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FACTORS AFFECTING PUBERTY, ESTRUS AND OVULATION IN CORRIEDALE AND CRIOLLO SHEEP OF THE SOUTHERN PERUVIAN HIGHLANDS

by

Pedro Walter Bravo Matheus

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Animal Science
(Reproductive Physiology)

UTAH STATE UNIVERSITY
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Walter M. Bravo

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ABSTRACT

Factors Affecting Body Weight, Puberty, Estrus and Ovulation in Corriedale and Criollo Sheep of the Southern Peruvian Highlands

by

Pedro Walter Bravo Matheus, Master of Science
Utah State University, 1986

Major Professor: Dr. Warren C. Foote.
Department: Animal, Dairy and Veterinary Sciences.

This research was conducted at the La Raya experiment station, Cusco, Peru (4200 m elevation, 15°S latitude, and 70°W longitude) using 60 Corriedale, and 60 Criollo ewes during three consecutive years (April 1981 - March 1984). Age, and weight at puberty, age at physical maturity, and the effects of breed, age (physically immature and mature), year, and month were measured on body weight, incidence of estrus, and incidence and rate of ovulation. There was a significant difference ($P<.05$) among breed, year, and the interactions for body weight at puberty. The mean age at puberty for 1982-83 was 693.6 days (23.1 months) for Corriedale and 483.3 days (16.1 months) for Criollo. The mean liveweight at puberty was 27.2 kg for Corriedale, and 25.3 kg for Criollo. Corriedale ewe lambs weighed more than

Criollo, attained puberty seven months later than Criollo. At comparable age (15-17 months) at the Southern Peruvian Highlands 100 % of the Criollo reached puberty, compared to 58 % of the Corriedale. Body weight, incidence of estrus and ovulation were affected (P<.01) by breed, age, year, month, and their interactions. Physical maturity was attained at 39 and 36 months of age for Corriedale, and Criollo, respectively. Weight changes during the year were associated with feed availability. The mean overall incidence of estrus was 45.4 % for Corriedale (43.6 in physically immature, and 47.2 % in mature ewes), and 67.1 % for Criollo ewes (66.3, in physically immature, and 68.7 % in mature ewes). The mean overall incidence of ovulation was 39.6 % for Corriedale (39.7, in physically immature, and 39.5 % in mature ewes), and 58.5 % for Criollo ewes (59.4, in physically immature and 56.7 % in mature ewes). Both breeds demonstrated seasonality of estrus and ovulation with the Corriedale being shorter than the Criollo. The incidence of ovulation in both breeds was less than that of estrus. The ovulation rate was 1.00 for Corriedale, and 1.03 for Criollo (P>.05). Even though Criollo ewes weighed less than Corriedale, they attained puberty earlier, and showed less seasonality in estrus and ovulated throughout the year than the Corriedale.

(88 pages)

INTRODUCTION

Approximately 32.5 % of the total 13 million sheep in Peru are located in the Southern Peruvian Altiplano (Martinez, 1984). Of this number, most are raised above 3800 m elevation (Ministerio de Agricultura, 1976). There are two main breeds in that area; the Corriedale and the Criollo. The Corriedale was introduced to Peru importation from Argentina, Australia, Chile, New Zealand and Uruguay, and this breed is used to improve by crossbreeding the native Criollo sheep.

The Criollo breed is descended from the Churro and Merino brought to the New World during the 15th and 16th century by the Spanish colonizers (Flores, 1977). This breed represents almost 80 % of the total sheep population in Peru and is produced mainly by small communities under traditional systems of management such as communally owned lands. In contrast the Corriedale is kept primarily on large co-operative units under relatively improved husbandry.

Literature concerning many aspects of sheep reproduction in Peru is incomplete or non-existent. Reproduction sets the limit for production. Therefore, it is necessary to obtain additional information about the process of reproduction under the environmental conditions in the highlands of Peru as a basis for increased production.

Objectives

1.- To measure the influence of breed on age and weight at puberty (first estrus).

