the peripheral plasma of goats were very low (0.2 ng/ml) on the day of estrus (Day 0) and were significantly different from those found in anestrus or ovariectomized animals. The concentration increased to reach maximum levels on about Day 10 of the cycle and decreased rapidly during the last 3 days of the cycle. This pattern of progesterone secretion is similar to that which has been observed in ewes (Thorburn et al., 1969; Thorburn and Mattner, 1971; Stabenfeldt et al., 1969; Obst and Seamark, 1970; Bjersing et al., 1972; Sarda et al., 1973; Yuthasastrakosol et al., 1975; Pant et al., 1977; Simaraks, 1978) and in cows (Robertson et al., 1972; Donaldson et al., 1970).

Progesterone concentrations were at their lowest levels on the day of estrus (Day 0). A positive correlation between plasma progesterone levels and CL function had previously been demonstrated (Thorburn and Mattner, 1971). Therefore, decreasing progesterone levels reflect CL regression.

Inversely related to the very low progesterone concentrations seen on the day of estrus in both the ewe and the cow, is the characteristic elevated level of LH and FSH. Throughout the cycle, mean serum LH and progesterone concentrations are also inversely related; LH being highest during the early and late-luteal phase. A progressive, five-fold increase in serum LH concentrations has been observed to occur between the onset of the precipitous fall in circulating progesterone attendant to luteolysis and the initiation of the pre-ovulatory surge on the day of estrus (Roche et al., 1970; Crighton et al., 1972; Pant et al., 1977; Yuthasastrakosol et al., 1975; Simaraks, 1978). Using biological assay techniques, Pretorius (1971) found suggestive evidence to the effect that LH secretion in the Angora goat peaked on the day of estrus as has been shown later by RIA in other species (Simaraks, 1978; Robertson et al., 1972).

Hauger et al. (1977) and Legan and Karsch (1979) have concluded that during the cycle, progesterone plays a dominant role assisted by estradiol and possibly other ovarian steroids in governing the tonic LH secretion. The initiation of the sequence of events which leads to ovulation is only achieved with progesterone withdrawal. Therefore, during the breeding season progesterone acts as the major organizer of the preovulatory events of the estrus cycle in the ewe. This is most probably the case in the goat, too, since highest LH biological activity correlated positively with very low progesterone values (Pretorius, 1971).

There is no documented information regarding the nature of estrogen changes during the estrous cycle in the goat. However data available from several investigators indicates that circulating estrogen levels peak at or around estrus with some day-to-day variation being seen in cycling ewes (Scaramuzzi et al., 1970; Pant et al., 1972; Yuthasastrakosol et al., 1975; Simaraks, 1978). More specifically, estradiol-17 has been observed to significantly increase 2 days before estrus to just prior to or at the time of the peak of the preovulatory surge (Cox et al., 1971). Similar increases were reported by Rawlings (1977) although the percentage of such significant elevations was found to be low. The time at which the experiments were conducted (either in the middle of the breeding season or at the end of the breeding season) may be held accountable for some of the observed inconsistencies in patterns reported.

It has previously been mentioned that the observed estradiol-17β increases result from both reduced progesterone and increased LH secretions during the early and late luteal phases, respectively, and it is importantly involved in the initiation of the sequence of events that lead to ovulation.

Hormonal Changes During Pregnancy and Parturition

During pregnancy, the sites of progesterone secretion as well as changes in plasma concentration seem to vary considerably between different species (Austin and Short, 1973). In the goat, pregnancy maintenance is dependent upon the secretion of progesterone from almost solely the CL (Linzell and Heap, 1968; Thorburn et al., 1977; Buttle, 1978). There may be a minor placental contribution to total progesterone production in late pregnancy but this is inadequate to protect the pregnancy in the absence of luteal function (Currie and Thorburn, 1977). Earlier work by Rawlings and Ward (1973) had shown that abortion after ovariectomy could be prevented by the administration of progesterone, thus emphasizing the ovary as the main source of this hormone in the goat during pregnancy.

Progesterone concentrations in the peripheral plasma of pregnant goats have been documented by several workers (Blom and Lyngset, 1971; Irving et al., 1972; Thorburn and Schneider, 1972; Thorburn et al., 1972; Currie and Thorburn, 1977; Flint et al., 1978; and Thorburn et al., 1977). All results obtained show that progesterone has a characteristic gradual rise during early pregnancy to the levels commonly observed in the luteal phase of a normal estrus cycle. This level is sustained until about day 40 of gestation when a slight decline is observed; a secondary increase, peaking during the third to fourth month of gestation being then reported. The decrease after the 40th day of gestation has been associated with reduced luteal cell size and reduced luteal secretory activity. The CL is later "rejuvenated" to full functional activity by placental lactogen which is synthesized by placental tissue beginning by about day 60 of gestation; hence the observed secondary increase (Thorburn et al., 1977).

The progesterone concentration increase in the third and fourth month of gestation was significantly greater in twin pregnancies than in singletons (Thorburn et al., 1977). A similar phenomenon was observed in women where plasma progesterone concentrations were significantly higher in twin than in singleton pregnancies; the mean levels of progesterone in twin pregnancies in the third trimester were at least 60% greater in twin than in singleton pregnancies (Batra et al., 1978). Similar observations have been made in sheep but not in pigs (Nalbandov, 1976).

As has been shown in other species, there is a steady decline in mean plasma progesterone concentration during the last week of pregnancy; this decline is suggested to be associated with the mechanisms for the initiation of parturition (Blom and Lyngset, 1971; Irving et al., 1972; Thorburn and Schneider, 1972; Thorburn et al., 1972; Bedford et al., 1972; Umo et al., 1976; Challis et al., 1976; Mitchell and Flint, 1977; Rawlings and Ward, 1978).

Associated with the foregoing changes in circulating progesterone concentration, various workers (Challis and Linzell, 1971; Thorburn et al., 1972; Currie et al., 1973; Umo et al., 1976; Currie and Thorburn, 1977) have observed temporal relationships between corticosteroids, estrogens and prostaglandin F (PGF). Their findings showed that maternal unconjugated estrogen levels were higher in the goat than those found in sheep but that in both species, they increased steadily throughout the third trimester of gestation; then rose sharply during the 4 to 5 days preceding delivery. The various proportions of the unconjugated estrogens were also found to be quite different in the two species: estrone being quantitatively the main estrogen found in the ewe while estradiol-17β was found to be the major estrogen circulating in the goat. Recently, Flint et al. (1978) and Umo et al. (1976) have also investigated circulating levels of estradiol-17β in pregnant goats. Since it has been demonstrated that administration of estradiol-17α does not induce labour (Currie and Thorburn, 1976) it was postulated that estradiol-17β though present in lower amounts, is the active estrogen.

The predominance of the -17α isomer of estradiol in the goat was thought to result from high activity of 17 -α reductase in the fetal-placental unit (Thorburn et al., 1972). In a more recent study, Flint et al. (1978) found that the activity of 17α-hydroxylase increased with the increase in the appearance of fetal androgens and glucorticoids in fetal and maternal circulation. Its increase in activity was therefore associated with the rising levels of estradiol-17α.

Experiments by Thorburn et al. (1972) showed that intra-fetal infusion of Adrenocorticotropic Hormone (ACTH) elevated estrogen concentrations in the maternal as well as the fetal plasma. The intra-fetal infusion was shown to cause an increase in the production of fetal cortisol. The cortisol then precipitated an increase in the production of estrogen by activating the enzymes involved in estrogen synthesis. This may also have been accompanied by increased fetal androgen which could be aromatized by placental tissue; now also activated by cortisol.

Umo et al. (1976) demonstrated that the consistent rise in estradiol-17β which occurred 3 to 4 days before delivery preceded an observed $PGF_{2\alpha}$ rise by 40 to 48 hours. The fall in maternal plasma progesterone in the goat appears very abruptly (about 24h before parturition) suggesting that luteolysis is accurately timed and is affected by a discrete luteolytic signal (Umo et al., 1976).

Currie and Thorburn (1973 showed that $PGF_{2\alpha}$ is the luteolytic signal by infusing physiological amounts of $PGF_{2\alpha}$ into the tributary uterine veins ipsilateral to the CL and demonstrated that as little as 2 to 5 ng $PGF_{2\alpha}$ /ml maintained in the uterine vein for up to 5 to 6 h provided a potent luteolytic signal. Umo et al. (1976) have shown that the initial increase in $PGF_{2\alpha}$ in the uterine vein draining the pregnant horn was some 48h before delivery, hence preceding the decrease in progesterone concentration by some 18 to 22h. It was found that when premature parturition was induced by infusing synthetic corticotrophin into a fetus, $PGF_{2\alpha}$ appeared in the utero-ovarian vein ipsilateral to the infused fetus some 24h before delivery and this increase was associated with a concurrent decrease in maternal progesterone concentrations. In the same experiment, Umo and Fitzpatrick, 1976) a sustained decline in progesterone occurred several hours before the increase in uterine activity; suggesting that $PGF_{2\alpha}$ acts first as a luteolysin and that myometrial activity increases only after progesterone concentration has fallen. This view is supported by the observation that during spontaneous parturition in the goat (Umo et al., 1976) the onset of uterine activity is preceded by a sustained decrease in plasma progesterone concentration and emphasizes the need for luteolysis and timed progesterone withdrawal during the initiation of uterine activity and parturition in this species.

The sequence of events that are involved in the initiation of parturition in the goat may be summarized as follows: as a result of fetal ACTH secretion, the fetal adrenals are stimulated to increase cortisol and androgen production. The cortisol either activates already synthesized 17-αhydroxylase and other enzymes involved in the production of estradiol-17β; or stimulates their increased production by the placenta; or both. This results in the production of estrogens by the placenta. Increased estrogen production either as estradiol-17β or by conversion of other estrogens to it results in the increased uterine production of $PGF_{2\alpha}$.

Immediately, $PGF_2\alpha$ causes luteolysis either alone or acting synergistically with falling levels of placental lactogen. This results in a sustained reduction in progesterone and enables $PGF_2\alpha$ to evoke uterine contractility and cervical dilation. Uterine muscular contractility and cervical dilation are maintained by further $PGF_2\alpha$ production and by the complementary effects of $PGF_2\alpha$, estrogen and oxytocin acting synergistcally; thus initiating labour and parturition.

GENERAL MATERIALS AND METHODS

Throughout the experimental period (September, 1975 to September, 1978) the female goats were penned together, but separated by a distance of some 20 to 25 meters from the males in a well-ventilated barn. Normally, in order to feed the animals and do general cleaning, lights were turned on and off at 0800h and 1700h, respectively. They were therefore exposed to natural photoperiod changes except when 24-h blood collections were being performed.

The goats were fed a daily ration of legume hay and grain; water and salt being available *ad libitum*. Blood was collected by venipuncture from the jugular vein using vacutainer tubes. After each collection, the blood was immediately placed in an ice-bath and later transferred to a cold-room, where it was kept at $4^{\circ}C$ until the next day. It was then centrifuged and serum was aspirated from above the clot and kept at $-20^{\circ}C$ until assayed.

Assays

The determination of various hormone concentrations was performed by radioimmunoassay (RIA). Details of individual hormone RIA procedures have already been reported for progesterone and estrogen by Yuthasastrakosol *et al.*, (1975), for LH by Howland (1972) and for FSH by Cheng (1976). Individual descriptions of each methodology follow below.

Progesterone

Serum progesterone concentrations were determined by use of a method previously described by Abraham et al., (1971) and modified by Yuthasastrakosol (1975). A highly specific antiserum (Pool #337) was generously provided by Dr. G, Niswender (Colorado State University). The antiserum was prepared by immunization of a rabbit with progesterone - 6 - hemisuccinate - BSA. The percentage cross-reaction of the antiserum with various steroids has been described by Niswender (1973) and 5 -pregnane-3, 20-dione is the only steroid that had significant cross-reactivity (>3%).

A routine determination of progesterone concentration in a pool sample from does in various reproductive states was used to determine inter-assay and intra-assay coefficients of variations. The average progesterone concentration in the pool sample was 3.8 ± 0.08 ng/ml determined in 12 separate assays. This yielded inter-assay and intra-assay coefficients of variations of 16.1% and 9.6%, respectively. The mean percentage recovery of ^{3}H-progesterone added to serum samples was 77.7 ± 0.6 (n = 11) and was utilized to correct the results for procedural losses.

Estrogen

Serum estrogen concentrations were evaluated by a radioimmunoassay previously described by Yu et al., (1974).

This methodology omits column chromatography and thus measures total estrogens. The anti-estradiol - 17β BSA (#029-14) used in this assay was obtained from Dr. B. Caldwell (Yale University). The antiserum was prepared by immunizing sheep with estradiol - 17β, 17 - hemisuccinate - BSA. The specificity of this antiserum had been extensively characterized by Wu and Lundy (1971). Its cross-reactivity to various estrogens was found to be 100% for estradiol - 17β, 63.7% for estrone and 5.1% for estradiol - 17α.

The mean percentage of recovery when ^3H - estradiol was added to serum samples was 63.8 ± 1.8 (n = 8). A routine estrogen measurement on a pool sample obtained from does in various reproductive states was utilized to determine inter-assay and intra-assay coefficients of variations. In 14 separate duplicate determinations, the average estrogen concentration in the pool sample was 27.4 ± 0.9 pg/nl with inter-assay and intra-assay coefficients of variations of 16.0% and 11.1% respectively.

The standards used in the assays of both progesterone and estrogen were obtained from Mann Research Laboratories, Orangeburg, New York and were used without further chromatographic treatment.

Luteinizing Hormone (LH)

A double antibody RIA was used to measure LH concentrations. Details of the procedure have been previously described by Howland (1972). Anti-ovine LH serum (GDN #15) supplied by Dr. G. Niswender (Colorado State University) was used in the assay. Purified ovine LH (LER-1056-C2) was labelled with ^{125} Iodine (Cambridge Nuclear Corporation) by a modification of the method of Greenwood et al., (1963). The modified procedure has been described by Sanford (1974) and Yuthasastrakosol (1975) and was previously used by Muduuli (1978) to assay LH in male pygmy goats. LH values are expressed as ng/ml of NIH-LH-S14 standard. By using LH values obtained in 12 separate duplicate assays carried out on a pool sample whose average LH concentration was 2.28 $\pm$ 0.4 ng/ml, it was found that the inter-assay and intra-assay coefficients of variations were 13.4% and 13.7%, respectively. The lowest detectable levels using serially diluted pool serum was 0.2 ng/ml, samples yielding values lower than 0.2 ng/ml were assigned that value for statistical purposes.

Follicle-Stimulating Hormone (FSH)

Serum FSH levels were evaluated using a procedure that employed an antibody developed against bovine FSH (Cheng, 1976). This antibody has been characterised and used to assay ovine FSH (Cheng, 1979). The same antibody was used in this study for the assay of caprine FSH. The antibody has been shown to exhibit parallel curves for ovine FSH preparations (Cheng, 1979). Since Muduuli (1978) showed that parallelism existed between sheep and goat preparations it was assumed that the evaluation of FSH in caprine serum was valid if this antibody was used. Hence, its use was made in this study without further parallelism tests. Purified bovine FSH was labelled with ^{125}Iodine (Cambridge Nuclear Corporation) by a modification of the method of Greenwood et al., (1963). The intra-assay and inter-assay coefficients of variation were determined using procedures described above. In 12 separate assays using pooled serum, the mean FSH concentration was found to be 26.1 $\pm$ 0.8 ng/ml. The inter-assay and intra-assay coefficients of variations were estimated to be 9.5% and 11.9%, respectively (n = 11). The minimum detectable level of FSH at 95% of initial binding (B/Bo) was 0.7 ng/ml. Values of FSH are expressed as ng/ml of NIH-FSH-S12 (ovine).

Statistical Analysis

Differences between onset of preovulatory LH and FSH surges and their duration were tested for significance by the t test procedure as described by Steel and Torrie (1960). The effect of type of pregnancy and stage of pregnancy on total estrogen and progesterone concentrations was estimated by one-way analysis of variance using a program developed for the Olivetti 602 desk-top computer. The Student-Newman-Keuls (SNK) test was used to detect any significant differences between means. The intra and inter-assay coefficients of variation were calculated as described by Rodbard (1971).

EXPERIMENT 1

Effects of Season and Stage of Estrous Cycle on Circulating LH and FSH Levels in Female Goats

Work by Roche et al., (1970) indicated that circulating LH levels were low in anestrual ewes, although pituitary concentrations were never depleted. Using anestrual and ovariectomized ewes Howland et al. (1978a, 1978b) demonstrated LH release following estradiol administration. The LH releases were always accompanied by FSH peaks in anestrual ewes but concurrent FSH peaks were not consistently seen in ovariectomized ewes.

Earlier, Yuthasastrakosol (1975) working with intact ewes, had shown that during the interestrus periods of the breeding season, the nature of LH secretion (peak magnitude and number of peaks per 24h) was dependent upon the reproductive state of the animal. Similar patterns of gonadotropin secretions are suspected to occur in the female goat but have not been investigated.

Therefore, the objective of this study was to determine the nature and pattern of gonadotropin secretion in intact female goats during the breeding and non-breeding seasons.

Materials and Methods

Two mature multiparous female goats were bled by venipuncture at 20-min intervals for 24h on the 22nd of June, September and December, 1976 and on the 23rd of March, 1977. Sampling started at 0900h on the 22nd of June and September and at 1800h on the 22nd of December, 1976 and the 23rd of March, 1977. Serum levels of LH and FSH were determined by radioimmunoassay using methodology previously described.

Results and Discussion

During the course of the experiment goats #5351 and 5353 began cycling on the 18th and 23rd November, 1976 and stopped on the 13th and 25th May, 1977, respectively. The serum LH and FSH profiles for each individual goat are presented in Figures 1 and 2. In Table 1 descriptive parameters regarding the nature of LH secretion are presented. The LH profiles in both animals indicate that throughout anestrus and breeding periods, LH release is episodic in fashion. However, the number of LH peaks increased from 3 and 4 per 24h during early anestrus (June) to 8 in each case, in late anestrus (September) for goats #5353 and 5351 repectively. Concurrently, there was a decrease in the average peak level from 6.7 $\pm$ 0.3 and 5.6 $\pm$ 0.4 ng/ml to 3.4 $\pm$ 0.3 and 4.2 $\pm$ 0.3 ng/ml for goat #5353 and 5351, respectively.

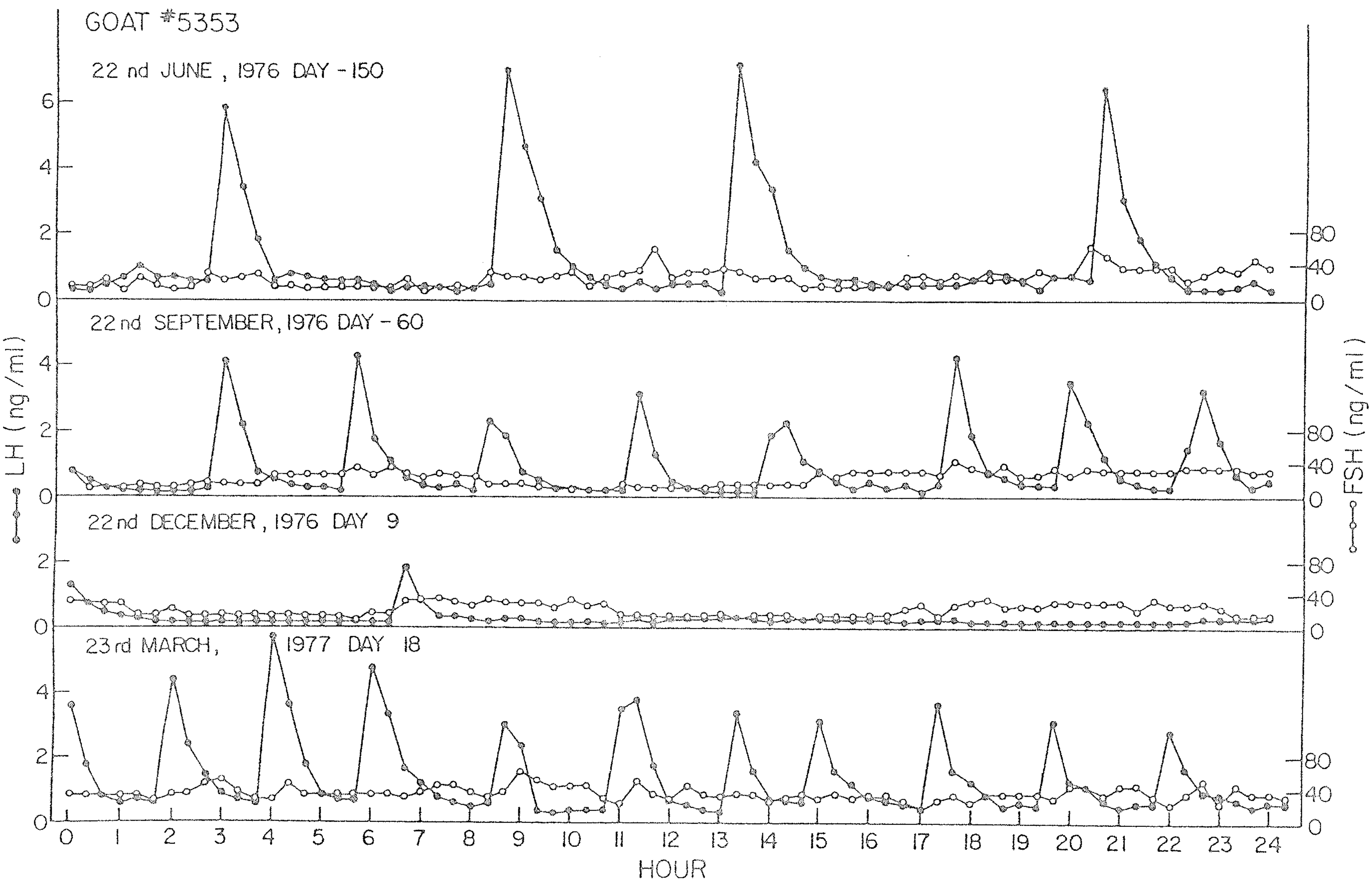

Figure 1. LH and FSH profiles obtained from Goat #5353 bled at 20-min intervals for 24h during the breeding and non-breeding seasons.

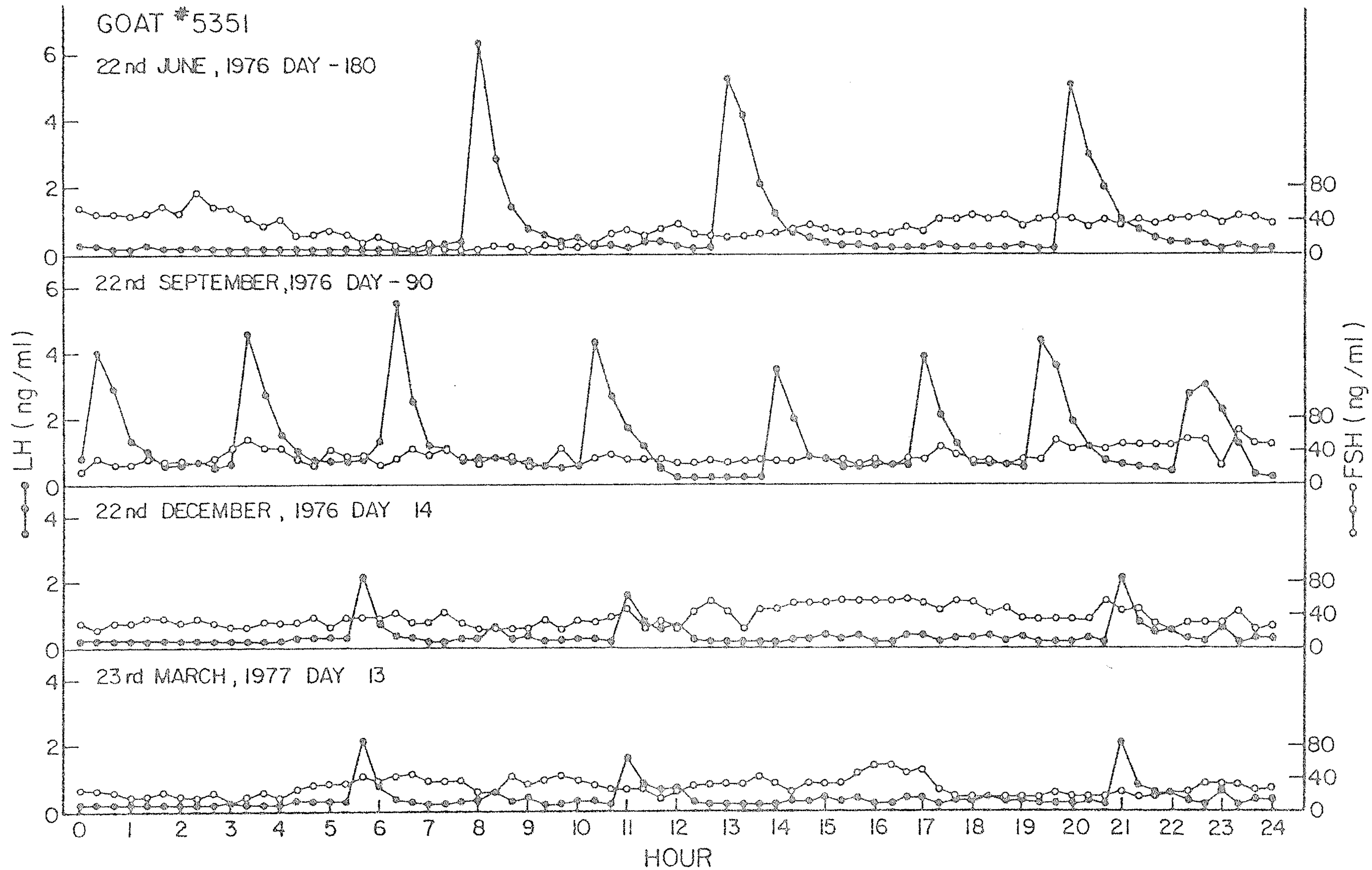

Figure 2. LH and FSH profiles obtained from Goat #5351 bled at 20-min. intervals for 24h during the breeding and non-breeding seasons.

Table 1. Profile Characteristics of LH Secretion in Goat #5353 and 5351 Bled at 20-min Intervals for 24h During the Breeding and Non-Breeding Seasons.