2.- To determine the influence of breed, age, year, and period of year on body weight, incidence of estrus and ovulation, and in on ovulation rate.

REVIEW OF LITERATURE

Puberty

A great deal of information is available about puberty in sheep, specially in the northern hemisphere. A mean age (36 weeks) and live body weight (35.9 kg) at puberty was reported by Hafez (1952) for various breeds, with a range of 29 to 43 weeks of age, and with an average of 23.6 to 51.3 kg of live body weight. The age at which ewes attain puberty (first estrus) is variable. It ranges from five months for D'man ewes (Lahlou-Kassi and Marie, 1981) to 14 months in Corriedale breed (Naranjo and Sabogal, 1978). However, both genetic (Land, 1978) and environment (Hafez, 1952; Robertson, 1977; Dyrmundsson, 1973, 1983) affect the attainment of puberty.

Among the genetic factors, should be considered the effect of breed in terms of purebreed, crossbreed or heterosis. Dickerson and Laster (1975), Hare and Bryant (1982), and Quirke et al (1985) strongly suggested that Finn crosses lambs reach puberty earlier (219 days) compared to Finn purebreed lambs (245 days). This is similar to the Rambouillet, Suffolk, Hampshire, Dorset, Targhee, Corriedale, and Galway. D'man sheep showed an extremely precocious puberty (150 days, Lahlou-Kassi and Marie 1981).

The Corriedale breed reached puberty at a younger age

(240 ± 15.8 days) in Nebraska (Dickerson and Laster, 1975) than those in Colombia at 2800 to 3300 m elevation, where only six out of 19 (31.58 %) females reached puberty at 13 to 14 months of age (Naranjo and Sabogal, 1978) .

Hulet, et al (1969), working with Rambouillet, Targhee and Columbia range lambs, reported that 11.5 % of the ewe lambs showed estrus during the first winter of their life. Southam, et al (1971) indicated that, Rambouillet, Targhee and Columbia breeds showed first estrus at 212 days (range 163 to 241). In other breeds the following ages have been reported; Galway (245 ± 4 days), Finnish Landrace (253 ± 3 days), Awassi (312 days), Somali (392 ± 47.8 days), Morada Nova (326 ± 55.6 days), Santa Ines (376 ± 53.4 days), and Suffolk (260 days); Quirke, (1978); Younis, et al (1978); Simplicio, et al (1981a, b), and Quirke et al (1985), respectively. However, the environmental conditions where the data have been obtained should be taken into consideration.

Data available for the Criollo breed in Peru is extremely rare. It has been shown that this breed reaches puberty at 518.2 days (17-18 months); however, Naranjo and Sabogal (1978) reported that 90 per cent of 11 Criollo sheep measured in Colombia showed first estrus while only 31.58 percent of 19 Corriedale sheep showed first estrus at 13-14 months of age.

The type of birth also affects the age at puberty.

Single born lambs reached puberty at a significantly younger age and heavier weight (273 days, 40.6 kg) than twin lambs (312 days, 37.4 kg), respectively (Younis, et al 1978).

Evidence exists that body weight has more influence on puberty than the age. Body weight is affected by level of nutrition. Suffolk ewe lambs which were supplemented in feeding attained puberty at a younger age (Keane 1976). Nutritional levels modulate the age at puberty. Accelerated feeding results in the animal reaching puberty at a younger age. On the other hand, if growth rate is reduced by underfeeding, puberty is delayed (Levasseur and Thibault 1980).