Goat No.		No. Peaks /24h	MEAN ± S.E.			
			Peak[a] Level (ng/ml)	Baseline[b] Level (ng/ml)	Δ Level[c] (ng/ml)	Apparent Half-life (min.)
5353	June 1976 Day -150	4	6.7 ± 0.3	0.6 ± 0.03	6.1 ± 0.3	30.0 ± 2.2
	Sept. 1976 Day -60	8	3.4 ± 0.3	0.3 ± 0.05	2.9 ± 0.4	20.0 ± 1.9
	Dec. 1976 Day 9	1	1.98	0.3 ± 0.01	1.78	20
	March, 1977 Day 18	11	3.8 ± 0.3	0.7 ± 0.0	3.2 ± 0.3	20.0 ± 0.2
5351	June 1976 Day -180	3	5.6 ± 0.4	0.3 ± 0.01	5.3 ± 0.3	28.0 ± 4.6
	Sept. 1976 Day -90	8	4.2 ± 0.3	0.5 ± 0.04	3.5 ± 0.2	23.3 ± 2.9
	Dec. 1976 Day 14	3	2.0 ± 0.2	0.3 ± 0.003	1.7 ± 0.03	20.0 ± 0.1
	March, 1977 Day 13	3	1.7 ± 0.3	0.3 ± 0.02	1.4 ± 0.3	20.0 ± 0.1
						23.2 ± 1.6*

[a] Peak was defined as any value more than one standard deviation above the baseline values and followed by one or more decreasing values.

[b] Calculated from all the baseline values not associated with a peak.

[c] Calculated as the difference between the peak value and the value immediately preceding it.

*Calculated from all the individual half-lives.

During the interestrus periods of the breeding season the LH secretory pattern varied with the reproductive state of the animal. The LH peaks were fewer (1 peak for goat #5353 on Day 9 of the cycle and 3 peaks for each on Day 13 and 14 of the cycle for goat #5351) during the luteal phase of the cycle. In that respect, these findings are in agreement with the results obtained by Yuthasastrakosol (1975) while working with ewes. However, they differ from those of Yuthasastrakosol (1975) and Cicmanec and Niswender (1973) in that the fewer peaks observed in these studies during the luteal phase were not of higher magnitude than the more numerous peaks that occurred in the early and the late follicular phase.

As previously demonstrated by earlier studies, the late follicular phase was characterized by many LH peaks (11 peaks for goat #5353 corresponding to Day 18 of the cycle) with a mean peak level of 3.8 $\pm$ 0.3 ng/ml.

Karsch et al. (1977) and Legan and Karsch (1979) have hypothesized progesterone as the major organizer of the estrous cycle and together with estrogen it governs the tonic release of LH secretions. Therefore, the nature and fashion of LH secretion observed in these findings reflects the inhibitory effect of progesterone on the tonicity of LH release. The inhibitory effect of progesterone on LH secretion is maximal during the luteal phase (around Day 17). At this point in time, according to Legan and Karsch (1979) estradiol levels are on the increase and act synergistically with the falling levels of progesterone to stimulate increased episodic LH secretion in the ewe.

From semi-logarithmic graphs of concentrations vs time, the mean half-life of LH was estimated at 23.2 $\pm$ 1.6 minutes (n = 40) with a range of 16.0 to 36.0 minutes. These estimates are within the range of those obtained by Geschwind and Dewey (1968) and Yuthasastrakosol (1975) for ewes.

Whereas LH secretion is episodic in nature during the breeding and non-breeding periods, a similar mode of secretion has not been verified for FSH. In this study FSH levels fluctuated randomly within narrow limits and its pattern of secretion during anestrus and the interestrus periods did not bear any recognizable relationship with the pulsatile nature of LH release.

Conclusion

The apparent half-life of LH was estimated at 23.2 $\pm$ 1.6 minutes, During anestrus LH peaks were less frequent but higher in magnitude than during follicular phase of the estrous cycle during the breeding season. During the breeding season, the nature and fashion of LH release was dependent on the reproductive state of the animal. These findings re-emphasize the importance of progesterone (and estradiol) as the major governor of tonic LH release during inter-estrous periods. During anestrus and the inter-estrous periods of the breeding season, the LH peaks were not accompanied by concurrent FSH peaks.

EXPERIMENT 2

Hormone Level Changes During the Transition from Anestrus to Breeding Activity

The main factors limiting continued productivity in seasonal breeders during the periods of anestrus are the failure to exhibit estrus and the continued absence of ovulation illustrated by relatively regressed ovaries that lack functional corpora lutea.

The ovarian quiescence and regression typical of anestrus cannot be attributed to a deficiency in gonadotropin secretion since the pituitary concentrations of LH and FSH are similar in ewes and ewe-lambs during anestrus and the breeding season (Roche et al., 1970; Foster et al., 1975). Rather, it is due to change in the responsiveness of the hypothalamo-pituitary unit toward ovarian hormone(s) feedback mechanisms according to Legan and Karsch (1979).

The evaluation of estradiol, progesterone and LH by Yuthasastrakosol et al. (1975) and of FSH, LH, prolactin and progesterone by Walton et al. (1977) has shown how these hormones interrelate in intact ewes during anestrus and during the transition from anestrus to the establishment of regular estrous cycles. There is no such information on the goat. Therefore, this study was conducted with the aim of trying to establish the interrelationships of various hormones during the transition from anestrus to resumption of breeding activity.

Materials and Methods

Four female pygmy goats (2 mature and 2 prepubertal) were bled daily by venipuncture throughout anestrus beginning June 25th, 1976 up to four days after the first overt estrus. The two prepubertals goats were 214 and 211 days of age at the initiation of sampling. Serum LH, FSH, progesterone and estrogen concentrations were determined by RIA.

Results and Discussion

Onset of Breeding Activity and/or Puberty

All the animals showed behavioural and endocrine changes that were characteristic of the establishment of normal estrus cycles between the 18th and 30th of November. The interval from first presumed ovulation (as indicated by progesterone profiles) to first behavioural estrus of the breeding season was 18, 20. 19, and 20 days for goat #'s 6258, 6257, 5353 and 5351, respectively (mean = 19.25 $\pm$ 0.47; n = 4). The two prepubertal females, goat #6258 and 6257 showed first overt estrus on 22nd and 30th November, at the age of 248 and 251 days, respectively. This observation is in agreement with the results of Simaraks (1978) who reported the age at first ovulation was 221.2 ± 0.6 days for ewe lambs. It is probable that the prepubertal goats in this study may have reached puberty earlier but were unable to start cycling due to environmental conditions not being optimum for them to have done so. This is supported by the observation that they reached puberty at the same time that their elder dams were resuming their seasonal ovarian cyclicity.

Hormone Level Changes

Mean ± S.E. levels of LH, FSH, progesterone and estradiol-17β in the four goats are illustrated in Fig. 3. The day of anestrus is normalized to the day of the first behavioural estrus of the breeding season.

LH and FSH levels fluctuated randomly throughout anestrus. However, a two-to-three fold increase in their mean values was observed five days before the preovulatory surge prior to the first ovulation. After the first ovulation, mean levels of FSH decreased and were similar to those observed during anestrus. LH mean levels decreased to baseline levels that were lower than prior to the first ovulation by the third day after the preovulatory surge. Prior to the first observed estrus, both gonadotropins were secreted in the same pattern as observed prior to the

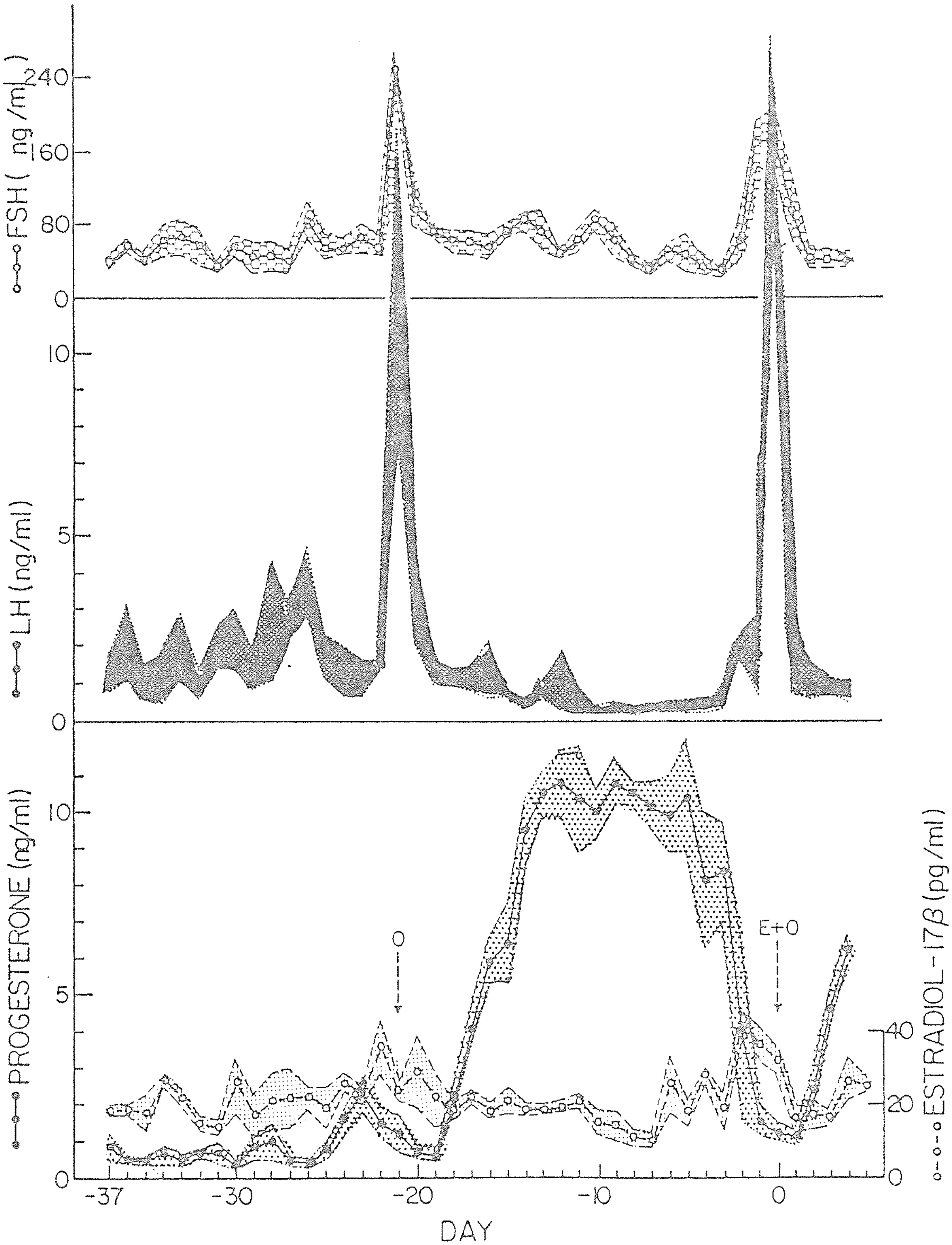

Figure 3. Composite hormone (mean ± S.E.) profiles for the 4 animals during transition from anestrus to breeding activity. (O designates first presumed ovulation and E + O = first estrus and presumed ovulation).

first ovulation; there were again elevations (from 0.5 to 1.8 and 27.3 to 61.7 ng/ml for LH and FSH, respectively) in both gonadotropins two days before their preovulatory surge.

Meanwhile, mean progesterone concentrations were low during anestrus but increased by about four-fold (from an average of 0.5 to 2.3 ng/ml) two days before the first ovulation (Day-23). They then declined to low values on the day of first ovulation. During the interval between the first presumed ovulation and the first behavioural estrus, progesterone concentration and pattern of secretion were characteristic of that observed during the normal cycle of a goat (Thorburn and Schneider, 1972).

The rise in mean progesterone concentration two days preceding first ovulation has been observed in cows before the first post-parturient ovulation (Donaldson et al., 1970; Robertson, 1972; Arije et al., 1974; Nkuuhe et al., 1978), during the transition from anestrus to breeding activity in ewes (Yuthasastrakosol, 1975; Walton et al., 1977; Wheeler et al., 1977) and in ewe lambs upon reaching puberty (Foster et al., 1975; Simaraks, 1978). In the ewe and most probably in the goat progesterone is derived almost exclusively from the corpus luteum. Its secretion, therefore, is a measure of the activity of this ovarian compartment. The increase in the release of LH five days before first ovulation is thought to induce luteinization of one or more follicles which then secrete the increased level of progesterone that is seen a few days preceding first presumed ovulation (Wheeler et al., 1977; Walton et al., 1977). This may come about either as a result of insufficient release of LH or from the inherent incapability of the follicle(s) to ovulate in response to the stimulus. This hypothesis has been cited and may be supported by the observation that ovarian follicles can grow and regress within 5 to 7 days (Smeaton and Robertson, 1971).

Serum mean estradiol-17β concentrations varied during anestrus and were observed elevated a day before the LH/FSH preovulatory surge of the first presumed ovulation. After that, they remained low and declined gradually to their lowest levels on Day-7 before the first estrus. Beginning on Day-6 before the first behavioural estrus mean estradiol-17β levels rose progressively peaking two days before the LH/FSH surge. This finding is in agreement with earlier studies and supports the hypothesis that rising levels of estradiol act synergistically with declining levels of progesterone to precipitate increased tonic LH secretion and the events that lead to ovulation (Legan and Karsch, 1979).

Conclusion

Puberty as measured by the manifestation of first pyschic estrus was reached at the age of 251 and 248 days by two prepubertal goats, respectively. From the progesterone profiles, it appeared evident that all the four animals resumed (or started) their breeding activity by exhibiting ovulations that were not accompanied by overt estrus. Profiles of LH, FSH, progesterone, and estradiol obtained in this study indicate that the hormonal interrelationships that result in resumption of ovarian cyclicity (or the attainment of puberty) in goats are similar to those which are operative in ewes and ewe lambs.

EXPERIMENT 3

Gonadotropin and Ovarian Hormone Concentrations During Consecutive Estrous Cycles

During the breeding season, at well-spaced regular intervals, the female goat is receptive to the buck at the time of estrus. It may be assumed that, as in other species that have been studied in detail, that this behaviour results from endocrine changes that attain rhythmicity as a consequence of clear-cut checks and balances within the hypothalamo-hypophyseal-gonadal feedback system. The feedback mechanism -- positive and negative, short loop and long loop -- in this system dictate the day to day variations in circulating hormone concentrations during the estrous cycle. The balance and temporal relationships between the various hormones of pituitary and ovarian origin do ultimately determine such phenomena as: cycle length; intensity of estrus manifestations; follicular growth, development and/or atresia; ovulation and ovulation rate; and corpus luteum formation, function and longevity.

Undoubtedly, the hormonal system acts on/or with the central nervous system in the control of these phenomena.

In the goat, information relative to the endocrinology of the estrous cycle is scanty. Only one study (Thorburn and Schneider, 1972) so far has evaluated the concentration of circulating progesterone by a protein-competitive binding assay. Luteinizing hormone, follicle-stimulating hormone and estradiol have not been evaluated to date.

Hence the following experiment was undertaken to evaluate circulating gonadotropin and ovarian-hormone concentrations during the estrous cycle.

Materials and Methods

During the breeding season (14th November, 1977 to 19th January, 1978) four cycling goats were bled once daily from the jugular vein by venipuncture. Estrus was detected by teasing with intact bucks two to three times per day during the daylight hours. Sera was handled and assayed by RIA to assess concentrations of LH, FSH, progesterone and estrogen as previously described.

Results and Discussion

Cycle Length

The sampling period represented at least three estrous cycles in each of the four goats used in the study. The mean cycle length was 19.0 $\pm$ 1.2 days; ranging from 5 to 24 days. Longer cycle lengths have been reported; 20.2 days for Angora goats by Pretorius (1973); 21 days for the Saanen breed by Thorburn and Schneider (1972) and 23.9 ± 1.2 and 19.0 ± 0.6 days for Pygmy (pure bred) and Pygmy (7/8 cross with Toggenburg) breeds, respectively, by Jarosz et al. (1971).

The discrepancies in cycle length may be attributed to breed differences (Saanen vs. Pygmy) or the characteristics of the estrous cycle studied and/or the methodology employed in the study. In this study, behavioural and endocrine changes were used as indicators of the day of estrus. Jarosz et al. (1971) used laparoscopic techniques for examining ovaries *in situ*, complemented with vaginal indications of estrus. Recently, Fortune and Hansel (1979) have reported that ovulation occurs some 22 to 30 hours after the preovulatory surge of LH in the bovine. If the same situation exists in the goat, then Jarosz and co-workers (1971) may have over-estimated cycle length by at least one day. Changes in cytology of the vaginal epithelium are precipitated by changes in the endocrine milieu. The biochemical changes that are triggered by hormonal changes, to result in the vaginal cytology that is indicative of estrus, occur considerably after the hormonal changes. Therefore, estimation of cycle length from vaginal cytology may inherently over-estimate cycle length in contrast to that evaluated from endocrine changes.

In one goat (#6258), some shorter cycle lengths of 5 days were observed during the experimental period and during the rest of the breeding season. Similar cases of short estrous cycles were reported by Pretorius (1973); their significance remains obscure but should be considered to be much shorter than usual.

Hormone Profiles During Consecutive Estrous Cycles

The profiles of LH, FSH, progesterone and estradiol concentration during the cycles in goat #5353, 5351, 6257 and 6258 are shown in Figs. 4, 5, 6, and 7, respectively. In all the animals and in each cycle, the circulating levels of progesterone were observed to be very low on Day 0 (mean ± S.E. of 0.7 ± 0.07 ng/ml) and began to increase rapidly by Day 3. Maximum mean values of 9.3 ± 0.3 ng/ml (range 7.2 to 12.2 ng/ml) were attained by Day 9. Individual circulating progesterone values remained high, fluctuating around the maximum mean value from Day 9 to Day 15. Beginning by Day 16 or 17 of the cycle a precipitous decline was observed; lowest values being again attained on Day 0 of the following cycle.

Conversely, LH mean concentrations peaked on Day 0 (maximum mean ± S.E. value was 11.4 ± 1.2; range -- 6.5 to 21.5 ng/ml) and fell to baseline values of 0.3 ± 0.1 ng/ml by Day 3 of the cycle. Meanwhile estradiol showed slight

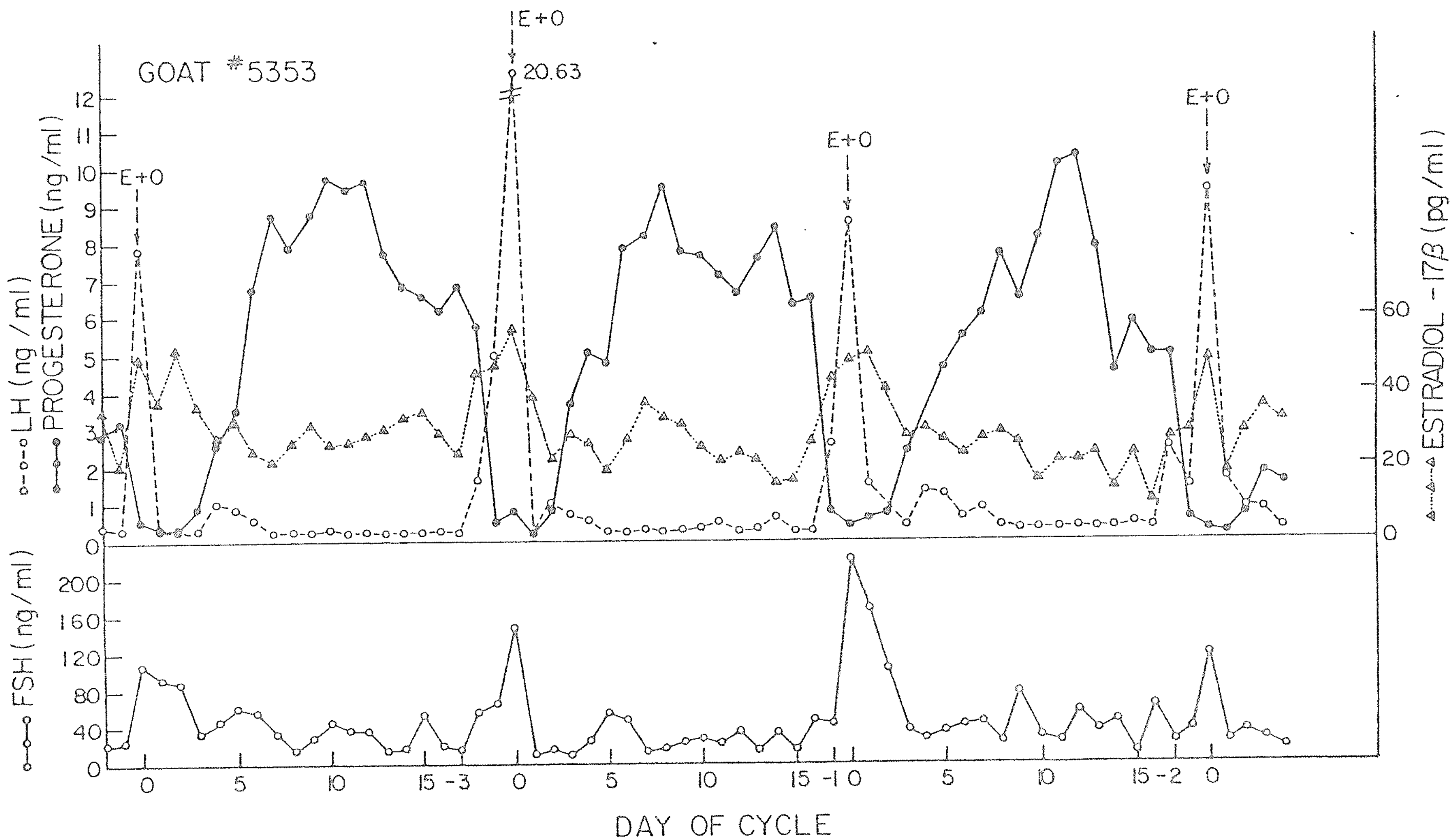

Figure 4. Hormone profiles for Goat #5353 during 3 consecutive cycles. E + O designates estrus with presumed ovulation. (Estrus = Day 0).

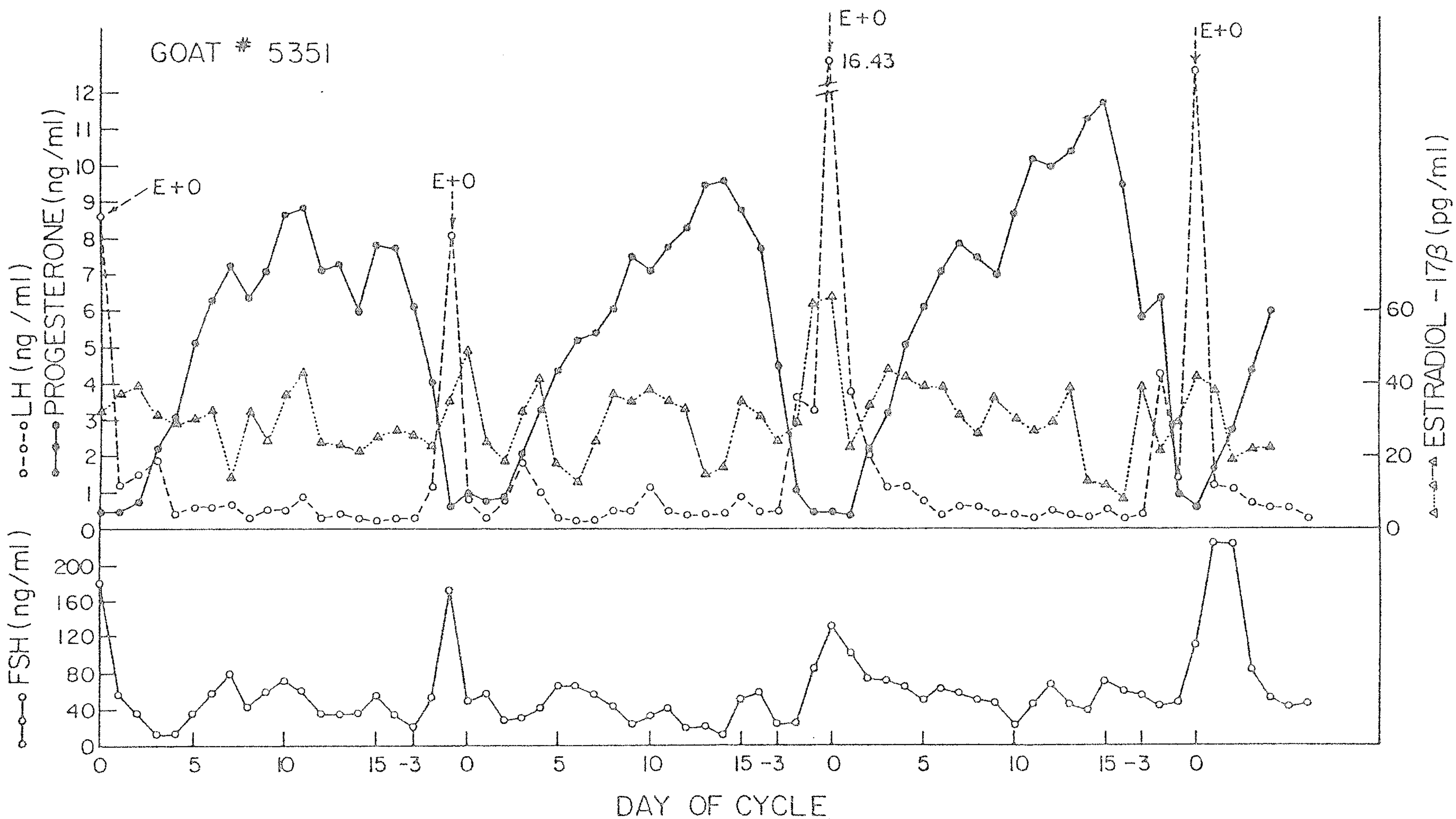

Figure 5. Hormone profiles for Goat #5351 during 3 consecutive cycles. E + O designates estrus with presumed ovulation. (Estrus = Day 0).

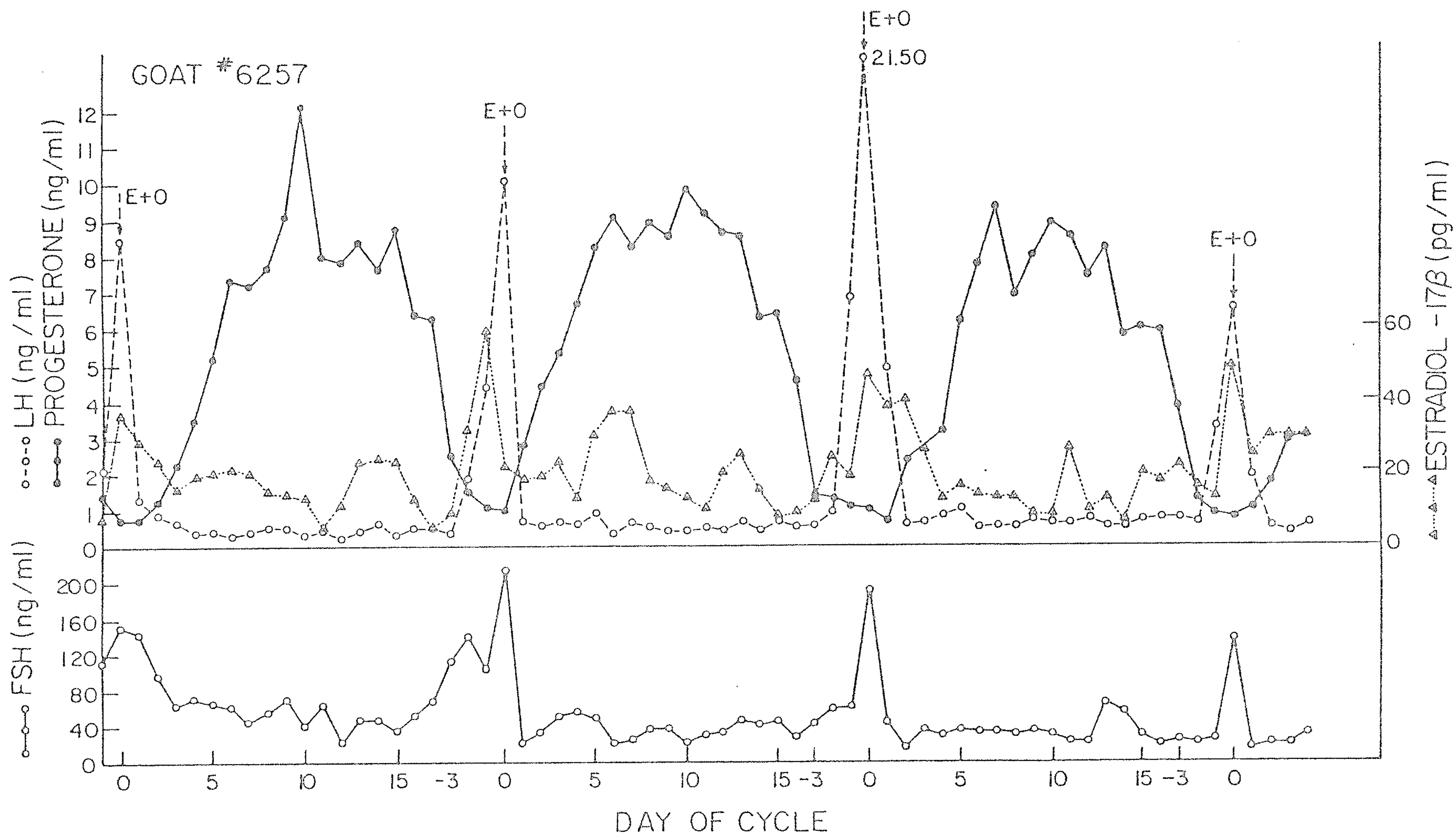

Figure 6. Hormone profiles for Goat #6257 during 3 consecutive cycles. E + O designates estrus with presumed ovulation (Estrus = Day 0).

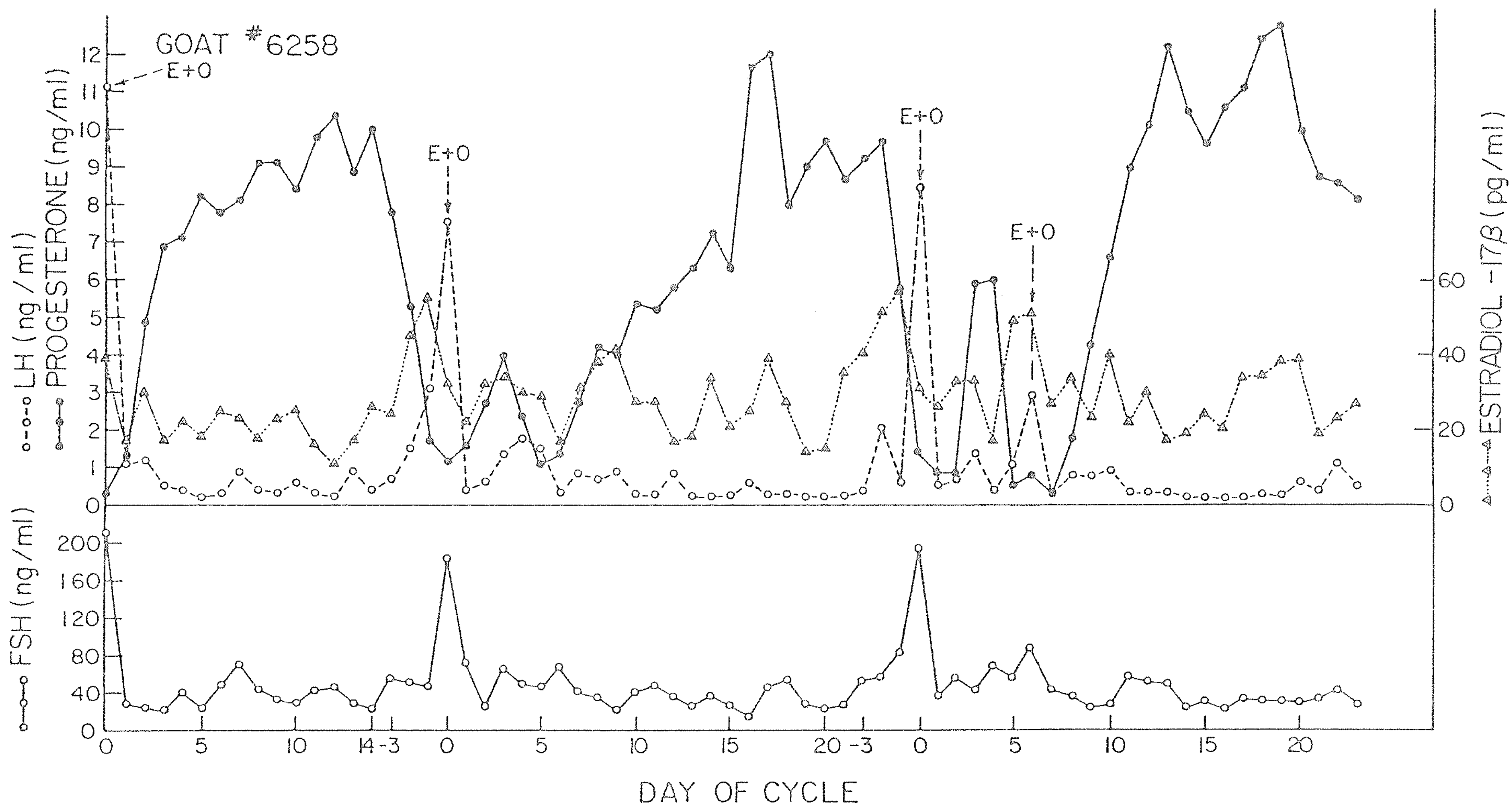

Figure 7. Hormone profiles for Goat #6258 during 3 consecutive cycles. E + O designates estrus with presumed ovulation. (Estrus = Day 0).

increases on Day-2, reached peak values of 49.2 ± 1.8 pg/ml on Day 0. Slight increases were also observed on Days 4 and 5 of the cycle. Thereafter, levels fluctuated randomly around a mean level of 14.8 ± 0.9 pg/ml for most of the cycle.

The FSH profile was characterized by random fluctuations within narrow limits. Mean values showed slight increases on Day-1 before the characteristic pre-ovulatory surge seen on Day 0. Peak mean values on Day 0 were 174.6 ± 9.7 ng/ml with a range of 112 to 225 ng/ml.

These hormone profiles are comparable with those reported for sheep and cattle by various workers (Pant et al., 1977; Karsch et al., 1978; Simaraks, 1978). It is clear from these and other findings that in both the ewe and the goat, base-line circulating LH levels are interrupted by a massive pre-ovulatory LH surge once each cycle. The low levels and the massive pre-ovulatory LH/FSH surge appear to be in an inverse relationship with circulating progesterone levels. These findings are therefore in agreement with the thesis that during the breeding season progesterone exerts a dominant inhibitory effect on tonic LH release. Therefore, the fall in circulating progesterone concentrations at the end of the luteal phase (Day 17 and 18, in this case) allows an increase in tonic LH secretion. The results of Experiment 1 also support this observation as more LH peaks were observed on Day 18 of the cycle than on Day 13 or 14 (a time which coincided with maximum corpus luteum function as indicated by the progesterone profile).

The increased LH secretion in turn increased estrogen secretion by the ripening follicle(s). In this study, this was observed to occur around Day-2 or Day-1. The increased secretion of estradiol is apparently sustained by LH secretion and reaches a threshold which is able to trigger the LH/FSH surge. A new cycle begins when after ovulation the remnants of the ovulating follicle(s) are organized and developed into a new corpus luteum in response to a stimulation from LH.

As the corpus luteum matures, its formation and release of progesterone exerts an inhibitory effect on the hypothalamus and/or pituitary and hence on LH and estradiol secretion (and possibly FSH). The regression of the corpus luteum creates an opening in this mechanism by removal of the progesterone block and the entire sequence of events leading to ovulation are repeated. The regression of the corpus luteum is reported to be caused by prostaglandin $F_{2\alpha}$, synthesized by the non-pregnant uterus at around Day 16 or 17 in several species including the goat (Wilson et al., 1972; Baird, 1978; Behrman, 1978; Carlson et al., 1979). However, prostaglandins were not measured in this study. Thus, no further evidence to either support or contradict previous work is possible.

Conclusion

The average length of the cycle in the female pygmy goat was estimated to be 19.0 $\pm$ 1.2 days (range 5 to 24 days). During the cycle, circulating LH concentrations were in inverse proportion to progesterone levels and peaked on the day of estrus (Day 0). Luteal regression, as indicated from falling progesterone levels, occurred by Day-3 to Day-2 (with reference to the subsequent cycle) and was followed or accompanied by increases in estradiol, FSH, and LH secretion, all of which peaked at or around Day 0 of the succeeding cycle.

EXPERIMENT 4

Profile of Gonadotropin Secretion During Estrus

During the breeding season, estrus is a major "marker" event in the process of ovarian cyclicity. When it occurs, it is usually accompanied by ovulation and signifies the end of one cycle while beginning the next.

Overt estrus manifestation is of special interest to both the researcher and to the goat breeder. Its detection yields information relative to the management of breeding herds. The success or failure of decisions as to when to allow insemination depends on its timely detection. If insemination is to be carried out it should be done such that there is high probability of fertilization. In this way breeding efficiency problems characterized by high return rates and/or high repeat-breeders can be minimized; in so doing the improvement and/or maintenance of individual and/or herd productivity can be attained.

In essence, the estimation of the most probable time when ovulation will occur after the onset of estrus holds the "key" to a successful insemination or breeding program. Insemination must be done at the proper time to allow for sperm capacitation and subsequent fertilization to occur.

Crighton et al. (1973), upon examination of ovaries from ewes slaughtered at estrus, found freshly ovulated follicles in some sheep that had been slaughtered 36h after the onset of estrus. More recently, Fortune and Hansel (1979) reported that in the bovine, ovulation occurs some 22 - 30h after the LH surge. In the ewe it has been found that the interval between the onset of estrus to the beginning of the preovulatory gonadotropin surge and the duration of the surge are significantly influenced by breed (Land et al., 1973, Simaraks et al., 1979). Hence the evaluation of the interval between the onset of estrus and the beginning of the preovulatory gonadotropin surge would be useful in estimating the most probable time of ovulation and time to breed. It was therefore deemed necessary to conduct the following experiment in order to characterize the nature and pattern of preovulatory gonadotropin secretion during estrus in the goat.

Materials and Methods

Four cycling goats were maintained in a single pen indoors under natural lighting conditions. Estrus detection began in November, 1976 and continued throughout the breeding season. Detection was made by putting a vasectomized buck into the doe-pen and observing for 15 to 20 minutes.

The frequency of checking was twice per day for the first fifteen days of the cycle and then three times per day from day 16 to the day of estrus.

Blood was taken from the jugular vein by venipuncture at 20 minute intervals for 24h beginning immediately when the animal was detected to be in heat. Serum was analysed for LH and FSH by RIA as previously described.

A computer program developed by Dr. Chebib, Dept. of Oral Biology, University of Manitoba, to estimate the total release of FSH and LH by computing the area under the curves of the gonadotropin blood profiles, was used. In this case, however, the sample number was fed into the computer as time. The results of the total release are therefore expressed as ng/ml x time for LH, and ng/ml x time x 10^2 for FSH, since FSH concentrations were larger in absolute amount.

Results and Discussion

A total of 18 estrous periods were sampled; five of which yielded complete preovulatory gonadotropin-surge profiles. In another 15% the beginning of the gonadotropin-surge was missed while in 12% the end part of the gonadotropin-surge was missed. In the remaining 40%, complete preovulatory gonadotropin-surges were missed. Some sample profiles are presented in Figures 8, 9, 10, 11, and 12 and were obtained from goat #'s 5351, 5353, 6257, 6257 and 6258, respectively. Their profile characteristics are presented in Table 2.

The mean interval from onset of estrus to the beginning of the gonadotropin surge, magnitude, duration and secretion rate of the LH and FSH preovulatory surges are given in Table 2 for the five complete profiles that were obtained. The interval from the onset of estrus to when LH and FSH concentrations rose and remained above the baseline levels is expressed in hours, the magnitude in ng/ml, the duration in hours and the secretion rate as ng/ml x time.

The nature and pattern of the LH and FSH profiles is similar to that reported by Simaraks (1978) in ewes. The concentration of LH began to rise an average of 6.5 $\pm$ 0.7h after the onset of estrus. LH secretion appeared to be episodic in nature as indicated by minor fluctuations prior to the beginning of the preovulatory surge. Levels of LH remained elevated (with some indications of secretion in episodic fashion) for a duration of 15.2 $\pm$ 0.5h. Thereafter LH secretion fell to baseline values. An assessment of LH and FSH profiles revealed that the LH surge preceded the FSH surge by 1.1 $\pm$ 0.4h. Also, the duration of the LH surge exceeded that of the FSH surge by 1.7 $\pm$ 0.7h. These differences, however, were not significant ($P>0.05$). It

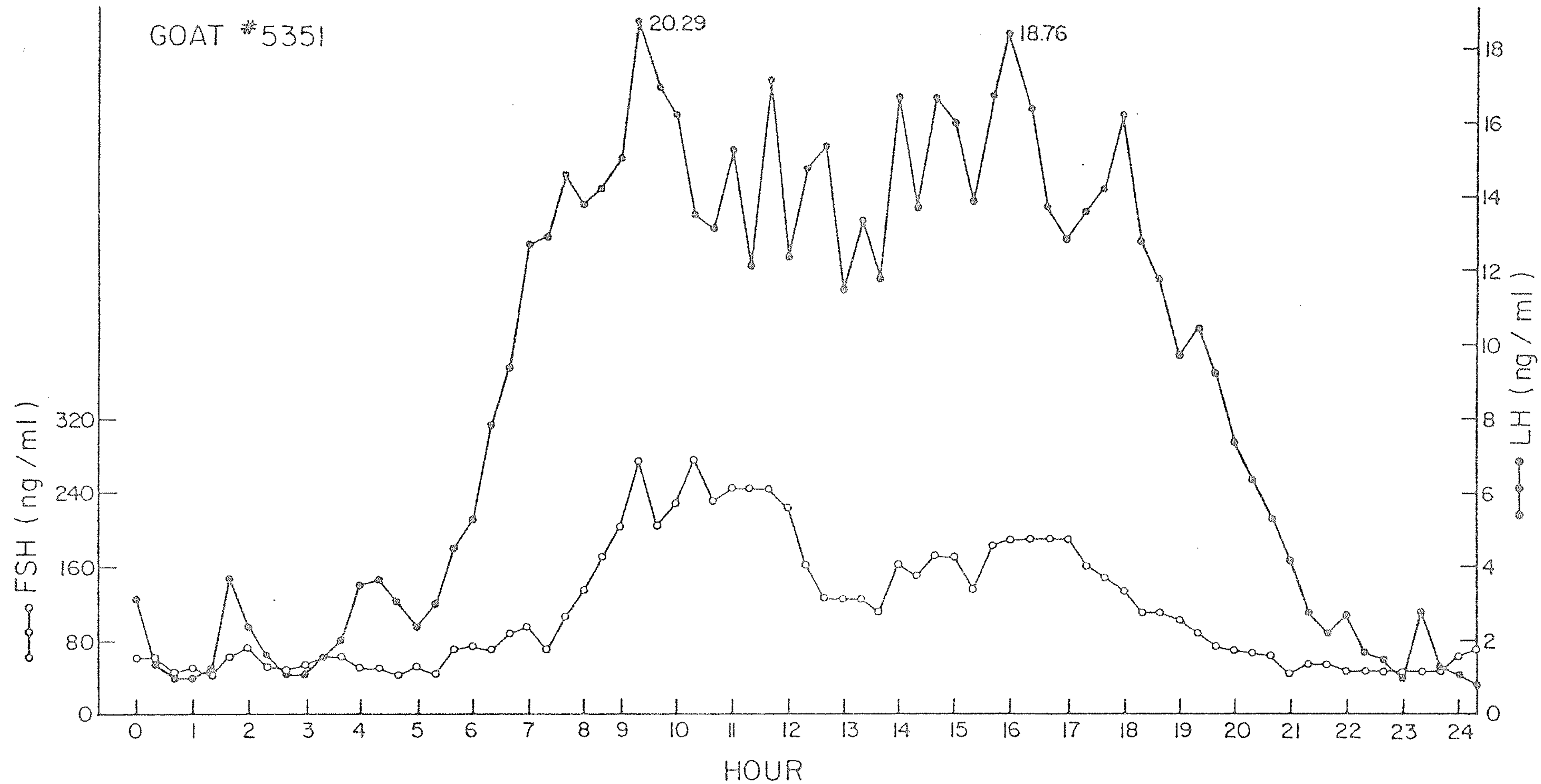

Figure 8. The profiles of the LH and FSH preovulatory surges in Goat #5351 during estrus. (Onset of estrus = 0 h).

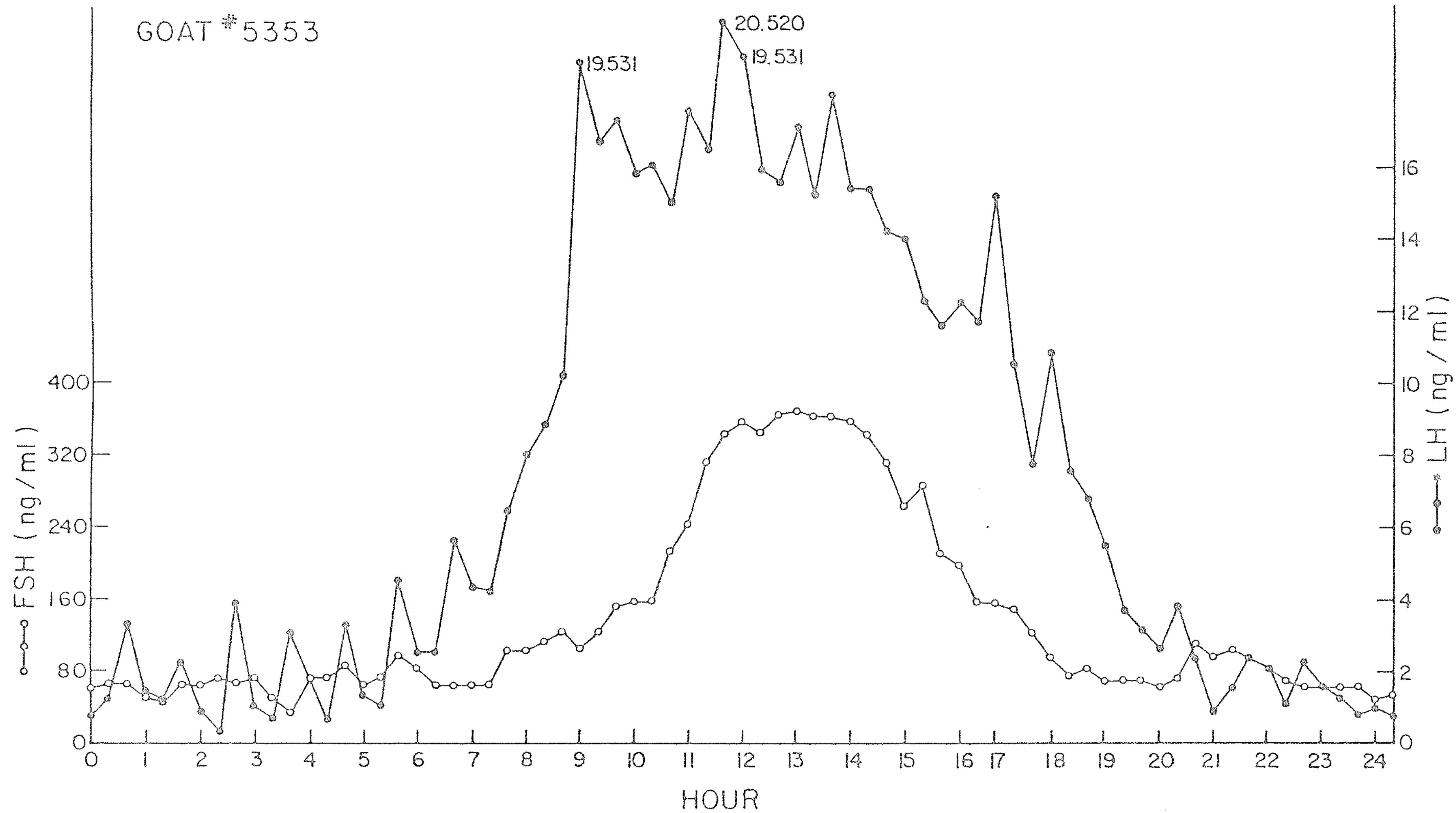

Figure 9. The profiles of the LH and FSH preovulatory surges in Goat #5353 during estrus. (Onset of estrus = 0 h).

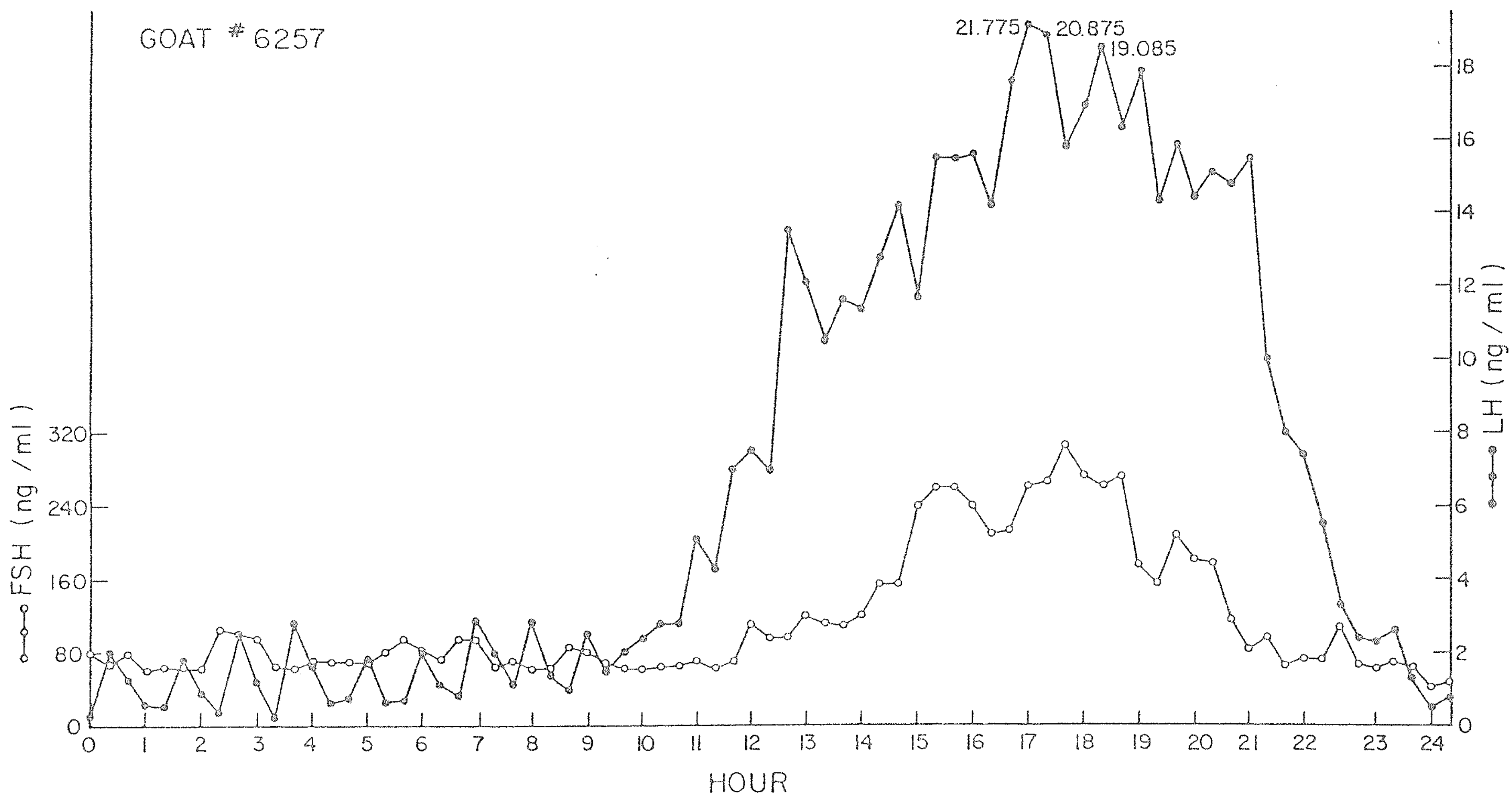

Figure 10. The profiles of the LH and FSH preovulatory surges in Goat #6257's third estrus. (Onset of estrus = 0 h).