Southam, et al (1971) concluded that the combination of fall range and 0.8 kg of alfalfa pellets was adequate to provide the necessary growth to reach puberty during their first breeding season under conditions of Western United States. These authors working with Rambouillet, Targhee and Columbia breeds, reported a mean live body weight of 45.5 kg (range 31 to 62 kg). Dickerson and Laster (1975) found that, Finnish Landrace and its crosses reach puberty earlier (219 days) and at lighter weight (40 kg) than Rambouillet, Suffolk, Hampshire, Dorset, Targhee, Corriedale and coarse wool breeds (mean 45 kg). In the case of Corriedale they have reported that only 41.4 percent (29 out of 70) reached puberty with 43.5 $\pm$ 3.1 kg of body weight. Similar

results were found for Corriedale in Uruguay and Colombia. A total of 41.1 percent ewes attained puberty, weighing 27.8 to 28.9 kg in Uruguay (Ponzoni and Azzarini, 1968), and 31.6 percent of Corriedale ewes reached puberty at 13 to 14 months of age, and an average liveweight of 46 kg, in Colombia (Naranjo and Sabogal, 1978).

Keane (1976) concluded that, Suffolk ewes must be at least 33 kg liveweight at puberty. Younis, et al (1978) reported that, Awassi ewes fed a high plane of nutrition reached puberty 38 days earlier and 3.0 kg heavier than ewes fed with a moderate plane of nutrition (350 vs 312 days and 39.5 vs 36.5 kg). In Criollo type sheep in Colombia it has been demonstrated that at puberty females weighed 42.3 kg (Naranjo and Sabogal, 1978). Simplicio, et al (1981a, b) reported that Somali, Morada Nova and Santa Ines weighed 16.74 $\pm$ 2.25, 19.93 $\pm$ 3.4, and 25.52 $\pm$ 3.79 kg at puberty, respectively.

The year affects significantly the age at puberty. Hulet, et al (1969) working with Rambouillet, Targhee and Columbia range lambs for a period of nine years (1952 to 1962) found significantly different breed response for age at puberty under different years. The same results were reported by Foote, et al (1970); ewes which reached puberty in 1965 (249.4 days) were significantly ($P<0.05$) younger than 1966 (293.3 days).

It has been shown in sheep that the reproductive

activity is related to the daylength (photoperiod). In regions away from the equator the age at which puberty occurs is markedly affected by the time of year when the lambs were born. Lambs of early maturing breeds born in early spring (March-April) will cycle and conceive at six to eight months af age (Robertson 1977). The percent of lambs reaching puberty varies from 11.5 % (Hulet, et al 1969) to 57.1 % (Dufour 1975). Whereas those born in late spring (May-June) may not cycle until they are about 16 months old or the next breeding season. The age at puberty is delayed in lambs born in the fall. Dufour (1975) indicated that, 93.3 % of lambs which born in the fall showed estrus at 312.8 days.

Puberty is also affected by season of birth especially at higher latitudes (Dyrmundsson 1973), and is related to live body weight. The average liveweight at first estrus in ewe lambs expressed as the percentage of the adult weight, was found to be 63 in Scottish Blackface, 51 in Suffolk, 40 in Romney Marsh, 56 in Romanov (Dyrmundsson 1973), and 64 in Galway (Quirke, et al 1981). Dyrmundsson (1983) concluded that this measurement is not constant, and in many cases range from 50 to 70 %.

Ovulation usually occurs before first behavioral estrus. Foote, et al (1970) reported 88 % of the lambs examined through laparotomy at their first estrus had previously ovulated. Similar results were obtained by Simplicio,

et al (1981b) in tropical hair sheep.

In post puberal lambs a high incidence of ovulation without estrus was also reported (Dyrmundsson 1983). The differential activity of the ovaries at puberty was reported by Simplicio, et al (1981a, b, 1982). They reported that in Somali, Morada Nova and Santa Ines breeds combined the right ovary was significantly more active than the left (60 vs 40 %).

Signs of behavioral estrus in ewe lambs are usually weak and the intensity of estrus is less evident compared to yearlings or adult ewes (Dyrmundsson 1983). Ewe lambs in estrus usually make little or no attempt to approach the ram, but accept service when the male make sexual advances. The duration of estrus in lambs is shorter than in older ewes. Therefore ewe lambs should be kept apart at mating and a higher ram/ewe ratio should be used (Keane 1976).