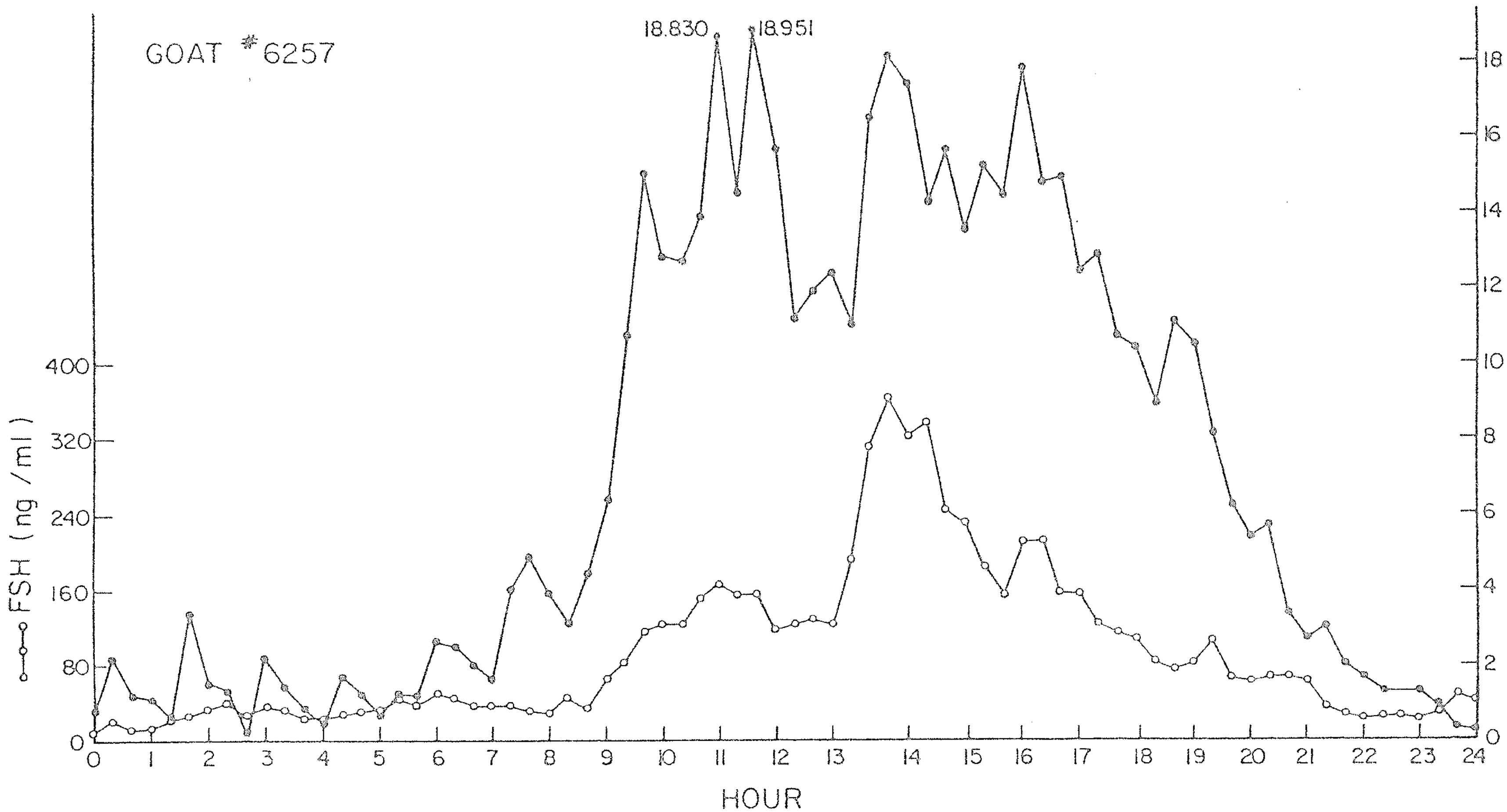

Figure 11. The profiles of the LH and FSH preovulatory surges in Goat #6257's second estrus. (Onset of estrus = 0 h).

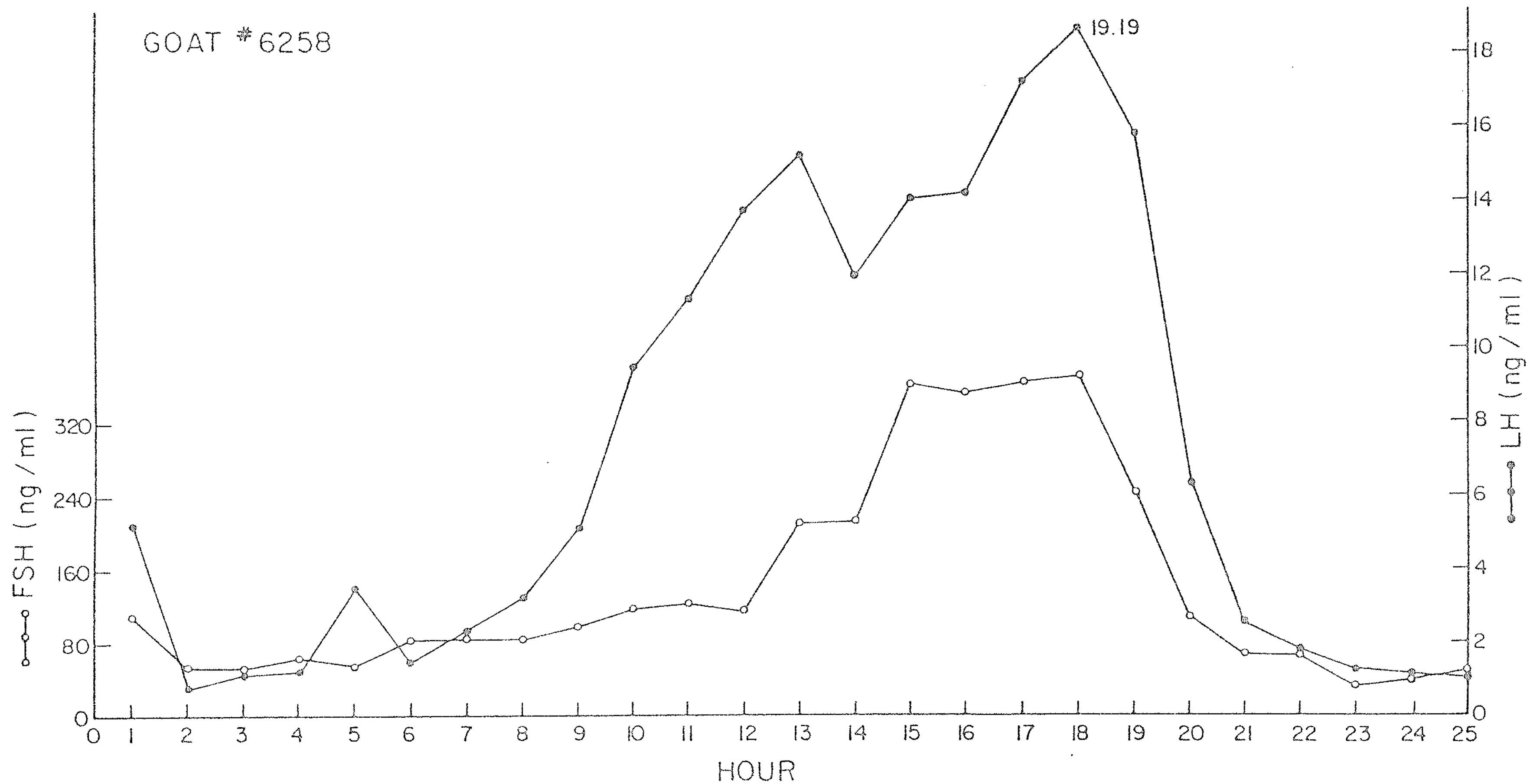

Figure 12. The profiles of the LH and FSH preovulatory surges in Goat #6258 during estrus. (Onset of estrus = 0 h). Sampled only every hour because of difficulty in collecting sample.

Table 2. Mean Interval from the Onset of Estrus, Magnitude, secretion Rate and Duration of the Preovulatory LH and FSH Surge (N=5).

	LH	FSH	[a]Time diff.
Interval (h ± S.E.)	6.5 ± 0.7	7.4 ± 0.8	1.1 ± 0.4
Magnitude (ng/ml ± S.E.)	20.1 ± 0.5	335.0 ± 17.9	
Duration (h ± S.E.)	15.2 ± 0.5	13.8 ± 0.7	[b]1.7 ± 0.7
Total Release (ng/ml x time ± S.E.)	3.8 ± 0.7	39.6 ± 6.4	

Interval = time from onset of estrus to beginning of either LH or FSH discharge (when values exceeded and remained above baseline levels).

Total release is derived from area under curve and is expressed as ng/ml x time for LH, and ng/ml x time x 10^2 for FSH.

Magnitude = highest concentration, expressed as ng/ml.

Duration = time from LH rise and fall to baseline levels, expressed as h.

a = Time difference between onset of LH and FSH surges.

b = Time difference in duration between LH and FSH profiles.

has been reported (Fortune and Hansel, 1979) that ovulation occurs some 22 to 30 hours after the preovulatory surge of LH in the bovine. Earlier, Jarosz et al (1971) had observed ovulation to occur about 4.25 ± 0.25, 3.1 ± 0.18 and 2.11 ± 0.16 days after the appearance of behavioural symptoms of estrus in the Toggenburg, Pygmy and crossbred (Pygmy (7/8)) breeds of goats, respectively. It is, therefore, possible to postulate that the interval from the onset of estrus to ovulation in this breed of goat may be between 36 and 48 hours.

Some of the ovarian events that are influenced by the preovulatory gonadotropin surge have been examined in the rat. Work by Strickland and Beers (1979), Hirschfield (1979), Epsey and Rawson (1979) and Richards (1978) have demonstrated three major ovarian events that are influenced by the gonadotropin surge, namely:

(i) the recruitment of a few follicles and enabling them to complete the final stages of development in preparation for ovulation during the subsequent cycle(s).

(ii) the initiation of enzymatic and biochemical processes that precipitate ovulation. This is thought to be accomplished in synergism with prostaglandins; especially of the E-series, and

(iii) the stimulation of luteinization and hence CL formation.

As follicles grow, there is a critical period during which most of them become atretic and the preovulatory gonadotropin surge (especially FSH) at estrus is instrumental in rescuing some follicles that continue to grow and complete the final stage of development in the subsequent cycle(s), (Hirshfield, 1979). It has also been demonstrated by Peters (1979) that during cell differentiation of the theca layer in the growing follicle, smooth muscle cells develop that later become the target of prostaglandins. Conceivably those may play a role in "squeezing" the ovum and the antral contents during ovulation.

It has long been felt that LH is the gonadotropin that is responsible for causing ovulation. However, enzymatic studies conducted by Strickland and Beers (1979) have shown that specific proteolytic enzymes are responsible for the disruption of the cell wall and release of the ovum. *In vitro* studies showed that in response to gonadotropins (especially FSH) and prostaglandins, granulosa cells through a mechanism mediated by cAMP, synthesize and secrete a substance known as "plasminogen activator". It was further demonstrated that the production of plasminogen activator by granulosa cells was closely correlated with ovulation. From these studies, then, it would appear that, the mechanism of ovulation therefore begins with the production and secretion of the plasminogen activator and is controlled by gonadotropins. Once produced the plasminogen activator acts on follicular fluid plasminogen converting it to plasmin. The plasmin then acts on the substrates within the follicle wall, weakening the follicle wall and disrupting it as ovulation proceeds.

In their studies with rat follicles, Strickland and Beers (1979) were able to demonstrate that FSH is much more effective than LH in causing the granulosa cells to sythesize the plasminogen activator and since this enzyme initiates the events that lead to ovulation, it was regarded by them as the ovulatory hormone. However, at the time of ovulation, LH and FSH reach peak levels at the same time and granulosa cells in preovulatory follicles have receptors for both hormones. Hence, LH may be involved in preparing cells for luteinization or initiating the second meiotic division of the oocyte.

Conclusions

The concentration of LH began to rise an average of 6.5 ± 0.7 h after the onset of estrus. LH secretion appeared to be episodic in nature as indicated by minor fluctuations, prior to the beginning of the preovulatory surge. Levels of LH remained elevated (with some indications of secretion in episodic fashion) for a duration of 15.2 ± 0.5h. Thereafter, LH secretion fell to baseline values. FSH levels fluctuated within narrow limits and began rising on an average of 1.1 ± 0.4h after the initial LH elevation. FSH levels remained above baseline values for 1.7 ± 0.7h less than did those of LH. These differences were, however, not significant ($P > 0.05$). Judging from the interval from the onset of estrus to the beginning of the preovulatory LH/FSH surge and its duration, ovulation could be estimated to occur an average of 36h after the onset of estrus, and the most optimum time for insemination or mating would be about 30h after the onset of estrus.

Experiment 5

Ovarian Hormone Profiles During Pregnancy and Parturition

Reproduction is a major contributing factor to efficiency of goat production. The endocrinological events that precipitate successful fertilization, implantation, pregnancy and delivery of healthy young lend contribution to maximizing its efficiency. In the recent past, the endocrinology of pregnancy, pregnancy maintenance and parturition in the goat, has received considerable attention from various research workers. Major breakthroughs have been made in the evaluation of progesterone and estrogen levels throughout pregnancy (Blom and Lyngset, 1971; Irving et al., 1972; Thorburn et al., 1972; 1977; Thorburn and Schneider, 1972; Currie and Thorburn, 1977 a, b; Rawlings and Ward, 1977) and of the need for intact hypothalamo-hypophyseal-adrenal-ovarian systems in the fetus and the mother for pregnancy maintenance and the initiation of normal term delivery (Buttle, 1978; Linzell and Heap, 1968; Rawlings and Ward, 1977; 1978).

In their studies, Kelly et al. (1976), Currie et al. (1977) and Buttle (1978) demonstrated the existence in circulation during pregnancy of placental lactogen, and of its role as a component of the luteotrophic complex maintaining the corpus luteum of pregnancy. The interactions between the fetus, fetal corticosteroids, placenta, estrogens, prostaglandins and oxytocin in the initiation and precipitation of spontaneous term parturition have also been examined and documented (McNeilly and Hart, 1973; Currie and Thorburn, 1973; 1976; 1977; Umo and Fitzpatrick, 1978; Umo et al., 1976; Challis et al., 1977; Mitchell et al., 1978; Flint et al., 1978; Currie, 1977).

It is now generally recognized that pregnancy maintenance in the goat is dependent on functional luteal tissue and that like in the sheep, parturition at term is initiated by fetal glucocorticoids by activating the placental C_{21}-steroid 17α-hydroxylase system. The end result of this system is the removal of the progesterone block while increasing concentrations of the hormones that precipitate uterine contractility (prostaglandins and estrogens). The purpose of this study, therefore, was the evaluation of progesterone and estradiol concentrations throughout pregnancy up to and including 3 to 4 days after parturition.

Materials and Methods

Four pregnancies were studied in two mature multiparous goats, i.e. two animals were followed through two successive pregnancies. Throughout pregnancy, the animals were kept inside a well-ventilated barn and fed legume hay supplemented with grain; water and salt were available *ad libitum*. Blood was collected from the jugular vein by venipuncture once every week for the first 20 weeks of pregnancy. Thereafter, the blood collection regime was changed to once every day until 3 to 4 days after parturition. Sera were handled and assayed for progesterone and estradiol-17β by RIA as previously described.

Results and Discussion

Gestation Length. Parturition was normal and spontaneous in all the four pregnancies, after a gestation length (mean ± S.E.) of 148.5 ± 1.4 days (range = 145 to 152 days). Of the four pregnancies, one resulted in triplet delivery, one in twin delivery and two each in a singleton.

The mean gestation length in this experiment is in agreement with that reported by earlier workers (Gupta, 1964; Wilson, 1960; Devendra and Burns, 1970; Blom and Lyngset, 1971; Shelton, 1978; Rawlings and Ward, 1977; Peaker, 1978). Using data obtained from a mainly British Sáanen goat herd accumulated over 23 years, Peaker (1978) reported a mean gestation period of 150 days and a median of 151 days. The findings in this experiment are from too few observations and would not permit fair comparisons between the two breeds.

Hormone Profiles. The profiles of progesterone and estradiol concentrations throughout pregnancy and around parturition are presented in Figures 13, 14, 15 and 16. In Tables 3 and 4, the effects of type of pregnancy and stage of pregnancy on progesterone and estradiol secretion are shown.

The mean progesterone concentration was quite low (2.2 ± 0.7 ng/ml) during the first week of pregnancy but rose quickly to levels usually seen during the luteal phase (8.1 ± 1.5 ng/ml) of the estrous cycle. From the 4th to the 8th week of pregnancy there was a decline in mean circulating progesterone levels. A secondary increase to mean levels fluctuating around those obtained in the 3rd week of pregnancy was observed in the 9th week of pregnancy. The second and final decline was very much evident in the samples taken during the 6 days preceding parturition. Samples taken within 24h pre- and post-parturition gave mean progesterone levels of 4.8 ± 0.9 and 1.5 ± 0.3 ng/ml, respectively.

Progesterone secretion was significantly (P 0.01) higher when the does were carrying three fetuses and twins than in singleton pregnancies (Table 3). In all the pregnancies, progesterone secretion was also significantly (P 0.01) higher in the second and last thirds than in the first (Table 3). The type of progesterone profile obtained in this study and the observed effects of the type of pregnancy

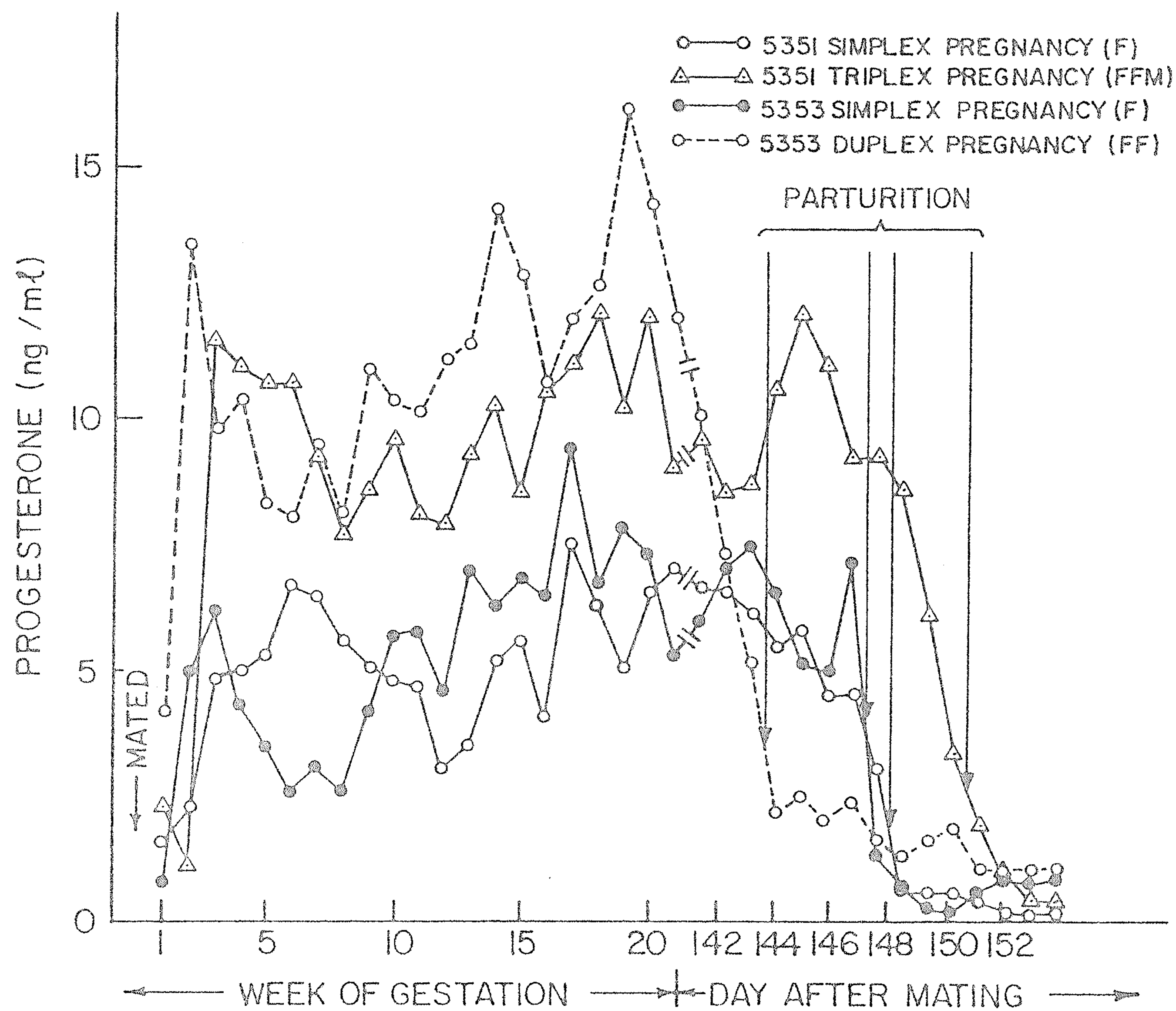

Figure 13. Progesterone profiles during the 4 pregnancies.

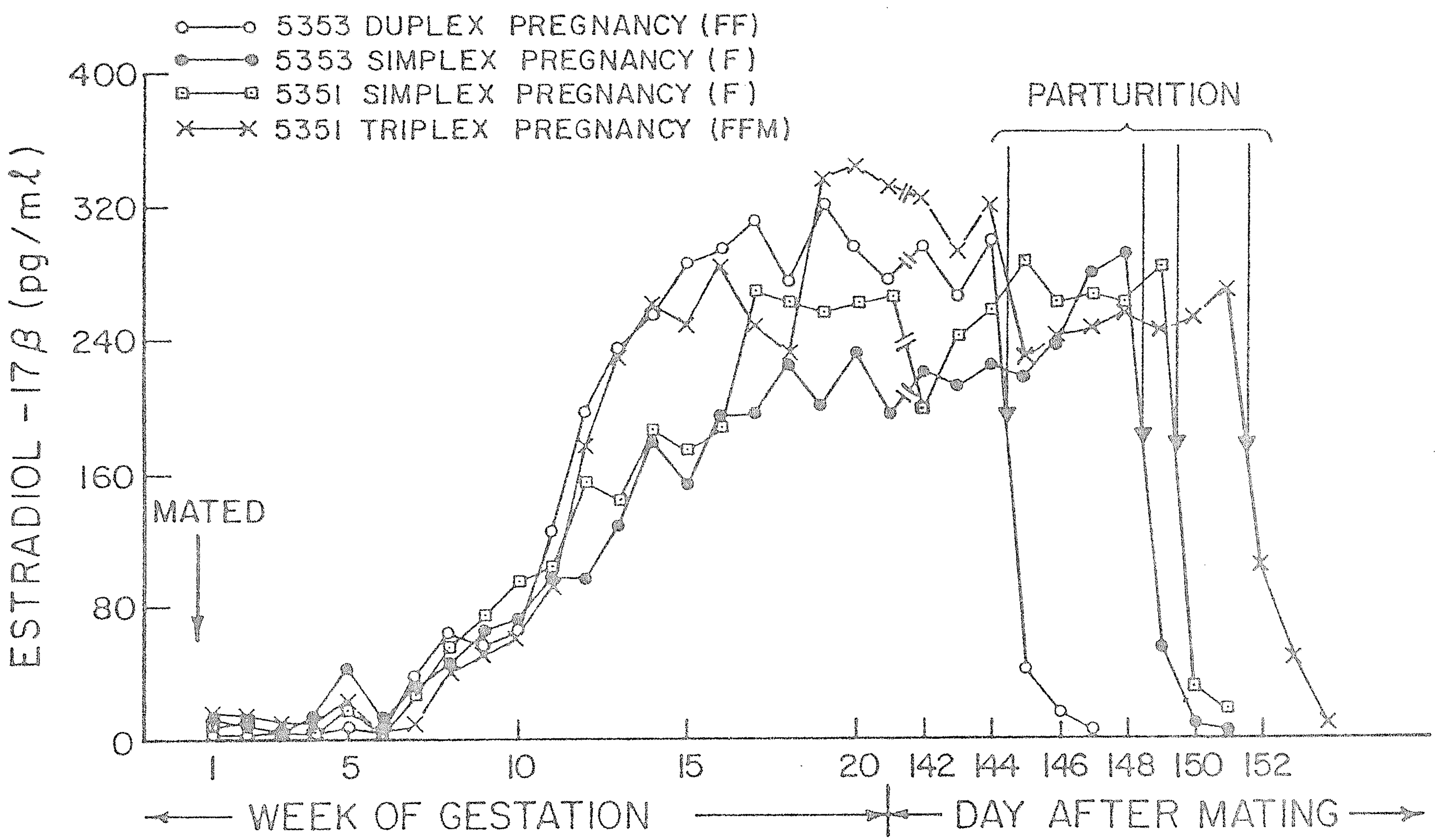

Figure 14. Estrogen profiles during the 4 pregnancies.

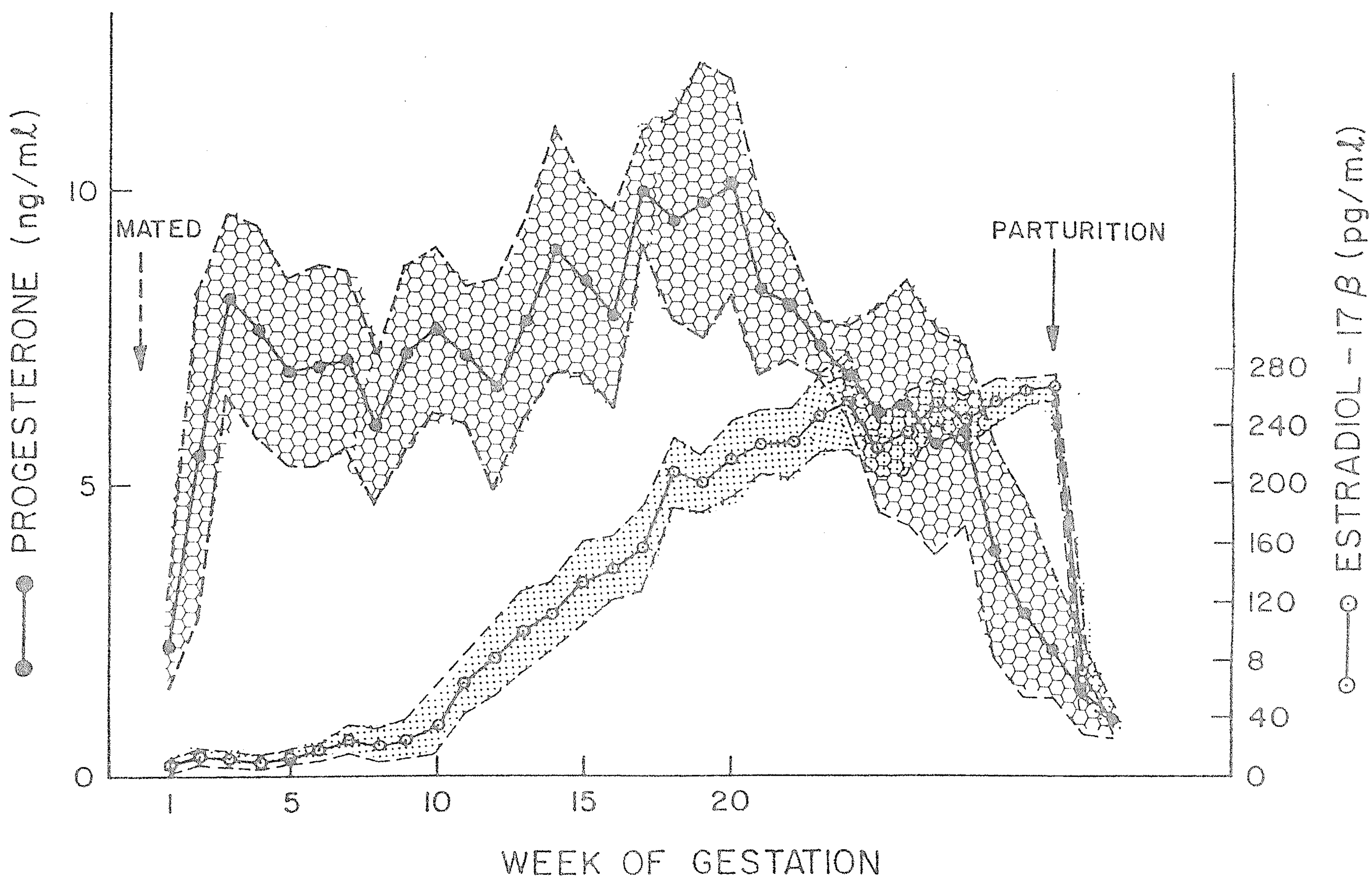

Figure 15. Composite estrogen and progesterone (mean ± S.E.) profiles during the 4 pregnancies.

Figure 16. Composite progesterone and estrogen (mean ± S.E.) profiles during the last 6 days of pregnancy. (Day of parturition = 0).

Table 3. ANOVA. Effect of type of pregnancy and stage of pregnancy on progesterone secretion.

	TYPE	OF	PREGNANCY		MEAN
	#5351 Singleton Pregnancy	#5353 Singleton Pregnancy	#5351 Triplet Pregnancy	#5353 Twin Pregnancy	
1st Trimester	4.65	3.65	8.11	9.16	6.40^{a}
2nd Trimester	4.60	5.22	8.81	10.98	7.40^{b}
3rd Trimester	6.10	7.25	10.54	13.00	9.22^{c}
MEAN	5.11^{a}	5.40^{a}	9.15^{b}	11.05^{c}	

a,b,c - Mean values with different superscripts are significantly ($P<0.01$) different from each other.

Source	df	SS	MS	F
Trimester	2	16.40	8.20	20.5**
Pregnancy type	3	76.00	25.33	63.5**
Error	6	2.38	0.4	
Total	11	94.8		

**($P<0.01$)

Table 4. ANOVA. Effect of type of pregnancy and stage of pregnancy on estradiol concentration.

	TYPE OF PREGNANCY				MEAN
	#5351 Singleton Pregnancy	#5353 Singleton Pregnancy	#5353 Twin Pregnancy	#5351 Triplet Pregnancy	
1st Trimester	29.89	99.23	34.51	222.05	96.42[a]
2nd Trimester	127.37	200.29	246.02	312.65	221.58[b]
3rd Trimester	239.06	241.38	288.99	248.48	254.48[b]
MEAN	132.11	180.3	189.84	261.06	

Mean values with different superscripts are significantly ($P<0.05$) different from each other.

Source	df	SS	MS	F
Trimester	2	55638.5	27819.3	9.05*
Pregnancy type	3	25476.0	8492	2.76NS
Error	6	18429.7	3071.6	
Total	11	99544.2		

*($P<0.05$)

NS = Non-Significant.

and the stage of pregnancy on progesterone secretion are in agreement with data available from earlier work on the goat and other species (Thorburn and Schneider, 1972; Batra et al., 1978; Adelakoun et al., 1978).

The initial decline in progesterone concentrations is attributable to some "aging" of the corpus luteum. After the 9th week of gestation a secondary increase in progesterone concentration was observed which is attributable to the "rejuvenation" of the corpus luteum. It is now generally recognized that by about Day 60 of pregnancy, a placental lactogen with luteotrophic function is synthesized and secreted (Kelly et al., 1976; Currie et al., 1977). The fact that the timing of the "rejuvenation" coincides with placental development and is more in goats carrying twins (hence more placental tissue) lends support to this thesis (Thorburn and Schneider, 1972).

Unlike progesterone concentrations, mean estradiol levels were consistently low, fluctuating around 10.4 ± 4.2 pg/ml during the first 9 weeks of pregnancy. From the 10th week of pregnancy, they showed a continued and gradual increase reaching maximum mean values of 281.1 ± 10.8 pg/ml on the day of parturition. By 24h postpartum they had dropped dramatically to mean levels of 71.8 ± 17.3 pg/ml.

While assessing the estradiol data, it became apparent that the stage of pregnancy, but not the type of pregnancy, had a significant effect on estradiol secretion (Table 4). Estradiol was present in significantly ($P < 0.05$) higher levels in the third trimester as compared to the second trimester and in the second trimester when compared to the first trimester (Table 4). These findings are in agreement with earlier data reported by Thorburn and Schneider (1972) but differ from data published by Adelakoun (1978) and Thimonier et al. (1977) who reported that besides progesterone, estradiol-17β was considerably higher during pregnancy in cows and ewes bearing more than one fetus. This discrepancy may be attributed to the fact that in the goat estradiol-17α and not estradiol-17β is the major circulating hormone during pregnancy. Since total estrogens were not measured in this study, it becomes difficult to compare the two data.

The foregoing results are in agreement with data obtained from earlier work on the endocrinology of pregnancy and parturition in the goat; namely that the observed increase and decline in progesterone concentration in the 1st and 4th week of pregnancy respectively is due to function and gradual "aging" of the corpus luteum. The increase in progesterone levels in the 9th week of pregnancy is attributable to the luteotrophic function of the placental lactogen. At about the 10th week of pregnancy estradiol production increases due possibly to its increased production by the then established placenta. As indicated earlier in the literature review, a rise in fetal glucocorticoids results in the activation of the placental 17α-hydroxylase system (Flint et al., 1978). This results in increased estradiol production which stimulates uterine production of prostaglandin $F_2\alpha$. The prostaglandin $F_2\alpha$ causes luteolysis (probably in synergism with decreasing concentrations of placental lactogen). The ultimate effect of falling progesterone concentrations in maternal circulation causes further synthesis of prostaglandins which together with estradiol cause uterine contractions and the onset of labour (Currie and Thorburn, 1973; 1977a, 1977b; Umo et al., 1976; Rawlings and Ward, 1977; Challis et al., 1977; Thorburn et al., 1977; Flint et al., 1978; Currie, 1977).

Conclusions

The mean gestation length of the pygmy goat in this study was estimated to be 148.5 ± 1.4 days (range = 145 to 152 days). During pregnancy, there were two phases of increased progesterone secretion. The first occurred from the 1st to about the 3rd week of pregnancy; the second was observed at about the 9th week of pregnancy. The secondary increase in progesterone secretion may be attributed to placental lactogen which is generally known to be synthesized by Day 60 of pregnancy. Estradiol production increased steadily from the 10th week of pregnancy up to parturition.

The stage of pregnancy significantly ($P<0.01$, 0.05) affected both progesterone and estradiol production, respectively. Significantly ($P<0.01$) more progesterone was secreted during the third and second trimesters compared to the first trimester. In addition, the type of pregnancy significantly affected progesterone secretion. Significantly ($P<0.01$) higher progesterone levels were obtained in twin and triplet pregnancy samples than in singleton pregnancy samples. The type of pregnancy did not significantly ($P>0.05$) affect estradiol concentration.

GENERAL DISCUSSION

Results obtained from experiments one, two and three indicate that during the breeding season, the daily LH secretion pattern is in an inverse relationship with that of progesterone and is dependent on the reproductive state of the animal. There are more frequent LH peaks of lower magnitude during the early and late luteal phases of the estrous cycle; consequently mean LH values during these phases of the cycle are 4 to 5-fold higher than mean values observed during the midluteal phase of the cycle. This relationship is suggested to be the result of the inhibitory effect of circulating progesterone on the tonic release of LH. Circumstantial evidence (from experiments 2 and 3) indicate that 2 to 3 days before the onset of the LH surge on day 0 of the cycle, circulating progesterone levels begin a precipitous decline while serum LH levels rise in mean values to 5-fold greater than baseline values (1.8 ± 1.0 vs 0.4 ± 0.01 ng/ml). It has also been demonstrated that physiological levels of progesterone can exert a potent inhibition on tonic LH secretion in the ewe, and that this effect was dose dependent thus accounting for the inverse relationship between progesterone and basal circulating LH levels throughout the cycle (Goodman and Karsch, 1978). Further evidence in support of the suggestion that progesterone exerts an inhibitory effect on LH secretion was obtained from the work of Karsch et al., (1977c) in which surgical removal of the corpus luteum on Day 8 of the cycle caused a rapid premature decrease in circulating progesterone and resulted in an immediate 4 to 5-fold increase in circulating LH; levels of LH that are normally observed during and after corpus luteum regression. Moreover, the premature increase in tonic LH secretion which followed corpus luteum removal was prevented when circulating progesterone levels were maintained at mid-luteal phase values by inserting a progesterone-releasing implant at the time of surgery. These observations therefore lend compelling supportive evidence that progesterone could be the dominant inhibitor of tonic LH secretion during the breeding season and that the fall of progesterone which occurs concurrently with luteolysis leads to the sustained increase in tonic LH secretion and the subsequent events associated with the preovulatory gonadotropin surge.

During the non-breeding season the nature of LH secretion was observed to be similar to that occurring during the mid-luteal phase of the estrous cycle in one respect; it was characterized by a fewer number of LH peaks similar to that observed on day 9 in goat #5353 and on days 13 and 14 in goat #5351. Contrary to previous findings in the ewe (Yuthasastrakosol, 1975) these peaks were also lower in magnitude than those observed in the midluteal phase of the cycle. This would possibly have been significant if more experimental animals had been used.

Results obtained from studies concerning the nature and pattern of gonadotropin secretion on the day of behavioural estrus indicate that of the 18 periods of estrus observed complete preovulatory gonadotropin surges were obtained in only about one-third of them. Either end of the profile was missed in another 27% of the cycles. Complete absence of any sign of preovulatory gonadotropin surge was recorded in 40% of the estrous periods studied. The reason for the inconsistencies observed could be attributed to a number of factors, namely:

(1) Detection of estrus was confined to a daily time period ranging from 0800h to 2300h. Therefore, the onset of estrus for animals which came into heat between 2300h and 0800h would either have been missed or the onset would not have been accurately determined.

(2) Although estrus detection was done daily throughout the breeding season, the intensity and regularity of heat detection was confined to the late luteal phase of each cycle (4 to 6 visits compared to two or three visits during the mid-luteal phase). Any short estrous cycles were not anticipated and therefore, blood samples were not timely collected.

(3) Even when estrual behaviour was timely detected and blood samples were collected, assay of some of such samples yielded not preovulatory gonadotropin surges.

(4) Some animals could have accepted the billy and displayed behavioural estrous signs (bleating, shaking tail) even if they were not in heat. This phenomenon has been observed before in another breed of goats (Wilson, 1960).

Land _et al._, (1973) and Simaraks _et al._, (1979) found that in the ewe, the breed had a significant effect on estrus duration and on the time interval between the onset of estrus and the onset of the preovulatory gonadotropin surge. Both of these phenomenon have not been studied in the goat. The results in this study indicate that the interval from the onset of estrus to the onset of the preovulatory LH surge (as obtained from the 33% of the animals in which complete surges were recorded) was 6.5 ± 0.7 h. The LH preovulatory surge lasted an average of 15.2 ± 0.5 h while that of FSH lasted an average of 13.8 ± 0.7 h. It is probable that breed and individual differences may have influenced these findings but comparable information related to this phenomenon is lacking. Further work in which half-hourly blood samples would be collected over a period of time from Day -2 to Day 2 would be helpful in pinpointing the temporal relationship between the onset of estrus and that of the preovulatory gonadotropin surge.

In experiment five, where the two major ovarian and placental steroids were determined during pregnancy and parturition, it was found that the mean gestation period of the pygmy goat was 148.5 ± 1.4 days, which is in agreement with that reported by earlier workers for various other breeds and types of goats (Gupta, 1964; Wilson, 1960; Devendra and Burns, 1970; Blom and Lyngset, 1971; Shelton, 1978; Rawlings and Ward, 1977; Peaker, 1978).

Progesterone concentrations showed increases in two phases; one phase was associated with the first to the 4th week of gestation period and the other occurred in the 10th week of gestation. Similar observations were made by Irving et al., (1972) and Thorburn and Schneider (1972) and were attributed to the activity of the corpus luteum of pregnancy and the establishment of a functional placenta capable of synthesizing a luteotrophin - caprine placental lactogen which appears in the circulation of pregnant goats from Day 60 of pregnancy and increases with gestation (Kelly et al., 1976; Currie et al., 1977).

Progesterone concentrations were significantly ($P<0.01$) higher when does were carrying triplets and twins than in singleton pregnancies. Adelakoun et al., (1978) and Batra et al., (1978) have reported similar types of increased progesterone secretion in cows and humans, respectively.

Progesterone concentrations were also higher in the second and last third of pregnancy than those obtained during the first third of pregnancy.

During the first 9 weeks of pregnancy, estrogen levels were low, fluctuating around a mean of 10.4 $\pm$ 4.2 pg/ml. Beginning with the 10th week of pregnancy they showed rapid increases and reached maximum levels of 281.1 $\pm$ 10.8 pg/ml on the day of parturition. The role of estrogens during the early periods of pregnancy in sheep and goats is not known; in the rat, however, estrogen secretion is obligatory for implantation to occur. Whatever changes estrogen induces in the rat uterine endometrium to make it hospitable to a blastocyst are not clear but its specific effects are localized (Nalbandov, 1976). It is possible that estrogen together with progesterone are involved in conditioning the goat uterine endometrium for blastocyst implantation. Estrogen may also play a role in the maternal recognition of pregnancy in the goat as has been reported in the sheep (Heap et al., 1977).

Estrogen concentrations were significantly ($P < 0.05$) lower in the first third of pregnancy compared to the rest of the gestation period (Table 4). However, estrogen concentrations were not significantly ($P > 0.05$) affected by the type of pregnancy studied. Since the assay procedure used measured total estrogens it is impossible to determine from this study if there were any changes in the relative proportions of the various estrogens throughout pregnancy. Other investigators have shown that maternal conjugated estrogen levels were higher in the goat than those in sheep. In both species they increased steadily throughout the last third of pregnancy and estradiol-17β but not estradiol-17α was demonstrated to be the active form (Thorburn et al., 1972; Currie et al., 1973; Umo et al., 1976; Currie and Thorburn, 1977).

Interpretation of the role of changing progesterone and estrogen levels during pregnancy would have been much easier and objective if concurrent assays of $PGF_2\alpha$ and glucocorticoids had been performed. It would have been easier to explain the suggested mechanisms that precipitate labour and parturition. More importantly blood samples collected more frequently at and around time of parturition (30-36 hours pre- and post-parturition) would be useful in "mapping" endocrine millieu changes associated with increased glucocorticoids, estrogens, $PGF_2\alpha$ and declining progesterone levels that are suggested to evoke labour and parturition. Although a considerable amount of information has been provided by the studies of Currie et al., (1973) and Currie and Thorburn (1977) in other species of goats this study provides the first reported observations on the new pygmy goat.

In conclusion, although the observations reported in this study are perhaps not as complete as those reported previously for breeds of goats of normal size, these data are the first recorded for the African Dwarf or pygmy goat. Further studies perhaps utilizing a greater number of individuals are required to obtain additional data on the onset and duration of the breeding season. Observations obtained in the present study suggest that endocrinological changes that occur at the beginning of the breeding season are the same as those that are seen in the sheep. Further data is also needed in the area. Finally, it would appear that the pygmy goat could serve as an useful animal model to study certain areas of reproductive physiology that pertain to the sheep, and possibly other species.

SUMMARY

The endocrinology of various reproductive states was studied in female pygmy goats.

In the first investigation, mature multiparous does were bled from the jugular vein by venipuncture at 20-min. intervals for 24h on the 22nd of June, September, and December, 1976 and on the 23rd of March, 1977 to assess the effect of season on reproductive and hormone activity. Serum luteinizing hormone (LH) and follicle-stimulating hormone (FSH) concentrations were determined by radioimmunoassay (RIA). LH profiles indicated that throughout anestrus and the breeding season, LH release was episodic in fashion. During anestrus, LH peaks were less frequent (3 to 4 per 24h in June vs 8 to 11 per 24h in December) but higher in magnitude (6.2 $\pm$ 0.3 ng/ml vs 3.8 $\pm$ 0.3 ng/ml). During the breeding season, the nature and fashion of LH release was dependent on the reproductive state of the animal. The apparent half-life of LH was estimated at 23.2 $\pm$ 1.6 min. FSH concentrations fluctuated randomly within narrow limits

and during anestrus and the inter-estrous periods FSH pattern of secretion did not bear any recognizable relationship with the pulsatile nature of LH release.

In the second experiment, LH, FSH, progesterone and estradiol-17β concentrations were determined by RIA in serum obtained from two mature does and two prepubertal does during transition from anestrus to breeding activity resumption (or puberty attainment). All animals showed behavioural and endocrine changes that were characteristic of the establishment of normal estrous cycles between the 18th and 30th of November. The two prepubertal does showed first overt estrus at the age of 248 and 251 days, respectively. From progesterone concentration profiles, all animals appeared to have a presumed ovulation without overt estrus an average of 19.2 $\pm$ 0.5 days before the first behavioural estrus. LH and FSH levels fluctuated randomly throughout anestrus; a two-to-three fold increase in their mean values was apparent 5 days before the preovulatory surge prior to the first presumed ovulation. The pattern of their secretion during the interval from first presumed ovulation to first behavioural estrus was similar to that observed during anestrus, both were elevated on the day of first behavioural estrus. Progesterone levels were low during anestrus; their first elevation (from 0.5 ± 0.08 to 2.3 ± 0.4 ng/ml) occurred 2 days before the first presumed ovulation (day-23). During the interval between the first presumed ovulation and the first overt estrus, progesterone concentration and pattern of secretion were characteristic of that observed during the normal cycle. Estradiol concentrations were varied during anestrus and the interval from first presumed ovulation to first overt estrus. Levels of estradiol were observed to be elevated a day before the LH/FSH preovulatory surges of the first presumed ovulation and the first overt estrus, respectively.

In the third investigation, serum gonadotropin and ovarian hormone concentrations were determined in sera collected during the breeding season. The mean estrous cycle length was estimated to be 19.0 ± 1.2 days. In all animals and in each cycle, serum progesterone concentrations were low on Day 0 (mean=0.7 ± 0.07 ng/ml) and began to rise rapidly on Day 3, reaching maximum mean levels of 9.3 ± 0.3 ng/ml on Day 9. A precipitous fall in serum progesterone concentrations was noticeable beginning by Day 16 or 17. In contrast, LH mean concentrations were highest on Day 0 (mean=11.4 ± 1.2 ng/ml) and fell to baseline values of 0.3 ± 0.1 ng/ml by Day 3. Both estradiol and FSH showed random variations during the inter-estous periods; peak values of 49.2 ± 1.8 pg/ml and 174.6 ± 9.7 ng/ml respectively, occurred on Day 0. These findings support the thesis that during the inter-estrous periods of the breeding season, progesterone exerts a dominant inhibitory effect on tonic LH release.

In a fourth experiment to study the nature and pattern of gonadotropin secretion during behavioural estrus, blood was collected from four cycling does from the jugular vein by venipuncture at 20-min intervals for 24h beginning immediately when the animals were detected to be in heat. Serum was assayed by RIA to determine LH and FSH concentrations. LH secretion was episodic in fashion as indicated by minor fluctuations before the onset of the preovulatory surge. The concentration of LH began to rise an average of 6.5 ± 0.7h after the onset of estrus and was followed by an FSH elevation an average of 1.1 ± 0.4h later. The duration of the preovulatory LH surge was 15.2 ± 0.5h and was 1.7 ± 0.7h longer than that of FSH. However, these differences were not significant ($P>0.05$). Considering the time interval from the onset of estrus to the beginning of the preovulatory gonadotropin surge and its duration, ovulation was postulated to occur an average of 36h after the onset of estrus.

In experiment five, two does were followed through two pregnancies each to study ovarian hormone concentration profiles during pregnancy and parturition. Blood samples were collected at weekly intervals for the first 20 weeks of gestation; thereafter samples were collected daily until 3 to 4 days postpartum. Serum progesterone and estradiol concentrations were evaluated by RIA. Parturition was normal and spontaneous after a mean gestation length of 148.5 $\pm$ 1.4 days. The mean progesterone concentration rose from 2.2 $\pm$ 0.7 ng/ml in the first week to 8.1 $\pm$ 1.5 ng/ml by the 3rd to 4th week; it then declined slightly up to the 8th week of gestation. From the 9th week on ward there was a gradual increase in concentration, but levels declined rapidly during the 6 days preceding parturition. Samples taken within 24h pre- and post-parturition gave mean concentrations of 4.8 $\pm$ 0.9 and 1.5 $\pm$ 0.3 ng/ml, respectively, illustrating the rapidity with which circulating progesterone declines around parturition. Estradiol levels showed a continued rise from the 10th week of pregnancy to maximum mean levels of 281.1 $\pm$ 10.8 pg/ml on the day of parturition. Within 24h, postparturient levels of 71.8 $\pm$ 17.3 pg/ml were observed. Progesterone concentrations were significantly ($P<0.01$) higher when the does were carrying triplets and twins than in singleton pregnancies. The stage of pregnancy affected progesterone and estradiol concentrations significantly ($P<0.01$ and $P<0.05$, respectively).

REFERENCES

Abraham, A.M., Swerdloff, R., Tulchinsky, D and Odell, W.D. (1971). Radioimmunoassay of plasma progesterone. Endocr. 32:619.

Adelakoun, V., Matton, P. and Dufour, J.J. 1978. Steroid hormone levels in beef cows during pregnancy terminating in normal calving or abortion and with single or multiple ovulation. Can. J. Anim. Sci. 58:345.

Arije, G.R., Wiltbank, J.N. and Hopwood, M.L. 1974. Hormone levels in pre- and post-parturient beef cows. J. Anim. Sci. 39(2):338.

Austin, C.R. and Short, R.V. 1973. Eds, Reproduction in mammals. Bk. 3. Hormones in reproduction. Cambridge University Press.

Baird, D.T. 1978. Local Utero-Ovarian Relationships. In: control of ovulation. Eds. D.B. Crighton, N.B. Haynes, G.R. Foxcroft and G.E. Lamming. Butterworth. London. Boston.

Batra, S., Sjoberg, N.O. and Aberg, A. 1978. Human placental lactogen, estradiol-17β, and progesterone levels in the third trimester and their respective values for detecting twin pregnancy. Amer. Jour. Obstet. and Gynecol. 131(1):69.

Beck, T.W. and Reeves, J.J. 1973. Serum LH in ewes treated with various dosages of 17β-estradiol at three stages of the anestrus season. J. Anim. Sci. 36:566.

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

Behrman, H.R., Luborsky-Moore, J.L., Pang, C.Y., Wright, K. and Dorflinger, L.J. 1978. Sites of PGF action in functional luteolysis. Workshop on ovarian follicular and corpus luteum function. Americana Hotel, Miami Beach, Florida. June 11-13, 1978.

Bissonnette, T.H. 1941. Experimental modification of breeding cycles in goats. Physiol. Zool. XIV (3):379.

Bjersing, L., Hay, M.F., Kann, G., Moor, R.M., Naftolin., Scaramuzzi, R.J., Short, R.V. and Younglai, E.V. 1972. Changes in gonadotropins, ovarian steroids and follicular morphology in sheep at oestrus. J. Endocr. 52:465.

Blom, A.K. and Lyngset, O. 1971. Plasma progesterone levels in goats during pregnancy measured by competitive protein binding. Acta Endocrinologica 66:471.

Buttle, H.L. 1978. The maintenance of pregnancy in hypophysectomised goats. J. Reprod. Fert. 52:255.

Burgus, R., Butcher, M., Amos, M., Ling, N., Monahan, M., Rivier, I., Fellows, R., Blackwell, R., Vale, W., and Guillemin, R. 1972. Primary structure of the ovine hypothalamic luteinising hormone releasing factor (LRF). Proc. Nat. Acad. Scr. 69(1):278.

Carlson, J.C., Buhr, M.M. and Thompson, J.E. 1979. New evidence on the mechanism of corpus luteum regression. Biol. of Reprod. Vol. 20 Suppl. 1:31.

Challis, J.R.G. and Linzell, J.L. 1971. The concentration of total unconjugated oestrogens in the plasma of pregnant goats. J. Reprod. Fert. 26:401.