The onset of puberty can be enhanced under the influence of the male. Lopez, et al (1984) reported that, in the Manchega breed, when a male was introduced for five days each month to a group of females five months old, the age at puberty was 32 days earlier in those ewe lambs born in spring than those born in autumm (257 vs 289 days). Likewise in D'man ewes, teaser ram introduction twice a day on a group of 23 D'man ewes resulted in puberty begining at three months. The mean age at puberty in this particular case was 219 $\pm$ 14 days (Lahlou-Kassi and Marie, 1985).

Incidence of estrus and ovulation

A large amount of information is published on this subject. They have been mainly carried out primarily in the northern hemisphere and do not deal with the Corriedale and Criollo breeds. It has been pointed out that the occurrence of estrus is inversely related to the length of daylight. In locations neighboring the equator the seasonal fluctuation of photoperiod is minimal or non existent, the sheep seasonal sexual activity is also conditioned by other environmental factors such as temperature and humidity, and/or the availability of food for an adequate level of nutrition (Hafez 1952; Robertson 1977).

There are breed differences in the length of breeding season and in the incidence of estrus (Hafez 1952; Wheeler and Land 1977). Some breeds can show a marked seasonality (De Lucas, et al 1984), and others can show estrous periods throughout the year (Hafez 1952; Robertson 1977; Ward 1980; and De Lucas, et al 1984). In general the maximum sexual activity occurs in the autumm and early winter irrespective of the hemisphere (Hafez 1952; Robertson 1977). Prealpes and Merino breeds are long-season breeders, whereas Blackface and Southdown are short-season breeders (Levasseur and Thibault 1980). A long sexual season activity in sheep is a genetically dominant character and all Merino crosses exhibit extended sexual season (Hafez 1952, Levasseur and

Thibault 1980).

In Peru the first reports dealing with the incidence of estrus was determined in Junin breed by Varela (1958). He has shown that during the first two weeks of the onset of the breeding season there was at least seven percent of the ewes showing estrus. Also, in the southern Peru, Paez (1963) surveyed 16 farms "haciendas". He reported a mating period of 40-80 days from April to July, and only two farms had their breeding period from August to September. Wheeler (1973) working with Finnish Landrace, Scottish Blackface and Tasmanian Merino in the United Kingdom showed that the incidence of estrus and ovulation for the Blackface was the shortest (mean 146 days) followed by the Merino (159 days) and the Finn sheep (199 days). A later report also showed that the duration of the breeding season was significantly different for each breed. The variation in the incidence of ovulation was similar to that in the incidence of estrus (Wheeler and Land, 1977).

Naranjo and Sabogal (1978) working in Colombia with Romney Marsh adult ewes at 2800 to 3300 m elevation have determined that 93.3 percent (401/430) of ewes showed estrus throughout the year. The higher incidence of estrus in Dorset breed was observed in Mexico from October to February, decreasing in March to 41 % and in April to 29 %. In contrast the Criollo ewes have shown estrus regularly throughout these months (Valencia, et al 1978). De Lucas,

et al (1984) in Mexico found a marked reproductive seasonality in Corriedale, Suffolk and Romney adult sheep; while estrus in Rambouillet and Criollo was observed throughout the year. They have indicated that at least 50 percent of the Criollo ewes show estrus throughout the year, whereas the Corriedale only 60 per cent from July to December. Igono, et al (1982) in Yankasa sheep reported that, this breed show a higher incidence of estrus during the hot-dry season, than during the wet "harmattan" season.

The breeding season in domestic breeds in latitudes away from the equatorial line apparently coincides with the breeding season of their wild ancestors (Hafez, 1952). The mid breeding season (date between the first and last estrus observed during the breeding season) always occurs before the shortest day. The latitude, temperature, humidity and possibly the elevation have an influence on the duration of the breeding season. It has been reported that at high latitudes the onset of the breeding season is later and its duration is shorter than at lower latitudes (Hafez 1952, Hulet, et al 1974).