Challis, J.R.G., Foster, C.S., Furr, B.J.A., Robinson, J.S. and Thorburn, G.D. 1976. Production of prostaglandin F in ewes following luteal regression induced with prostaglandin analogue, estrumate (cloprostenol ICI 80986). Prostaglandins 11:537.

Challis, J.R.G., Kendall, J.Z., Robinson, J.S. and Thorburn, G.D. 1977. The regulation of corticosteroids during late pregnancy and their role in parturition. Biol. Reprod. 16:57.

Cheng, K.W. 1976. Purification and properties of bovine pituitary follitropin. Biochem. J. 159:651.

Cheng, K.W., Simaraks, S. and Palmer, W.M., 1979. Characterization of a radioimmunoassay for ovine-FSH utilizing an anti-bovine FSH serum. J. Reprod. Fertil. (submitted for publication).

Cicmanec, J.L. and Niswender, G.D. 1973. Arterial-venous differences in gonadotropin concentration across the ovary of sheep during different reproductive states. Exp. Biol. Med. 144:99.

Cordova, F.J. and Wallace, J.D. 1975. Nutritive value of some browse and forb species. Proc. West Sect. Amer. Soc. Anim. Sci. 26:160.

Cox, R.I., Mattner, P.E. and Thorburn, G.D. 1971. Changes in ovarian secretion of oestradiol-17β around oestrus in the sheep. J. Endocr. 49:345.

Crighton, D.B., Hartley, B.M. and Lamming, G.E. 1973. Changes in the luteinizing hormone releasing activity of the hypothalamus, and in pituitary gland and plasma luteinizing hormone during the oestrus cycle of the sheep. J. Endocr. 58:377.

Currie, W.B. 1977. Endocrinology of pregnancy and parturition in sheep and goats. Proceedings: Symposium on management of reproduction in sheep and goats. Madison, Wisconsin July 24-25, 1977.

Currie, W.B. and Thorburn, G.D. 1973. Induction of premature parturition in goats by prostaglandin $F_{2\alpha}$ administered into the uterine vein. Prostaglandins 4:201.

Currie, W.B., Wong, M.S.F., Cos, R.I., and Thorburn, G.D. 1973. Spontaneous or dexamethasone-induced parturition in sheep and goats: changes in plasma concentrations of maternal prostaglandin F and foetal oestrogen sulphate. Mem. Soc. Endocrinol. 20:95.

Currie, W.B. and Thorburn, G.D. 1977. The fetal role in timing the initiation of parturition in the goat. In: the fetus and birth. Ciba Foundation Symposium 47 (new series).

Currie, W.B. and Thorburn, G.D. 1977. Parturition in goats: Studies on the interactions between the foetus, placenta, prostaglandin F and progesterone before parturition, at term or at parturition induced by corticotrophin infusion of the foetus. J. Endocr. 73:263.

Currie, W.B., Kelly, P.A., Friesen, H.G. and Thorburn, G.D. 1977. Caprine placental lactogen: Levels of prolactin - like and growth hormone - like activities in the circulation of pregnant goats determined by radio-receptor assays. J. Endocr. 73:263.

Davies, R.V., Main, S.J., and Setchell, B.P. Seasonal changes in plasma follicle-stimulating hormone and testosterone in rams. J. Endocr. 72:12 (Abstr.)

Devendra, C. and Burns, M. 1970. Goat production in the tropics.

Donaldson, L.E., Bassett, J.M., and Thorburn, G.D. 1970. Peripheral plasma progesterone concentration of cows during puberty oestrus cycles, pregnancy and lactation, and the effects of undernutrition or exogenous oxytocin on progesterone concentration. J. Endocr. 48:599.

Donovan, B.T. and Ter Haar, M.B. 1977. Effect of luteinizing hormone-releasing hormone on plasma follicle-stimulating hormone and luteinizing hormone levels in the ferret. J. Endocr. 73:37.

Dyrmundson, O.R. 1973. Puberty and early reproductive performance in sheep. 1. Ewe lambs. Anim. Breed. Abstr. 41(6):273.

Epsey, L.L. and Rawson, J.M.R. 1979. Regarding the role of plasminogen activator in ovulation. In. Ovarian follicular development and function. Eds. A.R. Midgley and W.A. Sadler. Raven Press, New York.

Falvo, R.E., Buhl, A.E., Hunzicker, M.E. and Foxcroft, G.R. 1975. Diurnal fluctuations of testosterone and luteinizing hormone in the ram: Effect of human chorionic gonadotrophin and gonadotrophin releasing hormone. J. Reprod. Fert. 42:467.

FAO Production Yearbook 1977. Fiat Paris. Rome, Italy.

Flint, AP.F., Kingston, E.J., Robinson, J.S. and Thorburn, G.D. 1978. Initiation of parturition in the goat: Evidence for control by foetal glucocorticoid through activation of placental C_{21}-steroid 17α-hydroxylase. J. Endocr. 78:367.

Forster, D.L., Lemons, J.A., Jaffe, R.B. and Niswender, G.D. 1975. Sequential patterns of circulating luteinizing hormone and follicle-stimulating hormone in female sheep from early postnatal life through the first estrus cycles. Endor. 97(4):985.

Fortune, J.E. and Hansel, W. 1979. Effects of the LH surge on the steroid secretion by theca and granulosa cells of bovine preovulatory follicles. Biol. Reprod. Vol. 20 Suppl. 1:46A.

Geschwind, I.I. and Dewey, R. 1968. Dynamics of LH secretion in the cycling ewe: a radioimmunoassay study. Proc. Soc. Exp. Biol. Med. 129:451.

Godley, W.C., Wilson, R.L. and Hurst, V. 1966. Effect of controlled environment on the reproductive performance of ewes. J. Anim. Sci. 25:212.

Goodman, R.L. and Karsch, F.J. (1978). Actions of estradiol in the control of tonic LH secretion during the breeding season in the ewe. Program 60th Annual Meeting, The Endocrin Society. Abstr. 121.

Greenwood, F.C., Hunter, W.M. and Glover, J.S. (1963). The preparation of ^{131}I-labelled human growth hormone of high specific activity. Biochem. J. 89:114.

Guillemin, R., and Burgus, R. 1972. The hormones of the hypothalamus. Scientific American 227(5):24.

Gupta, S., Som, T.L. and Bhatta-Charya, S. 1964. Studies on gestation lenth in Black-Bengal goat. Anim. Breed. Abstr. 36:92.

Haenlein, G.F.W. 1978. Dairy goat management. J. Dairy Sci. 61:1011.

Hafez, E.S.E. 1952. Studies on the breeding season and reproduction of the ewe. J. Agric. Sci. 42:189.

Hauger, R.J., Karsch, F.J. and Foster, D.L. 1977. A new concept for control of the estrous cycle of the ewe based on the temporal relationships between luteinizing hormone, estradiol and progesterone in peripheral serum and evidence that progesterone inhibits tonic LH secretion. Endocr. 101(3):807.

Heap, R.B., Flint, A.P.F. and Jenkin, G. 1977. Control of ovarian function during the establishment of gestation. In: Control of Ovulation. Eds. D.B. Crighton, G.R. Foxcroft, N.B. Haynes and G.E. Lamming. Butterworths. London. Boston. Sydney. Wellington. Durban. Toronto.

Hirschfield, A.N. 1979. The role of FSH in the recruitment of large follicles. In: Ovarian follicular development and function. Eds: A.R. midgley and W.A. Sadler. Raven Press, New York.

Hoversland, A.S., Parer, J.T. and Metcalfe, J. 1965. The African dwarf goat as a laboratory animal in the study of cardiovascular physiology. Fed. Proc. 24:705.

Howland, B.E., Sanford, L.M. and Palmer, W.M. 1978. Estrogen-induced LH and FSH release in ovariectomised ewes: Effect of season. Can J. Anim. Sci. 58:547.

Howland, B.E., Sanford, L.M. and Palmer, W.M. 1978a. Progesterone blockade of estrogen-induced LH release in anestrual ewes. Can. J. Anim. Sci. 58:329.

Howland, B.E., Palmer, W.M. and Sanford, L.M. 1978b. Changes in serum levels of LH and FSH in progesterone-treated ovariectomised ewes following a single injection of estrogen. Can. J. Anim. Sci. 58:15.

Huston, J.E. 1978. Forage utilization and nutrient requirement of the goat. J. Dairy Sci. 61:988.

Irving, G., Jones, D.E. and Knifton, A. 1972. Progesterone concentration in the peripheral plasma of pregnant goats. J. Endocr. 53:447.

Jarosz, S.J., Deans, R.J. and Dukelow, W.R. 1971. The reproductive cycle of the African Pygmy and Toggenburg goat. J. Reprod. Fert. 24:119.

Jeffrey, H.E. 1975. Goats. 2nd Edition. Casell & Collier Macmillan Publishers Ltd. Sydney, Aukland, Toronto, Johannesburg.

Karsch, F.J., Foster, D.L., Legan, S.J., Peter, G.K. and Ryan, K.D. (1977c). Hormonal interrelationships during the preovulatory period in the ewe. Program 60th Annual Meeting, The Endocrine Society. Abstr.270.

Karsch, F.J., Legan, S.J., Hauger, R.L. and Foster, D.L. 1977. Negative feedback action of progesterone on tonic luteinizing hormone secretion in the ewe: Dependence on the ovaries. Endocr. 101:800.

Karsch, F.J., Legan, S.J., Ryan, K.D. and Foster, D.L. 1978. The feedback effects of ovarian steroids on gonadotrophin secretion. In: Control of ovulation. Eds:

D.B. Crighton, N.B. Haynes, C.R. Foxcroft and G.E. Lamming. Butterworths. London. Boston. Sydney. Wellington. Durban. Toronto.

Katongole, C.B., Naftolin, F. and Short, R.V. 1974. Seasonal variation in blood luteinizing hormone and testosterone levels in rams. J. Endocr. 60:101.

Kelly, P.A., Tsushima, T., Shiu, R.P.C. and Friesen, H.G. 1976. Lactogenic and growth hormone-like activities during pregnancy determined by radioreceptor assays. Endocr. 99:765.

Land, R.B., Pelletier, J., Thimonier, J. and Mauleon, P. 1973. A quantitive study of genetic differences in the incidence of estrus, ovulation and plasma luteinizing hormone concentration in the sheep. J. Endocr. 58:305.

Legan, S.J., Karsch, F.J., and Foster, D.L. 1977. The endocrine control of seasonal reproductive function in the ewe: A marked change in response to the negative feedback action of estradiol on luteinizing hormone secretion. Endocr. 101(3):818.

Legan, S.J. and Karsch, F.J. 1979. Neuroendocrine regulation of the estrous cycle and seasonal breeding in the ewe. Biol. Reprod. 20:74.

Lincoln, G.A., Peet, M.J. and Cunningham, R.A. 1977. Seasonal and circadian changes in the episodic release of follicle-stimulating-hormone, luteinizing hormone and testosterone in rams exposed to artificial photoperiods. J. Endocr. 72:337.

Lincoln, G.A. 1978. Induction of testicular growth and sexual activity in rams by a "skeleton" short-day photoperiod. J. Reprod. Fert. 52:179.

Lincoln, G.A. and Peet, M.J. 1977. Photoperiod control of gonadotropin secretion in the ram: A detailed study of the temporal changes in plasma levels of follicle-stimulating hormone, luteinizing hormone and testosterone following an abrupt switch from long to short days. J. Endocr. 74:355.

Linzell, J.L. and Heap, R.B. 1968. A comparison of progesterone metabolism in the pregnant sheep and goat: sources of production and an estimation of uptake by some target organs. J. Endocr.

McNeilly, A.S. and Hart, I.C. 1973. The release of oxytocin and prolactin during parturition in the goat. J. Endocr. 56:159.

Mitchell, M.D. and Flint, A.P.F. 1977. Progesterone withdrawal: Effect on prostaglandins and parturition. Prostaglandins 14(3):611.

Mitchell, M.D., Flint, A.P.F., Robinson, J.S. and Thorburn, G.D. 1978. In-vitro production of prostaglandins by intrauterine tissues from pregnant goats. J. Reprod. Fert. 52:151.

Muduuli, D.S. 1978. Reproductive hormone secretion patterns in the male pygmy goat. M.Sc. Thesis - University of Manitoba.

Nalbandov, A.V. 1976. Reproductive physiology of mammals and birds. 3rd edition. W.H. Freeman and Company. San Francisco.

Nkuuhe, J., Manns, J.G., Humphrey, W.D. and Mapletoft, R. 1978. Combined $PGF_{2}\alpha$ -progesterone to initiate ovulation in postpartum suckled beef cows. Can. J. Anim. Sci. 58:83.

Obst, J.M. and Seamark, R.F. 1970. Plasma progesterone concentrations during the reproductive cycle of ewes grazing yarloop clover. J. Reprod. Fert. 21:140.

Ortavant, R. 1977. Photoperiodic regulation of reproduction in sheep. Symposium on management of reproduction in sheep and goats. Univ. Wisconsin, Madison, Wis. 58.

Palmer, W.M., Phillips, G.D., Howland, B.E. and Ibrahim, E.A. 1972. Effect of day length on reproduction in ewes. J. Anim. Sci. 34:903 (abstr.)

Pant, H.C., Hopkinson, C.R.N. and Fitzpatrick, R.J. 1972. Plasma oestradiol, progesterone and luteinizing hormone concentrations during the ovine oestrous cycle. J. Reprod. Fert. 31:501.

Pant, H.C., Hopkinson, C.R.N. and Fitzpatrick, R.J. 1977. Concentration of oestradiol, progesterone, luteinizing hormone and follicle-stimulating hormone in the jugular venous plasma of ewes during the estrous cycle. J. Endocr. 73:247.

Peaker, M. 1978. Gestation period and litter size in the goat. Br. Vet. Jour. 134:379.

Pelletier, J. and Ortavant, R. 1964. Influence de la duree d'e'clairement sur le contenu hypophysaire en hormone gonadotropes FSH et ICSH chez le belier. Annales de biologie animale, biochimie et biophysique 4:17.

Pelletier, J. 1973. Evidence for photoperiodic control of prolactin release in rams. J. Reprod. Fert. 35:143.

Peters, H. 1979. Discussion summary: Session on follicular development. In: Ovarian follicular development and function. Eds: A.R. Midgley and W.A. Sadler. Raven Press, New York.

Pretorius, P.S. 1971. Gonadotrophic hormone activity in female Angora goats exhibiting hormal and aberrant reproductive activity. Paper presented at Biennial Scientific Congress of the South African Veterinary Association, East London, S. Africa.

Pretorius, P.S. 1973. Cyclic reproductive activity in the Angora goat. Agroanimalia 5:55.

Ravault, J.P. 1976. Prolactin in the ram: Seasonal variations in the concentration of blood plasma from birth until three years old. Acta Endocr. (kbh) 83:720.

Rawlings, N.C., Kennedy, S.W., Chang, C.H., Hill, Jr., J.R. and Henricks, D.M. 1977. Onset of seasonal anestrus in the ewe. J. Anim. Sci. 44(5):791.

Rawlings, N.C. and Ward, W.R. 1977. Progesterone and the initiation of parturition in the goat. Theriogenology 7(6):317.

Rawlings, N.C. and Ward, W.R. 1978. Effect of fetal hypophysectomy on the initiation of parturition in the goat. J. Reprod. Fert. 52:249.

Rawlings, N.C. and Ward, W.R. 1973. The effect of the administration of progesterone on the initiation of parturition in the goat. J. Reprod. Fert. 35:605.

Reeves, J.J., Beck, T.W. and Nett, T.M. 1974b. Serum FSH in anestrous ewes treated with 17 -estradiol. J. Anim. Sci. 38:374.

Reichlin, S. 1978. Introduction. In: The hypothalamus. Eds: S. Reichlin, R.J. Baldessarini and J.B. Martini. Research Publications: Association for Research in Nervous and Mental Diseases. Vol. 56. Raven Press. New York.

Richards, J.S. 1978. Actions of pituitary gonádotrophins on the ovary. In: Control of ovulation. Eds: D.B. Crighton, N.B. Haynes, G.R. Foxcroft and G.E. Lamming. Butterworth - London - Boston.

Robertson, H.A. 1972. Sequential changes in plasma progesterone in the cow during the estrous cycle, pregnancy, at parturition and post-partum. Can. J. Anim. Sci. 52:645.

Robertson, H.A. 1977. Reproduction in the ewe and the goat. In: Reproduction in Domestic Animals. 3rd edition. H.H. Cole and P.T. Cupps (eds.). Academic Press. New York. San Francisco. London.

Roche, J.F., Foster, D.L., Karsch, F.J., Cook, B. and Dziuk, P.J. 1970. Levels of luteinizing hormone in sera and pituitaries of ewes during the estrous cycle and anestrus. Endocr. 86:568.

Rodbard, D. 1971. Statistical aspects of radioimmunoassays. In: Principles of Competitive Proteins - Binding Assays. Eds: W.D. Odell and W.H. Daughaday, J.B. Lippincott Co., Philadelphia and Toronto.

Sanford, L.M., Palmer, W.M. and Howland, B.E. 1977. Changes in the profile of serum LH, FSH and testosterone, and in mating performance and ejaculate volume in the ram during the ovine breeding season. J. Anim. Sci. 45:1382.

Sanford, L.M., Beaton, D.B., Howland, B.E. and Palmer, W.M. 1978. Photoperiod-induced changes in LH, FSH, prolactin and testosterone secretion in the ram. Can. J. Anim. Sci. 58:123.

Sanford, L.M. 1974. The secretory patterns of luteinizing hormone and testosterone in the ram as influenced by sexual activity, season, age and breed. PH.D Thesis - University of Manitoba.

Sarda, I.R., Robertson, H.A. and Smeaton, T.C. 1973. Sequential changes in plasma progesterone levels in the ewe during the estrous cycle, and during pregnancy in intact and ovariectomised sheep. Can. J. Anim. Sci. 53:25.

Scaramuzzi, R.J. and Baird, D.T. 1977. Pulsatile release of luteinizing hormone and the secretion of ovarian steroids in sheep during anestrus. Endocr. 101:1801.

Scaramuzzi, R.J., Caldwell, B.V. and Moor, R.M. 1970. Radioimmunoassay of LH and estrogen during the estrous cycle of the ewe. Biol. Reprod. 3:110.

Schanbacher, B.D. and Lunstra, D.D. 1976. Seasonal changes in sexual activity and serum levels of LH and testosterone in Finnish Landrance and Suffolk rams. J. Anim. Sci. 43:644.

Schanbacher, B.D. and Lunstra, D.D. 1977. Acute and chronic effects of gonadotropin releasing hormone on reproductive characteristics of rams during the non-breeding season. J. Anim. Sci. 44(4):650.

Shelton, M. 1978. Reproduction and breeding of goats. J. Dairy Sci. 61(7):994.

Simaraks, S. 1978. Hormone levels in prepubertal ewe lambs and in mature ewes throughout the breeding season. Ph.D. Thesis, University of Manitoba.

Simaraks, S., Cheng, K.W., Howland, B.E., Sanford, L.M., and Palmer, W.M. 1979. FSH and LH levels during estrus in two breeds of sheep throughout the breeding season. Paper presented at the Inaugural Winter Meeting of the Canada West Society for Reproductive Biology, Saskatoon Feb. 22-24, 1979.

Smeaton, T.C. and Robertson, H.A. 1971. Studies on the growth and atresia of Graafian follicles in the ovary of the sheep. J. Reprod. Fert. 25:243.

Snedecor, G.W. and Cochran, W.G. 1976. Statistical Methods, 6th edition. The Iowa State University Press, Iowa.

Stabenfelt, G.H., Holt, J.A. and Ewing, L.L. 1969. peripheral plasma progesterone levels during the ovine estrous cycle. Endocr. 85:11.

Steel, R.G.D. and Torrie, J.H., 1960. The principles and procedures of statistics. McGraw Hill Inc. Toronto.

Strickland, S., and Beers, W.H. 1979. Studies of the enzymatic basis and hormonal control of ovulation. In: Ovarian Follicular Development and Function. Eds: A.R. Midgley and W.A. Sadler. Raven Press, New York.

Thimonier, J. and Mauleon, P. 1969. Seasonal variations in estrous behaviour and ovarian and pituitary activities in the ewe. Annu. Biol. Anim. Biochem. Biophys. 9:233.

Thimonier, J., Bosc, M., Djiane, J., Martal, J., and Terqui, M. 1977. Hormonal diagnosis of pregnancy and number of fetuses in sheep and goats. Proceedings: Symposium on management of reproduction in sheep and goats. Madison, Wisconsin July 24-25, 1977.

Thorburn, G.D., Bassett, J.M. and Smith, I.D. 1969. Progesterone concentration in the peripheral plasma of sheep during the oestrus cycle. J. Endocr. 45:459.

Thorburn, G.D. and Mattner, P.E. 1971. Anastomosis of the utero-ovarian and anterior mammary veins for collection of utero-ovarian venous blood; progesterone secretion rate in cyclic ewes. J. Endocr. 50:307.

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

Thorburn, G.D. and Schneider, W. 1972. The progesterone concentration in the plasma of the goat during the oestrous cycle and pregnancy. J. Endocr. 52:23.

Thorburn, G.D., Challis, J.R., and Currie, W.B. 1977. Control of parturition in domestic animals. Biol. Reprod. 16:18.

Turek, F.W. and Campbell, C.S. 1979. Photoperiodic regulation of neuroendocrine-gonadal activity. Biol. Reprod. 20(1):32.

Umo, I., Fitzpatrick, R.J. and Ward, W.R. 1976. Parturition in the goat: Plasma concentrations of prostaglandin F and steroid hormones and luterine activity during late pregnancy and parturition. J. Endocr. 68:383.

Umo, I. and Fitzpatrick, R.J. 1976. Induction of parturition in goats with prostaglandins $F_{2\alpha}$. Proc. VIIIth Intern. Congr. on Anim. Reprod. and Artif. Insemination, Krakow, Poland.

Walton, J.S., McNeilly, J.R., McNeilly, A.S. and Cunningham, F.J. 1977. Changes in concentrations of follicle-stimulating hormone, luteinizing hormone, prolactin and progesterone in the plasma of ewes during the transition from anoestrus to breeding activity. J. Endocr. 75:127.

Wheeler, A.G., Baird, D.T., Land, R.B., and Scaramuzzi, R.J. 1977. Seasonal variation in oestrus, the secretion of oestrogen and progesterone and LH levels before ovulation in the ewe. J. Reprod. Fert. 51:427.

Wilson, P.N. 1960. The effect of plane of nutrition on the growth and development of the East African Dwarf Goat. Ph.D. Thesis - Makerere University College.

Wu, C.H. and Lundy, L.E. 1971. Radioimmunoassay of plasma estrogens. Steroids 18:91.

Yuthasastrakosol, P. 1975. Hormone levels in ewes. Ph.D. Thesis, University of Manitoba.

Yuthasastrakosol, P., Palmer, W.M., and Howland, B.E. 1975. Luteinizing hormone, oestrogen and progesterone levels in peripheral serum of anoestrous and cyclic ewes as determined by radioimmunoassay. J. Reprod. Fert. 43:57.

Yu, J. Y-L., Yuthasastrakosol, P., Marquardt, R.R. and Palmer, W.M. 1974. Estrogen levels in peripheral plasma of immature female chickens as determined by radioimmunoassay. Endocr. 94:1168.

APPENDIX I

Serum LH and FSH Levels in Goat #5353 and 5351 Bled at 20-min Intervals for 24h During the Breeding and Non-Breeding Seasons

LH Levels for Goat #5353 (ng/ml)

June 22, 1976 (First sample taken at 0900h)

0.435	0.649	1.049	0.795	0.747
0.450	0.613	0.715	0.677	0.620
0.595	0.664	0.524	0.618	6.491
0.735	0.531	0.474	0.588	3.073
1.013	0.494	0.612	0.555	1.891
0.720	0.431	0.444	0.541	1.040
0.739	0.449	0.550	0.582	0.810
0.621	0.478	0.528	0.520	0.555
0.601	0.376	0.558	0.599	0.471
5.939	0.460	0.397	0.611	0.464
3.523	0.571	7.278	0.832	0.347
1.876	7.038	4.303	0.618	0.422
0.696	4.780	3.484	0.663	0.508
0.873	3.143	1.510	0.361	0.358
0.764	1.516	1.058	0.700	

September 22, 1976 (First sample taken at 0900h)

0.729	0.339	0.399	0.854	3.570
0.506	0.263	0.191	0.577	2.340
0.303	4.360	0.197	0.477	1.220
0.211	1.840	0.218	0.505	0.667
0.241	1.195	3.135	0.343	0.448
0.261	0.687	1.380	0.459	0.336
0.200	0.408	0.592	0.292	0.306
0.253	0.384	0.343	0.429	1.505
0.336	0.422	0.273	4.250	3.246
4.139	0.270	0.247	1.904	1.714
2.225	2.365	0.200	0.843	0.779
0.899	1.928	0.215	0.697	0.356
0.696	0.839	1.994	0.499	0.522
0.403	0.597	2.306	0.416	
0.342	0.397	1.118	0.434	

LH Levels for Goat #5353 (Continued)

December 22, 1976 (First sample taken at 1800h)

1.309	0.204	0.277	0.324	0.212
0.760	0.206	0.244	0.344	0.346
0.530	0.224	0.217	0.332	0.273
0.418	0.202	0.297	0.324	0.213
0.481	0.204	0.324	0.343	0.222
0.225	1.988	0.269	0.268	0.222
0.240	0.864	0.316	0.313	0.263
0.249	0.461	0.326	0.309	0.224
0.108	0.435	0.349	0.351	0.331
0.111	0.385	0.359	0.209	0.365
0.113	0.275	0.301	0.236	0.380
0.103	0.311	0.447	0.189	0.329
0.107	0.314	0.287	0.229	0.339
0.105	0.216	0.421	0.208	
0.239	0.212	0.379	0.256	

March 23, 1977 (First sample taken at 1800h)

3.681	0.961	0.463	3.158	1.334
1.802	0.873	0.427	1.696	1.114
0.852	0.748	0.415	1.223	0.813
0.628	4.886	3.532	0.825	0.584
0.706	3.477	3.884	0.729	0.634
0.681	1.749	1.882	0.628	0.635
4.427	1.288	0.766	0.513	2.897
2.482	0.854	0.638	3.790	1.788
1.594	0.622	0.483	1.670	1.094
0.987	0.566	0.462	1.392	0.946
0.727	0.694	3.387	0.813	0.777
0.629	3.090	1.608	0.572	0.556
5.702	2.437	0.882	0.612	0.682
3.685	0.484	0.710	0.589	
1.828	0.326	0.683	3.121	

LH Levels for Goat #5351

June 22, 1976 (First sample taken at 0900h)

0.360	0.210	0.504	0.453	0.516
0.362	0.286	0.322	0.319	3.026
0.280	0.200	0.384	0.307	2.528
0.232	0.242	0.281	0.241	1.013
0.334	0.232	0.425	0.216	0.834
0.200	0.290	0.440	0.255	0.596
0.208	0.299	0.338	0.217	0.409
0.197	0.327	0.280	0.365	0.461
0.167	0.429	0.225	0.271	0.433
0.175	6.433	5.370	0.173	0.200
0.244	2.984	4.286	0.216	0.324
0.287	1.448	2.140	0.273	0.188
0.273	0.855	1.263	0.308	0.220
0.226	0.607	0.789	0.294	
0.208	0.454	0.588	0.265	

September 22, 1976 (First sample taken at 0900h)

0.880	0.762	0.527	0.897	1.915
4.00	0.743	4.331	0.562	1.100
2.917	0.859	2.732	0.590	0.716
1.370	1.399	1.787	0.694	0.600
1.021	5.557	1.134	0.664	0.518
0.684	2.556	0.557	0.604	0.503
0.608	1.280	0.235	3.936	0.450
0.704	1.109	0.228	2.127	2.808
0.537	0.733	0.277	1.250	3.092
0.639	0.827	0.271	0.718	2.383
4.646	0.817	0.247	0.706	1.216
2.816	0.741	0.115	0.654	0.395
1.552	0.751	3.517	0.570	0.226
1.069	0.532	2.084	4.455	
0.795	0.547	0.962	3.680	

LH Levels for Goat #5351 (Continued)

December 22, 1976 (First sample taken at 1800h)

0.513	0.379	0.304	0.482	0.200
0.172	0.320	0.309	0.301	0.372
0.156	2.148	0.268	0.408	0.271
0.188	0.740	1.688	0.290	2.131
0.208	0.450	0.860	0.294	0.805
0.173	0.372	0.646	0.449	0.556
0.200	0.293	0.709	0.433	0.520
0.215	0.294	0.327	0.288	0.324
0.198	0.371	0.250	0.337	0.242
0.200	0.362	0.207	0.354	0.677
0.210	0.625	0.272	0.412	0.204
0.211	0.332	0.279	0.395	0.364
0.219	0.421	0.299	0.404	0.325
0.305	0.268	0.320	0.288	
0.396	0.152	0.334	0.205	

March 23, 1977 (First sample taken at 1800h)

0.261	0.254	0.343	0.336	0.497
0.204	0.390	0.372	0.312	0.428
0.255	0.345	0.426	0.343	0.413
0.392	0.363	0.289	2.266	0.357
0.291	0.250	0.234	1.786	0.423
0.239	1.588	0.296	0.808	0.501
0.215	0.838	0.388	0.520	0.461
0.281	0.510	0.469	0.400	0.352
0.291	0.370	0.353	0.478	0.418
0.242	0.348	0.381	0.404	0.401
0.272	0.298	0.362	0.421	0.405
0.276	0.373	0.547	0.414	0.445
0.263	0.248	0.349	0.420	0.315
0.239	1.263	0.338	0.405	
0.316	0.643	0.312	0.416	

FSH Levels for Goat #5353

June 22, 1976 (First sample taken at 0900h)

16.042	16.042	34.552	19.744	34.555
16.042	16.042	19.744	18.510	61.700
24.680	16.042	27.148	19.744	50.594
12.340	16.042	37.020	19.744	39.484
27.148	18.510	39.488	19.744	39.488
19.744	24.810	61.700	29.616	39.488
13.574	13.574	27.148	29.616	39.488
18.741	16.042	34.552	24.680	24.682
34.552	18.510	34.552	28.615	34.552
27.148	16.042	37.020	24.680	39.488
29.616	34.552	34.552	24.685	37.020
34.552	29.616	29.616	24.681	44.424
18.510	29.616	29.148	24.680	39.488
19.744	24.810	27.148	34.552	
16.042	29.616	19.744	27.448	

September 22, 1976 (First sample taken at 0900h)

29.616	24.681	13.574	27.148	39.020
13.754	24.680	9.872	34.552	34.552
12.345	37.020	9.878	34.552	34.552
12.340	28.148	16.042	34.552	34.552
16.042	37.00	12.340	34.552	34.552
12.340	34.552	12.300	34.552	34.552
12.340	27.148	12.340	29.616	36.610
18.510	29.616	12.340	44.424	36.610
19.744	27.148	19.744	37.021	38.00
19.744	24.680	19.744	34.552	39.488
19.744	19.744	19.740	39.488	34.552
19.744	19.740	19.00	29.616	34.552
27.148	19.744	19.744	29.616	
27.148	16.042	19.744	34.552	
24.680	13.057	34.545	29.616	

FSH Levels for Goat #5353 (Continued)

December 22, 1976 (First samples taken at 1800h)

37.020	13.574	37.020	18.510	29.616
34.552	13.574	24.680	18.510	29.616
34.552	9.874	29.600	18.510	29.616
34.552	19.744	19.744	18.510	28.382
19.744	19.744	18.510	18.510	25.00
18.100	34.552	16.042	24.680	37.00
24.080	37.020	18.510	27.148	27.148
13.074	37.020	16.042	18.510	27.148
13.000	34.550	16.042	27.148	27.148
16.042	27.140	19.744	30.850	24.680
13.574	37.020	16.042	34.552	19.744
13.574	34.552	18.00	27.148	19.744
13.574	34.552	17.276	29.00	18.511
18.510	34.552	16.042	24.070	
13.574	241680	13.500	27.670	
		18.510		

March 22, 1977 (First samples taken at 1800h)

39.488	37.020	34.552	28.382	38.254
37.020	37.020	24.680	32.084	44.424
37.020	37.020	50.491	28.382	43.190
37.020	34.551	37.01	27.765	34.552
37.020	39.488	55.530	19.744	25.914
29.610	44.424	44.424	27.765	38.294
37.020	44.244	37.01	34.552	50.594
37.020	39.488	34.051	25.914	29.616
44.424	37.020	38.294	38.254	44.424
50.954	39.488	37.016	39.488	39.488
39.481	61.700	29.616	38.254	39.488
29.616	50.594	32.084	38.254	37.020
29.616	44.424	35.786	34.552	
44.424	44.424	28.382	43.180	
37.020	44.424	35.786	43.180	

FSH Levels for Goat #5351

June 22, 1976 (First samples taken at 0900h)

52.85	31.870	13.25	31.500	41.550
49.00	26.62	15.75	30.00	37.500
49.00	18.00	24.85	30.00	41.250
45.03	21.75	30.00	27.00	37.500
49.00	21.750	30.00	30.00	41.250
56.25	8.25	30.00	35.250	37.500
48.75	18.00	35.25	27.00	40.500
71.25	11.25	24.375	41.250	40.500
56.30	9.38	24.375	41.250	45.00
56.27	8.30	21.750	48.750	35.250
45.00	11.30	21.750	41.550	45.00
37.05	13.11	24.375	48.75	45.00
41.25	9.37	24.375	35.250	37.500
24.375	11.25	31.500	41.55	
24.375	14.25	31.500	45.00	

September 22, 1976 (First samples taken at 0900h)

19.530	41.361	33.315	32.172	41.368
33.315	36.765	36.768	25.278	45.960
22.990	22.980	32.172	32.321	45.960
22.990	33.316	32.172	20.682	45.960
31.980	41.340	33.321	32.321	45.960
25.278	36.768	25.278	32.321	51.705
27.348	41.340	25.278	45.960	55.152
25.271	33.315	33.321	36.760	22.980
32.172	25.278	27.528	32.321	66.642
41.363	32.170	33.321	32.321	48.864
58.597	32.325	33.321	25.278	48.114
41.360	20.683	33.321	33.391	33.321
41.363	25.270	33.321	32.329	32.321
33.321	45.960	36.768	51.705	
22.970	22.980	34.170	41.364	

FSH Levels for Goat #5351 (Continued)

December 22, 1976 (First samples taken at 1800h)

32.321	22.990	32.321	51.705	36.800
22.980	36.967	33.321	58.599	36.760
32.320	36.769	36.760	51.675	36.762
33.321	36.00	45.960	51.675	58.132
36.769	41.362	22.980	51.675	41.363
36.700	32.321	32.321	58.132	45.960
32.921	32.351	22.980	55.152	33.321
36.775	41.365	40.364	45.966	22.980
32.321	33.320	58.599	51.675	33.321
26.028	22.980	41.360	51.675	33.321
25.278	22.980	22.988	41.364	33.320
32.321	22.980	43.290	45.960	41.364
32.321	22.980	45.961	36.768	25.370
32.321	33.321	51.705	36.768	
36.679	22.980	51.705	36.780	

March 22, 1977 (First samples taken at 1800h)

25.277	32.321	36.888	33.321	18.382
25.270	32.325	33.326	32.321	19.533
22.900	41.366	25.278	45.960	19.533
19.533	36.768	25.278	55.153	21.080
19.533	41.364	25.278	51.068	19.533
20.682	45.961	18.384	45.960	19.533
19.500	36.768	20.682	48.864	20.682
18.304	36.768	32.321	25.278	20.680
22.980	36.768	32.321	19.533	33.321
10.341	20.682	32.321	19.533	32.321
18.164	22.980	32.321	19.533	31.034
22.181	41.364	41.364	19.533	25.278
16.088	33.321	31.321	19.533	25.278
25.278	36.068	22.980	19.533	
33.320	41.464	32.321	20.682	

APPENDIX II

Mean $\pm$ S.E.M. of LH, FSH, PROGESTERONE and ESTROGEN Values for the 4 Animals During the Transition from Anestrus to Breeding Activity (or Onset of Puberty)

LH (ng/ml)

Day-37	1.297 ± 0.491	1.41 ± 0.74
	2.18 ± 1.00	0.80 ± 0.08
	1.10 ± 0.45	0.50 ± 0.11
	1.19 ± 0.66	0.897 ± 0.21
	2.03 ± 0.90	1.12 ± 0.80
	1.05 ± 0.38	0.64 ± 0.40
	2.28 ± 0.30	0.37 ± 0.10
	2.25 ± 0.83	0.40 ± 0.10
	1.49 ± 0.49	0.39 ± 0.09
	2.70 ± 1.51	0.491 ± 0.08
	2.70 ± 0.58	0.44 ± 0.11
	3.85 ± 0.86	0.44 ± 0.12
	1.80 ± 0.55	0.49 ± 0.10
	1.38 ± 0.65	0.54 ± 0.13
	1.22 ± 0.46	1.96 ± 0.34
	1.53 ± 0.10	1.80 ± 1.02
	12.22 ± 3.92	16.33 ± 2.93
	3.31 ± 1.18	1.18 ± 0.42
	1.30 ± 0.30	1.08 ± 0.45
	1.23 ± 0.22	0.92 ± 0.16
	1.16 ± 0.33	0.84 ± 0.29

FSH (ng/ml)

Day-37	38.69 ± 3.14	57.14 ± 9.93
	56.25 ± 6.76	74.25 ± 6.75
	40.08 ± 4.56	83.66 ± 8.69
	60.34 ± 17.91	73.57 ± 21.97
	63.75 ± 20.72	47.41 ± 6.01
	56.80 ± 18.46	62.50 ± 13.27
	33.07 ± 4.52	85.87 ± 10.14
	56.87 ± 10.27	62.30 ± 18.02
	45.28 ± 14.55	45.91 ± 2.67
	47.50 ± 13.30	35.98 ± 4.56
	40.12 ± 12.27	52.5 ± 8.29
	84.37 ± 20.47	51.67 ± 19.09
	57.56 ± 9.68	37.89 ± 7.06
	56.39 ± 8.50	27.37 ± 1.80
	65.08 ± 15.27	61.78 ± 22.62
	57.68 ± 10.17	168.0 ± 26.49
	253.0 ± 21.71	171.76 ± 40.36
	96.28 ± 18.15	97.87 ± 33.74
	73.76 ± 3.14	44.12 ± 7.91
	63. ± 9.65	41.25 ± 10.07
	62.66 ± 10.84	40.16 ± 2.89

Progesterone (ng/ml)

Day-37	0.90 ± 0.38	5.98 ± 0.62
	0.58 ± 0.08	6.42 ± 1.11
	0.52 ± 0.10	9.52 ± 0.82
	0.70 ± 0.27	10.56 ± 0.62
	0.54 ± 0.20	10.85 ± 0.92
	0.761 ± 0.13	10.43 ± 1.43
	0.75 ± 0.26	10.04 ± 0.64
	0.48 ± 0.09	10.85 ± 0.64
	0.91 ± 0.38	10.56 ± 0.42
	1.01 ± 0.55	10.18 ± 0.64
	0.52 ± 0.08	9.98 ± 1.03
	0.48 ± 0.09	10.46 ± 1.54
	0.82 ± 0.28	8.19 ± 1.82
	1.60 ± 0.34	8.42 ± 1.36
	2.31 ± 0.44	4.04 ± 2.50
	1.54 ± 0.44	1.59 ± 0.49
	1.26 ± 0.47	1.23 ± 0.27
	0.73 ± 0.18	1.16 ± 0.23
	0.64 ± 0.11	2.40 ± 0.48
	2.17 ± 0.39	4.66 ± 0.50
	4.18 ± 0.47	6.22 ± 0.39

Estrogen (pg/ml)

Day-37	18.77 ± 1.76	18.35 ± 2.30
	19.03 ± 1.18	21.55 ± 3.98
	18.10 ± 4.90	18.72 ± 1.29
	27.10 ± 1.98	18.39 ± 1.13
	22.46 ± 1.87	19.24 ± 1.72
	15.70 ± 1.87	21.80 ± 1.88
	14.29 ± 2.56	15.99 ± 3.44
	26.36 ± 7.44	14.43 ± 3.94
	17.68 ± 5.89	11.59 ± 1.64
	21.99 ± 7.46	10.98 ± 1.16
	22.76 ± 7.80	26.19 ± 7.52
	22.60 ± 3.02	18.19 ± 3.46
	19.69 ± 5.37	26.31 ± 0.75
	26.89 ± 2.15	18.58 ± 5.10
	23.14 ± 2.43	43.68 ± 2.31
	36.34 ± 7.17	36.710 ± 4.82
	24.44 ± 2.52	32.07 ± 3.64
	29.55 ± 9.93	16.13 ± 3.04
	22.01 ± 7.63	17.19 ± 4.12
	18.85 ± 2.82	27.09 ± 5.94
	22.25 ± 1.17	25.81 ± 1.34

APPENDIX III

Gonadotropin and Ovarian Hormone Concentrations During Consecutive Estrous Cycles

LH Levels for Goat #5351

8.697	1.810	0.420
1.236	1.007	0.644
1.595	0.343	0.600
1.956	0.240	0.411
0.478	0.295	0.456
0.670	0.593	0.365
0.614	0.592	0.570
0.707	1.278	0.412
0.336	0.508	0.322
0.540	0.435	0.598
0.542	0.451	0.372
0.813	0.433	0.490
0.337	0.989	4.32
0.493	0.516	1.425
0.310	0.535	13.466
0.282	3.636	1.204
0.378	3.336	1.109
0.349	16.435	0.729
1.160	3.858	0.616
8.148	2.168	0.664
0.829	1.210	0.334
0.358	1.276	
0.933	0.891	

LH Levels for Goat #5353

1.83	1.670	0.435
1.200	5.08	1.367
1.091	20.63	1.200
0.411	0.383	0.797
0.345	0.108	0.855
7.810	0.779	0.400
0.340	0.557	0.393
0.414	0.200	0.306
0.385	0.106	0.255
1.060	0.210	0.296
0.906	0.175	0.247
0.695	0.218	0.233
0.200	0.320	0.458
0.070	0.551	0.310
0.147	0.207	2.560
0.369	0.383	1.450
0.069	0.611	9.430
0.168	0.288	1.606
0.059	0.290	0.855
0.143	2.683	0.837
0.110	8.56	0.341
0.184	1.511	
0.263	0.973	

LH Levels for Goat #6257

2.165	0.770	0.837
8.415	0.670	1.063
1.343	0.778	0.526
0.911	0.679	0.541
0.729	0.838	6.562
0.454	0.312	0.764
0.441	0.659	0.611
0.385	0.573	0.655
0.486	0.469	0.724
0.580	0.468	0.524
0.504	0.570	0.541
0.333	0.437	0.745
0.469	0.661	0.707
0.294	0.481	0.702
0.411	0.619	0.681
0.692	0.538	3.260
0.347	0.577	6.538
0.510	0.929	1.990
0.524	6.870	0.546
0.368	21.50	0.495
1.800	4.95	0.627
4.380	0.588	
10.015	0.611	

LH Levels for Goat #6258

11.114	1.541	1.422
1.139	0.290	0.452
1.255	0.959	1.180
0.529	0.731	2.960
0.431	0.841	0.312
0.246	0.391	0.785
0.347	0.256	0.702
0.835	0.855	0.946
0.474	0.171	0.359
0.332	0.265	0.320
0.616	0.210	0.381
0.321	0.669	0.165
0.286	0.277	0.288
0.964	0.306	0.224
0.495	0.140	0.236
0.709	0.101	0.378
1.597	0.271	0.241
3.101	0.434	0.657
7.549	2.026	0.404
0.492	0.684	1.108
0.655	8.443	0.518
1.472	0.520	
1.825	0.726	

FSH Levels for Goat #5351

180.00	32.50	64.25
56.25	42.50	61.75
37.50	66.75	57.37
14.00	65.00	53.00
15.00	59.00	24.25
39.25	44.25	50.25
59.63	25.50	68.50
80.00	35.01	50.25
43.750	41.750	46.50
61.75	4.25	73.75
72.50	21.00	60.500
62.75	13.25	58.75
37.50	54.26	45.75
37.50	59.25	48.00
39.25	26.00	112.50
57.00	25.50	225.00
39.25	87.50	225.00
21.00	132.50	86.75
55.50	105.00	54.250
175.00	18.75	46.25
50.25	77.50	50.25
58.50	67.50	
30.50	52.75	

FSH Levels for Goat #5353

57.0	58.71	38.00
45.0	64.0	30.00
21.0	144.0	35.870
23.0	12.00	41.75
23.5	18.00	42.25
108.0	11.55	20.500
92.75	24.25	79.25
87.52	51.75	30.00
33.78	47.50	26.52
45.0	12.50	58.00
60.10	16.00	37.25
57.00	23.75	46.25
32.50	25.50	11.50
15.00	22.50	59.00
30.00	31.25	19.25
45.00	15.50	32.75
36.50	31.25	118.00
39.25	18.75	19.50
17.00	43.75	32.750
18.00	40.00	34.25
51.5	220.00	16.75
20.00	167.500	
17.50	102.500	

FSH Levels for Goat #6257

115.00	20.00	28.75
155.00	33.75	35.00
146.25	54.25	34.37
96.25	58.75	33.75
65.50	55.00	31.25
72.50	21.25	35.00
67.50	25.00	27.50
62.50	39.00	25.50
46.25	37.50	23.75
56.00	23.25	66.00
70.00	30.50	57.50
42.50	34.25	28.75
66.50	47.50	20.50
27.50	42.00	26.25
48.50	45.500	21.25
48.75	29.50	26.25
37.50	41.25	136.00
51.50	59.25	16.25
68.00	60.00	21.00
112.0	190.00	23.00
141.25	43.75	32.500
109.25	16.25	
215.00	36.25	

FSH Levels for Goat #6258

210.00	47.75	43.00
29.250	68.00	68.00
24.250	46.50	58.00
22.250	37.75	88.75
40.00	21.25	42.500
22.15	40.50	36.00
47.625	48.75	27.00
73.00	37.25	28.75
46.50	26.25	56.75
32.500	36.500	53.00
30.00	27.75	50.00
40.00	18.75	22.25
44.250	44.25	30.75
30.00	51.250	41.25
25.50	28.00	31.25
56.25	21.25	34.50
51.75	27.500	32.50
48.75	52.500	33.75
182.50	56.250	38.75
74.75	81.50	40.00
26.25	195.00	34.500
67.50	36.50	
50.00	55.00	

Progesterone Levels for Goat #5351

0.564	2.146	7.12
0.513	3.307	7.94
0.821	4.44	7.51
2.225	5.23	7.06
3.19	5.44	8.72
5.65	6.15	10.26
6.40	7.58	10.08
7.26	7.14	10.40
6.40	7.88	11.33
7.17	8.34	11.80
8.70	10.02	9.54
8.99	10.15	5.95
7.12	8.81	6.23
7.36	7.75	1.066
6.09	4.54	0.688
7.940	1.104	1.62
7.80	0.58	2.82
6.18	0.50	4.74
4.19	0.47	6.00
0.66	2.26	7.96
1.08	3.23	4.20
0.895	5.14	
0.949	6.13	

Progesterone Levels for Goat #5353

0.81	5.37	2.46
1.38	0.54	3.94
1.14	0.84	4.62
2.96	0.195	5.40
3.29	0.89	6.08
0.62	3.73	7.78
0.40	5.13	6.53
0.49	4.85	8.20
0.98	7.92	10.11
2.60	8.24	10.37
3.54	9.55	7.90
6.88	7.76	4.50
8.72	7.67	5.84
7.90	7.13	5.06
8.70	6.69	5.06
7.81	7.64	0.68
9.58	8.45	0.38
9.70	6.31	0.24
7.72	6.53	0.72
6.96	0.82	1.83
6.64	0.45	1.56
6.20	0.61	
6.95	0.71	

Progesterone Levels for Goat #6257

1.43	2.81	3.11
0.87	4.45	6.25
0.86	5.33	7.79
1.34	6.75	9.35
2.37	8.25	6.98
3.57	9.04	8.03
5.20	8.26	8.91
7.45	8.94	8.53
7.20	8.58	7.43
7.73	9.86	8.28
9.10	9.13	5.88
12.22	8.65	6.03
8.04	8.52	5.99
7.94	6.36	3.92
8.41	6.44	1.34
7.72	4.60	0.97
8.78	1.49	0.88
6.42	1.32	1.03
6.34	1.13	1.74
2.55	1.05	2.96
1.50	0.76	3.09
1.17	2.33	
1.00	2.72	

Progesterone Levels for Goat #6258

0.31	1.17	5.94
1.30	1.40	6.0
4.69	2.77	0.57
6.90	4.20	0.894
7.14	4.04	0.422
8.24	5.44	1.18
7.84	5.74	4.33
8.14	5.87	6.78
9.19	6.35	9.00
9.16	7.28	10.13
8.42	6.35	12.35
9.83	11.64	10.50
10.43	12.05	9.69
8.90	8.00	10.65
10.07	9.00	11.12
7.80	9.70	12.41
5.30	8.73	13.12
1.77	9.24	10.06
1.21	9.79	8.81
1.63	5.80	8.64
2.72	1.45	8.28
4.06	0.91	
2.42	0.96	

Estrogen Levels for Goat #6257

8.227	18.256	13.303
37.433	19.343	16.078
29.580	23.751	14.565
24.722	13.607	13.766
16.716	30.988	13.565
19.586	37.169	7.598
20.677	36.856	7.027
21.769	18.843	26.101
20.169	16.032	10.303
15.176	13.812	13.301
14.106	10.374	7.336
13.352	20.279	20.751
5.663	25.655	17.931
11.498	15.926	22.153
23.300	8.633	16.718
24.00	9.854	13.885
23.990	12.006	49.553
13.651	24.893	25.514
5.941	19.972	30.650
9.163	47.586	30.962
32.240	38.349	30.215
59.527	40.470	
22.501	26.886	

Estrogen Levels for Goat #5353

57.702	45.280	28.519
46.574	47.717	30.815
19.993	57.839	27.013
35.630	38.509	23.642
21.993	22.958	27.156
48.205	28.249	29.912
36.977	26.080	26.205
51.062	19.057	17.609
36.810	27.520	21.207
28.813	36.724	21.493
32.170	33.067	23.876
24.792	31.921	14.902
21.738	25.231	23.195
26.498	21.264	10.299
32.357	23.139	27.571
26.209	21.346	29.724
26.756	15.705	48.693
28.593	16.043	16.432
30.256	26.074	29.757
33.925	43.994	37.222
34.210	48.189	33.352
29.228	50.994	
23.907	40.753	

Estrogen Levels for Goat #6258

39.489	29.489	33.238
17.433	17.439	17.888
30.599	31.034	49.284
17.416	38.869	51.668
22.487	41.756	27.541
18.585	27.052	34.726
25.821	28.735	23.620
23.057	17.320	40.778
18.566	18.313	23.679
23.069	34.517	30.048
25.052	21.916	17.040
16.566	25.121	19.217
11.599	39.179	24.273
17.677	27.362	20.670
26.977	14.963	34.768
24.336	15.052	34.263
45.019	35.778	38.764
55.602	40.804	39.439
32.923	51.684	19.419
22.540	56.284	23.679
32.129	31.998	27.351
34.00	26.773	
30.139	33.238	

Estrogen Levels for Goat #5351

31.066	32.942	39.276
36.621	41.261	31.479
37.806	18.572	26.374
31.047	13.048	36.634
29.684	24.034	30.118
30.083	37.722	27.398
32.812	35.004	29.277
13.318	38.00	38.825
32.505	35.515	13.804
24.360	28.888	12.648
37.381	15.766	8.923
43.313	17.777	38.567
24.839	35.461	21.616
23.332	31.501	29.331
21.968	23.729	42.289
25.989	28.844	38.770
27.747	62.189	19.228
26.759	64.473	22.337
23.435	23.379	22.783
35.545	34.318	28.937
48.463	44.773	44.963
24.540	42.735	
18.024	39.236	

APPENDIX IV

LH and FSH Concentrations in Sera Collected at 20-minute Intervals (Hourly for Goat #6258) for 24h During Estrus

LH and FSH Levels for Goat #6257. (1st Estrous Period

LH

0.869	0.623	12.882	15.685	6.205
2.281	1.262	12.718	13.530	5.440
1.294	1.224	13.901	15.293	5.600
1.110	2.659	18.830	14.425	3.385
0.639	2.502	14.523	17.805	2.715
3.449	2.090	18.951	14.890	3.030
1.566	1.641	15.676	14.960	2.005
1.344	4.024	11.174	12.415	1.750
0.219	4.937	11.953	12.905	1.365
2.293	3.907	12.447	10.735	1.305
1.459	3.126	11.009	10.400	1.015
0.831	4.481	16.585	8.910	0.495
0.402	6.377	18.182	11.195	0.540
1.721	10.799	17.401	10.535	
1.244	15.001	14.280	8.145	

FSH

10.00	33.50	120.00	240.00	65.00
20.00	44.50	120.00	210.00	60.00
15.75	36.00	150.00	180.00	65.00
15.75	49.00	165.00	150.00	65.00
20.00	45.00	157.00	210.00	60.00
27.50	35.00	156.00	210.00	35.00
35.00	35.00	115.00	157.50	30.00
40.00	35.00	120.00	157.50	40.00
30.00	32.00	124.00	120.00	45.00
38.00	30.00	120.00	115.00	45.00
35.00	45.00	190.00	110.00	40.00
20.00	30.00	310.00	80.00	49.00
20.00	65.00	360.00	71.00	70.00
25.00	80.00	320.00	80.00	
30.00	117.50	336.00	105.00	

LH and FSH Levels for Goat #6258. (2nd Estrous Period)

LH (ng/ml)	FSH (ng/ml)
5.226	110.00
0.865	52.50
1.103	52.50
1.257	62.50
3.571	56.00
1.516	80.00
2.351	84.00
3.299	80.00
5.159	95.00
9.558	115.00
11.421	120.00
13.834	117.50
15.286	210.00
12.006	210.00
14.161	360.00
14.260	356.00
17.281	360.00
19.195	364.00
15.667	200.00
6.324	105.00
2.548	65.00
1.820	65.00
1.245	52.50
1.130	60.00
1.068	64.00

LH and FSH Levels for Goat #6257. (2nd Estrous Period)

LH

0.350	1.885	2.495	11.705	14.430
2.050	0.695	2.875	15.535	15.125
1.340	0.735	2.825	15.550	14.850
0.680	2.040	5.130	15.620	15.555
0.565	1.160	4.320	14.290	10.065
1.820	0.835	7.090	17.685	8.040
0.985	2.990	7.540	21.775	7.495
0.490	2.035	7.035	20.575	5.590
2.550	1.210	13.575	15.850	3.310
1.200	2.975	12.100	16.930	2.410
0.230	1.455	10.530	19.085	2.315
2.855	1.000	11.755	16.310	2.620
1.690	2.590	11.440	17.920	1.320
0.615	1.555	12.840	14.380	
0.710	2.085	14.295	15.955	

FSH

80.00	71.00	60.00	240.00	180.00
70.00	80.00	65.00	260.00	178.00
80.00	95.00	65.00	260.00	115.00
60.00	80.00	70.00	240.00	80.00
65.00	77.00	65.00	210.00	95.00
65.00	95.00	70.00	215.00	65.00
60.00	95.00	115.00	260.00	71.00
105.00	65.00	95.00	265.00	71.00
100.50	72.50	98.00	310.00	115.00
96.00	65.00	120.00	276.00	70.00
65.00	63.00	115.00	260.00	65.00
62.70	87.00	110.00	272.00	70.00
70.00	80.00	120.00	175.00	67.50
68.00	70.00	157.50	157.00	
70.00	65.00	157.50	210.00	

LH and FSH Levels for Goat #5351.