The daylight/dark ratio (photoperiod) and temperature are the two main environmental factors influencing the animal sexual cycles (Levasseur and Thibault 1980), the former is of greatest influence. The non-fluctuating light rhythm had an adverse effect on the reproductive potential. Border Leicester ewes have been shown to be dependent on a fluc-

tuating light rhythm for normal reproductive function (Williams and Thwaites, 1974). A significant advancement on the onset of estrous periods was observed in Welsh Mountain, Border Leicester, North Country Cheviot, and Scottish Blackface sheep under simulation of an equatorial daylength (Williams and Thwaites, 1974), and resulted in a rephased and shorter breeding season in contrast to natural daylength at 51 43' North latitude. The advancement varied according the breed and it was greater in Welsh Mountain (62 days) and Border Leicester (42 days). There was no significant difference between North Country Cheviot (30 days) and Scottish Blackface (28 days). Madani and Williams (1983) defined three geographycal zones: 0° to 30° latitude, little or no apparent seasonal change; 30° to 60° latitude, regular seasonal change of varying amplitude and a daily occurrence of alternating daylight and darkness, and 60° to the Pole, continuous daylight exists during the summer and during the winter the sun does not rise above the horizon.

The effect of two geographycal locations in US (McGregor, Texas and Dubois, Idaho) on the sexual activity of Rambouillet was reported by Hulet, et al (1974). They concluded that the most striking effect was the difference in breeding season between locations, Texas and Idaho. Ewes located in Texas tended to show less marked seasonality in the occurrence of estrus than the ewes located in Idaho. Northwestern ewes did not show estrus during April through

August while Texas ewes did. Aboul-Naga, et al (1984) have determined that the small change of less than one hour daylength during September in Egypt was enough to bring all ewes in estrus by October.

The time of onset of the breeding season varies from year to year (Hulet, et al 1974, Ward 1980). Rambouillet breed showed less marked seasonality during the first year of study in Texas than the second year, and the difference was 20 % less during the first year (1969-70) than the second year (1970-71).

There is a significant relationship between estrus and ovulation (Irazqui and Menvielle 1982). In Argentina, a high proportion of ewes demostrating estrus and ovulation was observed in April to August (0.69 to 1.00), and lower in September to January (0.00 to 0.44).

Hafez (1952) reported that there were significant differences in the number of estrous periods per ewe per season for yearlings compared to adults.

Ovulation rate

The majority of domesticated breeds of sheep have ovulation rates between one and two (Scaramuzzi and Radford 1983). However, there are breeds in which the ovulation rate reaches or might be over three (Booroola Merino, Australia; D'man, Morocco; Finnish Landrace, Finland; Hu Yang, China; and Romanov, Russia) with an ovulation rate of

2.68, 2.50, 3.31, 3.11, and 2.86, respectively. Cardozo and Foote (1968) have determined the ovulation rate of 1.00 in Corriedale and 1.15 in Criollo breed; however, during the winter Criollo ewes produced more corpora lutea than the Corriedale.

The ovulation rate for Scottish Blackface, Tasmanian Merino and Finnish Landrace adult ewes was 1.26 to 1.3, 1.07 to 1.08, and 2.94 to 2.99, respectively (Wheeler 1973; Wheeler and Land 1977). The ovulation rate of Rambouillet ewes in McGregor, Texas and Dubois, Idaho was 1.42 and 1.70 (Hulet, et al 1974). Bindon, et al (1979) have shown a significant breed difference in the mean ovulation rate among Romanov, Prealpes, Romanov x Prealpes, and Ile-de-France (2.86, 1.75, 2.33, and 1.5, respectively). The ovulation rate in Corriedale was higher in April through July (1.56, 1.25, 1.5 and 1.06, respectively), compared to lower values during August through February (0.80, 0.25, 0, 0, 0.19, and 0.63, respectively; Irazqui and Menvielle (1982). Novoa (1985) reported no statistical differences in ovulation rate among St. Croix (2.06) and Rambouillet ewes (1.93). However, the ovulation rate was not significantly different among ewes lambing singles or twins. The ovulation rate in adult D'man ewes was 2.85 $\pm$ 0.22 (Lahlou-Kassi and Marie 1985).

Body live weight might be used as a predictor of ovulation rate (Cumming, 1977). Bradford, et al (1971)

studying the natural ovulation rate in adult ewes found breed differences and close positive association among body weight and ovulation rate being Welsh Mountain (1.43), Border Leicester (2.00), and Finnish Landrace (3.31), with corresponding body weights of 32.6, 75.2, and 51.1 kg, respectively.

The ovulation rate varies in regard to age and parity of the ewe (Kelly, et al 1976; Restall, et al 1976; Murray 1978; Lahlou-Kassi and Marie 1981, 1985; Scaramuzzi and Radford 1983; Meyer 1985; and Montgomery, et al 1985). In New Zealand, the ovulation rate in ewes 1.5 and 4.5 years of age was 1.03 and 1.11, 1.07 and 1.34, and 1.13 and 1.14 for Romney, Coopworth and Perendale, respectively (Kelly, et al 1976). In fine wool Merino, the ovulation rate for adult ewes was 1.73 compared to 1.2 and 1.27 in maiden ewes of 1.5 years of age when the weights were 40 and 35 kg for adult and maiden ewes, respectively (Restall, et al 1976).

The ovulation rate in D'man ewes was 2.78 $\pm$ 0.86 for multiparous ewes, and 2.33 $\pm$ 0.5 for nulliparous ewes (Lahlou-Kassi and Marie 1981). There were a great heterogeneity among females, ranging from one to six corpora lutea. However, twin ovulations were predominant. Montgomery, et al (1985) concluded that, ovulation rate was enhanced during breeding season in 1.5 and 3.5 years of age from 2.43 to 3.07. Ewes 3.5 and 5.5 years of age did not show a significant difference in ovulation rate. The age of ewes was

found to have significant effect on ovulation rate. Ewes 3.5 and 2.5 years old had 20 % and 14 % higher ovulation rate than 1.5 years old ewes (Meyer 1985). This trend was obtained in all breeds observed (Romney, Oxford, Finn, German Merino, Border Leicester, Cheviot, Dorset, and Booroola).

The nutrition of the ewe is one of the factors which strongly affects ovulation rate (Gunn and Doney 1975; Cumming 1977; Haresign 1981; Gunn 1983; Montgomery, et al 1985). Gunn and Doney (1975) determined the interaction of nutrition and body condition with ovulation rate in Scottish Blackface mature ewes. These authors concluded that, ovulation rate was positively related to body condition at mating but not to the level of pre-mating food intake. Ewes with 57.5 kg showed 1.93 ovulation rate compared to 1.00 in ewes weighing 39.3 kg. Furthermore, lighter ewes returned to service more than ewes in good condition. Evidence was established by Cumming (1977), indicating that there was an increase of 0 to 0.44 in mean ovulation rate per ewe for every 10 kg increase in body weight, and the body weight as well as the body condition can be used to predict the ovulation rate.

The flushing effect on ovulation rate was studied by Haresign (1981). Flushed ewes have a significantly higher ovulation rate (2.6) than non-flushed ewes (1.8). Gunn (1983) suggested that reproductive performance of the ewe

measured in terms of their ovulation rate, and the performance from fetal stage until she attains maturity can be influenced by nutrition, suggesting the existence of long-term energy effects.

Davis, et al (1976) reported that, ovulation rate may also be related to the stocking rate. A total of 540 five year old Australian Corriedale ewes stocked at five ewes/ha had a higher ovulation rate than those at 7.5 and 10 ewes/ha. These results confirmed previous reports where the ovulation rate was higher for well nourished heavier ewes than for lighter ewes.

The ovulation rate is higher in late summer and fall, and declines progressively during the late fall (Kelly, et al 1976; Davis, et al 1976; Robertson 1977; Scaramuzzi and Radford 1983; Montgomery, et al 1985). Nevertheless there are breeds with a potential to ovulate throughout the year (Murray 1978, Lahlou-Kassi and Marie 1985).