LH

3.142	2.456	13.548	13.963	6.491
1.480	3.079	13.159	17.754	5.328
1.050	4.554	15.384	18.762	4.251
1.031	5.383	12.164	16.451	2.804
1.274	7.921	17.229	13.712	2.218
3.784	9.449	12.420	12.904	2.776
2.452	12.722	14.898	13.687	1.766
1.668	12.867	15.480	14.223	1.598
1.150	14.673	11.595	16.223	1.030
1.148	13.810	13.401	12.894	2.813
1.501	14.297	11.804	11.811	1.397
2.028	15.044	16.710	9.795	1.154
3.584	20.290	13.750	10.514	0.800
3.674	17.029	17.789	9.287	
3.125	16.264	17.064	7.484	

FSH

61.280	55.152	277.292	137.880	68.940
61.280	44.428	231.332	183.840	61.280
44.428	71.280	245.120	191.500	44.428
49.024	76.040	245.110	191.500	55.152
42.896	72.00	245.140	191.500	55.152
61.280	88.850	222.140	191.500	49.024
73.636	93.452	160.860	160.860	49.024
55.152	73.536	126.624	150.136	49.024
49.024	104.176	122.560	137.880	49.024
55.152	137.880	122.560	110.304	49.024
61.280	170.052	110.304	110.304	49.942
61.280	202.224	160.860	104.176	61.280
55.152	275.453	150.136	88.856	68.980
55.152	204.224	170.052	78.132	
44.428	231.332	170.052	73.536	

LH and FSH Levels for Goat #5353.

LH

0.727	1.369	15.869	14.048	3.893
1.213	1.031	16.021	12.335	2.414
3.315	4.563	15.034	11.667	0.993
1.435	2.560	17.605	12.236	1.564
1.284	2.510	16.578	11.796	2.490
2.293	5.685	20.520	15.255	2.165
0.918	4.391	19.531	10.535	1.125
0.355	4.231	15.954	7.877	2.337
3.932	6.485	15.638	10.942	1.650
1.009	8.012	17.179	7.650	1.312
0.778	8.862	15.247	6.829	0.808
3.038	10.267	18.004	5.585	1.083
1.760	19.564	15.491	3.709	0.874
0.634	16.719	15.461	3.251	
3.208	17.323	14.254	2.674	

FSH

60.00	60.00	156.00	260.00	70.00
65.00	70.00	157.00	286.00	110.00
65.00	95.00	210.00	210.00	95.00
52.50	80.00	240.00	196.00	105.00
49.00	65.00	310.00	157.50	95.00
65.00	65.00	340.00	157.50	80.00
60.00	65.00	355.00	150.00	70.00
70.00	65.00	342.00	120.00	65.00
65.00	105.00	360.00	95.00	65.00
70.00	100.00	364.00	75.00	65.00
48.00	110.00	360.00	80.00	65.00
37.00	120.00	360.00	70.00	48.00
70.00	105.00	356.00	70.00	52.00
71.00	120.00	340.00	71.00	
85.00	150.00	310.00	60.00	

APPENDIX V

Progesterone and Estrogen Levels During Pregnancy and Parturition

Progesterone Levels During Pregnancy & Parturition.

Goat #5351
Singleton Pregnancy

1.618	4.861	5.097	4.607
2.364	4.760	6.623	3.154
4.906	3.111	7.064	0.697
5.073	3.548	6.727	0.624
5.353	5.234	6.605	0.673
6.701	5.674	6.224	0.550
6.556	4.110	5.511	
5.623	7.660	5.854	
5.091	6.378	4.670	

Goat #5353
Singleton Pregnancy

0.861	5.736	7.948	7.260
5.049	5.817	7.448	1.465
6.239	4.631	5.475	0.656
4.038	7.075	6.040	0.351
3.511	6.326	7.000	0.259
2.664	6.955	7.582	0.611
3.186	6.509	6.681	
2.686	9.561	5.20	
4.252	6.832	5.049	

Progesterone Levels During Pregnancy & Parturition (Cont'd)

Goat #5353
Twin Pregnancy

4.287	8.168	12.914	10.117
13.523	11.003	10.765	7.406
9.894	10.438	12.055	5.245
10.462	10.280	12.717	2.220
8.316	11.246	16.209	2.510
8.097	11.526	14.376	2.07
9.578	14.254	12.013	2.409

Goat #5351
Triplet Pregnancy

2.351	9.666	10.239	9.393
1.104	8.165	12.064	9.310
11.534	7.900	9.041	8.715
11.018	9.317	9.762	6.105
10.713	10.363	8.691	3.495
10.717	8.551	8.746	1.948
9.340	10.599	10.663	1.035
7.702	11.118	12.293	0.440
8.562	12.189	11.168	0.487

Estrogen Levels During Pregnancy and Parturition

Goat #5353
Singleton Pregnancy

17.37	66.06	195.02	218.15
3.83	74.71	226.28	239.91
8.41	98.69	202.11	280.35
17.53	98.89	232.11	292.44
44.35	129.77	196.62	58.59
15.61	179.57	221.22	9.19
33.95	154.20	213.16	4.23
46.94	195.76	224.46	

Goat #5351
Singleton Pregnancy

12.303	27.469	180.765	265.70
11.992	56.613	199.729	266.50
2.106	74.139	173.765	260.12
2.727	95.743	180.190	280.00
12.401	101.104	198.0	52.15
10.998	103.104	241.50	16.17
18.356	106.876	257.13	10.11
9.409	104.295	284.00	

Estrogen Levels During Pregnancy and Parturition (Cont'd)

Goat #5353
Twin Pregnancy

5.928	66.359	283.919	295.143
3.831	57.750	293.110	263.853
5.308	64.575	312.674	300.086
2.250	141.316	272.800	39.019
8.817	199.144	319.343	13.629
4.116	233.370	295.710	5.366
37.656	258.640	276.040	10.850

Goat #5351
Triplet Pregnancy

17.546	61.399	337.285	258.056
15.903	96.826	345.629	243.964
7.262	175.791	331.296	254.044
11.229	234.330	325.044	267.846
22.380	260.274	293.539	102.593
4.521	249.539	321.521	47.803
10.013	286.891	227.160	10.459
41.504	250.717	241.506	
53.275	234.258	246.778	

MEAN (± S.E.) Levels of Progesterone and Estrogen for the four pregnancies

Progesterone

2.27 ± 0.7	7.67 ± 1.4	9.87 ± 2.4	5.74 ± 1.9
5.51 ± 2.8	7.26 ± 1.2	10.13 ± 1.9	5.91 ± 1.5
8.14 ± 1.5	6.72 ± 1.8	8.40 ± 1.4	3.91 ± 1.8
7.65 ± 1.8	7.87 ± 1.7	8.16 ± 1.0	2.86 ± 1.9
6.97 ± 1.6	9.04 ± 2.1	7.42 ± 0.45	2.20 ± 1.3
7.07 ± 1.7	8.52 ± 1.6	6.95 ± 0.77	1.60 ± 0.7
7.17 ± 1.5	7.99 ± 1.6	6.27 ± 1.7	1.08 ± 0.3
6.04 ± 1.2	10.10 ± 0.9	6.46 ± 2.07	1.01 ± 0.2
7.22 ± 1.6	9.53 ± 1.7		

Estrogen

10.44 ± 4.24	82.87 ± 26.37	219.28 ± 25.28	259.52 ± 15.37
8.39 ± 1.51	101.51 ± 28.05	230.77 ± 23.38	246.67 ± 12.76
13.10 ± 2.16	110.56 ± 24.28	228.84 ± 24.37	259.04 ± 12.58
15.79 ± 5.28	132.75 ± 27.08	249.88 ± 27.18	264.99 ± 5.53
26.02 ± 9.88	142.25 ± 22.28	257.64 ± 34.38	269.32 ± 8.4
21.17 ± 10.98	156.38 ± 28.83	223.73 ± 20.27	281.1 ± 10.8
25.68 ± 13.88	208.32 ± 24.31	242.71 ± 10.15	71.82 ± 17.33
37.18 ± 22.47	200.0 ± 20.00	238.55 ± 28.13	40.0 ± 5.55
64.41 ± 20.06			

MEAN (± S.E.) Progesterone and Estrogen Levels during 6 days preceding parturition and 2 days post parturition

PROGESTERONE (ng/ml)	ESTROGEN (pg/ml)
8.13 ± 1.73	238.55 ± 28.13
7.49 ± 1.12	259.53 ± 15.37
8.46 ± 1.4	246.67 ± 12.76
7.18 ± 1.33	259.036 ± 12.58
5.78 ± 0.62	264.99 ± 5.53
4.78 ± 0.94	269.32 ± 8.40
1.58 ± 0.33	281.1 ± 10.8
1.206 ± 0.44	71.82 ± 17.33
0.88 ± 0.40	40.0 ± 5.53

APPENDIX VI

LH and FSH Levels During Estrous Periods in which the LH/FSH Surge was Missed

LH Levels in Goat #5351 in the 4th Estrous Period

0.816	0.714	0.320	2.140
0.668	0.568	0.245	2.00
0.348	0.224	0.247	0.400
1.680	0.228	5.681	0.506
4.800	0.186	3.810	0.446
1.568	2.160	3.010	0.316
0.965	2.106	0.714	0.226
0.861	1.930	0.513	0.606
0.714	1.807	0.214	0.701
0.816	0.803	3.16	0.900
0.204	0.713	3.601	0.805
0.224	0.614	2.760	4.110
0.356	2.816	2.150	3.16
6.600	3.240	0.800	3.065
3.960	2.560	0.306	2.18
3.560	2.142	0.387	1.00
3.174	1.004	5.140	0.306
2.148	1.860	4.67	
0.816	0.960	3.60	

LH Levels in Goat #5353 in the 4th Estrous Period

0.816	0.714	0.320	3.60
0.668	0.568	0.245	2.140
0.348	0.224	0.247	2.00
3.680	0.228	4.681	0.200
1.900	0.186	4.810	0.506
1.568	4.160	3.010	0.446
0.968	2.106	0.714	0.316
0.861	1.930	0.513	0.326
0.614	1.807	0.214	0.806
0.816	0.803	3.16	0.701
0.204	0.713	3.001	0.900
0.224	0.614	2.760	0.705
0.356	2.816	2.150	4.710
7.680	3.240	0.700	3.16
3.960	2.560	0.306	3.065
3.560	2.142	0.287	2.18
3.174	4.004	5.140	2.00
2.148	1.860	4.67	0.706
0.816	0.960		

LH Levels in Goat #5353 in the 5th Estrous Period

0.816	0.714	0.320	3.60
0.668	0.568	0.245	2.240
0.348	0.224	0.247	2.00
2.680	0.228	4.681	0.800
1.900	0.186	3.810	0.606
1.568	6.170	3.010	0.846
0.968	2.106	0.714	0.416
0.861	1.930	0.613	0.226
0.814	1.807	0.214	0.606
0.816	0.803	3.16	0.301
0.204	0.713	3.001	0.900
0.224	0.614	2.760	0.705
0.356	2.816	2.150	5.110
6.680	3.240	0.700	3.16
3.960	2.560	0.306	3.065
3.560	2.742	0.287	2.100
3.174	2.004	5.140	2.00
3.248	1.860	4.67	0.606
0.816	0.860		

LH Levels in Goat #5353 in the 6th Estrous Period

0.916	0.714	0.320	2.140
0.708	0.568	0.245	2.00
0.448	0.224	0.247	0.900
1.680	0.228	5.681	0.506
1.900	0.286	3.810	0.446
1.568	4.760	3.010	0.316
0.968	2.106	0.714	0.226
0.861	1.930	0.513	0.606
0.714	1.807	0.214	0.701
0.916	0.803	3.160	0.900
0.204	0.813	3.001	0.705
0.224	0.614	2.760	0.210
0.356	2.816	2.150	4.760
4.680	6.240	0.800	3.065
3.060	2.560	0.306	2.18
3.560	2.142	0.387	2.00
3.174	2.004	5.140	0.806
2.448	1.360	4.67	
0.816	0.960	3.60	

LH Levels in Goat #5353 in the 8th Estrous Period

16.565	6.205	0.200	0.200
18.180	5.440	0.150	0.200
17.400	5.600	0.245	0.568
14.280	3.385	0.225	0.430
15.685	2.715	0.180	0.300
13.530	3.03	0.200	0.200
15.292	2.005	0.210	0.215
14.425	1.75	0.175	1.195
17.805	1.365	0.200	0.275
14.890	1.360	0.186	0.210
14.960	1.305	0.300	0.330
12.415	1.015	0.43	0.450
12.905	0.495	0.290	0.160
10.735	0.540	0.210	0.200
10.400	1.025	0.230	1.090
8.910	0.385	0.615	0.220
11.195	0.410	0.175	
10.535	0.230	0.140	
8.145	0.240	0.175	

LH Levels in Goat #6257 in the 3rd Estrous Period

0.200	5.845	0.210	2.590
4.115	2.160	0.225	1.055
1.745	0.825	2.095	0.200
1.185	0.380	0.945	0.240
0.280	0.610	0.320	3.295
0.275	0.490	0.185	1.695
0.200	4.775	0.265	0.550
2.665	2.655	0.200	0.285
1.625	1.165	0.2500	0.220
0.480	0.520	3.450	2.015
0.165	4.195	1.255	0.805
0.275	2.900	0.440	0.395
0.170	0.720	0.200	0.240
3.075	0.330	0.360	2.085
2.12	0.210	2.520	1.130
0.575	2.845	1.280	0.233
0.170	1.125	0.225	0.840
0.340	0.565	0.285	0.810
0.190			

LH Levels in Goat #6257 in the 4th Estrous Period

0.816	0.714	0.320	3.60
0.668	0.568	0.245	2.140
0.348	0.224	0.247	2.00
1.680	0.228	4.681	0.800
1.800	0.186	3.810	0.506
1.568	2.160	3.010	0.446
0.968	2.106	0.714	0.316
0.861	1.930	0.513	0.226
0.714	1.807	0.214	0.606
0.816	0.803	3.16	0.701
0.204	0.713	3.001	0.900
0.224	0.614	2.760	0.705
0.356	2.816	2.150	4.110
4.680	3.240	0.800	3.16
3.960	2.560	0.306	3.065
3.560	2.142	0.287	2.18
3.174	2.004	5.140	2.00
2.148	1.860	4.67	0.606
0.816	0.960		

LH Levels in Goat #6258 in the 3rd Estrous Period

0.816	0.714	0.820	3.60
0.668	0.568	0.245	2.140
0.448	0.224	0.200	2.00
1.680	0.228	4.681	0.800
1.800	0.186	3.810	0.506
1.668	4.160	3.010	0.946
0.968	2.106	0.714	0.316
0.861	1.930	0.513	0.226
0.714	1.807	0.214	0.606
0.816	0.803	3.16	0.801
0.204	0.713	3.001	0.900
0.224	0.614	2.760	0.705
0.356	2.816	2.150	6.110
5.680	3.240	0.800	3.00
3.960	2.560	0.306	3.065
3.560	2.142	0.287	2.18
3.174	2.004	5.140	2.00
2.048	1.860	4.67	0.106
0.816	0.960		

LH Levels in Goat #6258 in the 5th Estrous Period

0.816	10.740	28.860	16.880
0.601	12.160	29.680	15.690
0.401	13.418	30.860	17.680
5.06	15.800	22.160	18.010
2.850	16.007	27.060	17.680
2.014	17.001	28.006	15.310
0.876	16.001	29.060	14.410
0.714	15.016	29.600	13.160
5.160	18.178	31.060	12.960
4.860	18.001	28.600	16.760
7.890	17.001	25.170	15.600
8.10	19.076	24.770	14.240
9.001	26.016	23.706	13.400
7.814	26.360	21.710	16.006
7.746	26.560	8.76	17.060
10.160	21.086	18.960	18.110
11.760	27.760	13.160	19.100
12.130	28.860	15.788	20.001
10.140	29.160		

FSH Levels for Goat #5351 in the 4th Estrous Period

60.00	43.46	61.00	60.00
65.07	44.45	56.00	56.00
57.06	41.01	56.00	57.00
51.00	43.06	55.56	44.00
37.80	80.00	54.54	48.00
42.17	80.00	54.60	50.00
45.45	70.00	60.00	52.00
60.00	71.80	61.07	57.00
60.00	71.80	80.00	56.00
60.00	70.00	83.80	59.00
63.65	71.08	84.08	63,07
71.80	72.32	85.00	64.00
72.00	70.80	91.07	61.00
73.00	68.00	92.03	57.00
66.00	65.00	96.07	58.00
57.08	66.05	80.00	56.00
59.02	61.08	81.00	
60.00	61.00	83.00	
45.44	61.00	84.00	

FSH Levels for Goat #5353 in the 4th Estrous Period

27.00	100.15	51.80	56.06
28.06	100.15	51.80	57.07
29.01	100.01	52.80	60.00
30.00	98.00	56.08	80.00
30.00	97.00	56.07	81.00
30.00	60.66	56.07	85.87
30.00	61.65	56.56	86.76
35.06	65.60	47.01	86.76
37.10	60.00	61.07	86.78
37.58	60.00	72.01	86.80
39.58	60.00	72.00	81.00
42.20	57.08	75.75	81.00
43.15	56.60	78.71	76.00
45.17	55.00	79.01	75.00
51.17	55.00	50.66	76.00
80.00	55.00	51.01	
70.00	51.07	51.00	
65.15	50.09	51.00	
90.00	51.99	51.00	

FSH Levels in Goat #5353 in the 5th Estrous Period

44.36	65.05	72.32	43.80
42.10	81.01	76.07	42.96
42.00	47.76	77.09	43.80
42.00	48.76	47.60	45.16
27.06	56.56	45.67	46.70
28.06	57.51	27.13	48.07
21.05	51.60	28.13	60.00
45.66	51.60	18.23	60.00
45.76	51.60	21.16	60.65
45.75	51.60	23.61	60.67
80.00	56.00	27.81	51.56
80.00	48.01	33.34	53.33
81.00	48.08	33.36	54.16
82.32	68.07	33.36	40.71
82.36	96.00	33.36	40.71
82.33	95.00	33.36	42.66
82.33	98.93	33.60	
75.00	95.91	42.40	
75.07	75.71	41.90	

FSH Levels for Goat #5353 in the 6th Estrous Period

45.00	65.60	60.00	53.00
51.00	65.66	62.00	54.00
52.65	65.00	63.60	55.00
48.90	65.00	64.00	60.00
60.00	65.60	65.00	63.66
60.00	64.60	43.00	63.66
60.00	56.00	45.00	64.00
62.00	54.00	45.00	67.06
65.62	56.00	48.00	68.00
67.71	66.00	45.75	60.00
71.18	71.00	46.00	57.56
90.80	60.00	44.44	58.00
88.00	62.00	43.10	58.00
86.80	67.80	46.00	59.00
84.16	48.00	48.90	60.00
71.08	45.00	49.00	60.00
68.00	44.43	49.00	
69.00	42.16	88.00	
70.00	43.16	82.60	

FSH Levels in Goat #5353 in the 8th Estrous Period

276.00	165.00	40.50	27.65
281.07	105.00	50.61	21.01
260.15	95.00	27.65	29.03
258.17	101.17	28.61	30.44
272.01	98.90	27.65	31.32
244.06	80.30	27.85	34.06
230.08	70.00	27.60	33.01
228.80	75.00	29.01	41.05
225.16	65.50	30.62	41.05
230.81	50.63	43.16	45.55
176.07	40.56	28.03	46.07
157.50	37.60	17.83	56.01
157.60	43.07	15.80	50.90
210.00	25.57	16.90	45.01
180.00	18.07	15.70	47.16
310.00	21.17	16.78	27.61
190.75	17.83	27.08	
156.00	43.01	27.10	
180.70	43.02	27.65	

FSH Levels in Goat #6257 in the 3rd Estrous Period

44.46	72.71	51.16	60.08
34.60	80.81	52.82	58.57
36.00	80.00	54.00	56.15
36.00	65.00	55.00	50.00
36.00	65.06	50.00	50.00
32.46	65.03	47.23	47.48
45.40	65.00	28.00	39.12
44.00	60.00	29.00	51.16
41.07	56.75	41.00	58.51
37.16	57.18	81.00	60.00
38.12	56.13	80.00	60.00
39.14	60.00	65.60	62.00
47.00	63.45	75.15	61.02
51.07	37.15	78.00	57.16
80.00	28.80	68.18	56.14
81.00	30.31	68.00	55.00
86.00	30.30	68.78	
76.01	30.30	68.07	
75.71	30.37	61.07	

FSH Levels for Goat #6257 in the 4th Estrous Period

60.66	71.07	97.00	48.90
61.00	71.00	96.00	42.00
56,76	75.65	90.00	44.40
54.16	78.06	94.60	45.00
52.00	63.62	60.00	46.60
55.00	64.6[illegible]	60.00	47.00
60.00	65.00	65.67	49.00
60.00	66.00	68.00	50.60
61.00	66.00	68.00	55.00
65.65	67.00	69.70	45.40
67.60	68.69	67.00	44.00
60.30	68.00	48.00	48.00
47.00	68.00	42.00	49.00
48.00	67.68	40.00	50.65
50.18	62.67	[illegible]	
50.28	75.00	[illegible]	
50.38	80.00	[illegible]	
50.18	[illegible]	[illegible]	
71.06	[illegible]	[illegible]	

FSH Levels for Goat #6258 in the 3rd Estrous Period

80.48	55.10	56.00	82.00
81.17	60.00	56.80	81.00
77.18	48.00	56.91	77.00
75.12	47.00	52.07	75.60
60.02	36.00	60.07	76.01
91.00	32.60	71.81	77.03
101.01	42.53	67.01	71.00
104.00	41.00	58.02	70.18
105.00	40.00	55.75	60.56
104.00	44.60	54.63	57.00
104.60	45.00	60.07	63.00
84.00	47.15	60.37	64.75
60.00	48.00	60.00	65.60
65.66	48.00	61.00	66.00
67.62	48.00	81.08	60.15
65.61	48.00	86.00	
60.01	54.16	90.00	
59.00	56.00	70.00	
57.16	56.60	80.88	

FSH Levels for Goat #6258 in the 5th Estrous Period

40.45	81.80	56.90	80.81
41.48	90.00	58.00	81.00
47.80	60.00	60.00	84.00
48.00	76.66	60.08	80.00
52.00	75.06	60.01	75.76
62.66	75.00	66.00	76.08
64.00	76.00	66.00	74.00
65.06	71.08	60.00	76.00
65.00	71.80	62.00	77.00
66.00	80.00	65.00	78.00
67.68	80.00	72.06	78.06
69.00	50.00	72.00	80.00
70.00	55.06	74.00	81.80
70.00	56.00	75.00	82.60
70.00	56.00	76.00	83.00
72.00	56.00	77.00	81.41
75.72	56.02	78.08	
76.00	55.00	78.07	
80.80	56.00	80.00	