In Australia ewes joined in April had higher ovulation rate (1.7) than ewes joined in February (1.49) Davis, et al (1976). Merino ewes located in a semi-arid tropical area have shown a different proportion of ewes ovulating in relation to time. However, this proportion did not fall below 0.78 indicating that a large proportion of the ewes were cycling and ovulating at any time of the year (Murray, 1978). Similar performance of D'man ewes was found in Morocco by Lahlou-Kassi and Marie (1985). Fifty percent of

ewes (2.5 - 3.5 years of age) were found to cycle from May to September, and from December to February. The ovulation rate was higher during May to July (2.87 $\pm$ 0.4) and lower during February to April (2.28 $\pm$ 0.4).

Stress factors such as fasting, cold, premating stress may also affect the ovulation rate (Doney, et al 1973; MacKenzie, et al 1975; Rhind, et al 1984). It has been demostrated that Scottish Blackface ewes maintained in a stressful condition (heavy rainfall simulated by an overhead spray out doors) for a full estrous cycle before mating had a lower ovulation rate than similar ewes maintained in non-stressful environment. On the other hand MacKenzie, et al (1975) found that, fasting or shearing had no apparent effect on ovulation rate. However, a significant supression of behavioral estrus was observed in both conditions. Stress caused by a harassing with a dog, soaking in a spray dipper did not affect significantly the ovulation rate in ewes of high body condition (56.2 kg), but in ewes of low body condition (48.6 kg) the ovulation rate was less (1.40 vs 1.10).

SUMMARY

The age at which ewes attain puberty (first estrus) is variable. It ranges from five months (D'man ewes) to 14 months in Corriedale breed. Several genetic and environmental factors affect the attainment of puberty.

Genetic have a significant effect on age at puberty. The Corriedale breed in Nebraska, USA, reaches puberty at eight months age, and only 31.58 % of the females reached puberty at 13-14 months in Colombia, South America. Rambouillet, Targhee, and Columbia range lambs show puberal estrus in the winter of their first year of life (212 days). However, the Finnish Landrace attained puberty at seven months of age.

Data available for the Criollo breed in any country in South America is extremely rare, it was reported that this breed reaches puberty at 518.2 days. However, 90 % and 31.58 % of Criollo and Corriedale lambs, respectively showed puberal estrus at a comparable same age.

Single born lambs reached puberty at a significantly younger age and heavier weight (273 days, 40.6 kg) than twin lambs (312 days, 37.4 kg). Evidence also exists that the age is less important than body weight which is a function of nutrition. Combination of fall range and 0.8 kg of alfalfa pellet per day was adequate to provide the necessary growth to reach puberty during the first breeding sea-

son. Suffolk ewe lambs must weigh at least 33 kg at puberty. Ewes on a high plane of nutrition reached puberty 38 days earlier than ewes fed a moderate plane of nutrition.

The age at puberty is also markedly affected by the season of year (photoperiod) when lambs were born. Lambs born in early spring will cycle and conceive at 6-8 months of age, whereas those born in late spring and fall will usually not attain puberty until the following breeding season (16 months old).

The average liveweight at first estrus in ewe lambs expressed as the precentage of the adult weight range from 50 to 70 %. Ovulation unaccompanied by behavioral estrus occurs in a high proportion of ewe lambs prior to puberal estrus. The expression of estrus in ewe lambs is usually weaker, shorter and more variable than yearlings or adult ewes.

The onset of puberty can be hastened by the influence of the male. Manchega ewe lambs (Spain) exposed to males reached puberty about 32 days earlier than lambs without the presence of the male.

The occurrence of estrus is inversely related to the length of daylight. In locations with constant photoperiod (near the equator) the seasonal sexual activity is conditioned by climate (temperature, humidity), and/ or level of nutrition.

There are breed differences in the length of breeding

season and in the incidence of estrus. Some breeds show a marked sexual activity within the breeding season and others throughout the year. In general the maximum sexual activity occurs in the autumm and early winter irrespective of the hemisphere.

In the United Kingdom, Blackface ewes show the shortest breeding season (146 days) followed by the Merino (159 days) and finally the Finnish Landrace breed (199 days).

In Colombia, Romney Marsh ewes did not show a seasonality and 93.26 percent of the ewes showed estrus throughout the year. In Mexico, the higher incidence of estrus in Dorset sheep was observed from October to February, decreasing in March to 41 % and in April to 29 %. In contrast Criollo sheep showed estrus regularly throughout the year.

The breeding season in domestic breeds in latitudes away from the equator apparently coincides with the breeding season of their wild ancestors. Is is quite apparent that at high latitudes the onset of the breeding season is later and its duration is shorter than at lower latitudes.

Rambouillet ewes kept in two different locations (McGregor, Texas and Dubois, Idaho) showed different pattern of incidence of estrus. Ewes located in Texas tended to show less marked seasonality than ewes in Idaho. The time of onset of the breeding season varies from year to year. Ewes showed less marked seasonality during the first year of study in Texas than the second year.

There is a significant relationship between estrus and ovulation. In Argentina a high proportion of ewes demonstrated estrus and ovulation in April to August, and lower in September to January.

Reports on body weight in Criollo sheep are extremely rare. In Bolivia the liveweight varied from 28.5 lb for 0.5 years, 33.87 for 1.5 years, 34.2 for 2.5 years, and 36-42.6 lb for 3.5 years old.

The majority of domesticated breeds of sheep have ovulation rates between one and two. However, there are breeds in which the ovulation rate exceeds three (Booroola Merino, D'man, Finnish Landrace, Hu Yang, and Romanov) with a mean ovulation rate of 2.68, 2.50, 3.31, 3.11, and 2.86, respectively.

The ovulation rate in Corriedale and Criollo sheep in Bolivia was reported as 1.00 and 1.15, respectively; however, Criollo ewes produced more corpora lutea than the Corriedale during the winter and summer.

In general, the ovulation rate varies according to location, breed, management, age and parity of the animals, under the conditions where the data were obtained, for instance, for Scottish Blackface, Tasmanian Merino and Finnish Landrace was 1.26 to 1.3, 1.07 to 1.08, and 2.94 to 2.99, respectively. In Rambouillet ewes it was 1.42 to 1.70 in Texas and Idaho, respectively.

There are significant breed differences in ovulation rate among Romanov, Prealpes, and Ile-de-France (2.86, 1.76, and 1.5, respectively).

In Argentina, the ovulation rate of Corriedale sheep was high in April through July (1.56 to 1.06) compared to lower values during August through February (0.80 and 0.00).

Ovulation rate was not different among ewes lambing singles or twins in St. Croix and Rambouillet ewes (2.06 and 1.93, respectively) measured in Utah, USA.

Body liveweight might be used as predictor of ovulation rate. In adult ewes the natural ovulation rate was in close positive association for Welsh Mountain, Border Leicester, and Finnish Landrace; the ovulation rate and body weight were 1.43, 32.6 kg; 2.00, 75.2; and 3.31, 51.1 kg, respectively.

Ovulation rate varies in regard to age and parity of the ewe. For ewes of 1.5 and 4.5 years of age the corresponding ovulation rate was 1.03 and 1.11, 1.07 and 1.34, and 1.13 and 1.14 for Romney, Coopworth, and Perendale, respectively.

The ovulation rate in D'man ewes was 2.78 $\pm$ 0.86 for multiparous ewes and 2.33 $\pm$ 0.5 for nulliparous ewes. In younger ewes the ovulation was 2.43 in contrast to 3.07 for 3.5 years old ewes. Nevertheless, ewes from 3.5 to 5.5 years did not show significant difference in ovulation

rate.

The nutrition of the ewe is one of the factors which strongly affects ovulation rate. Ewes with 57.5 kg showed ovulation rate of 1.93 compared to 39.3 kg and 1.00 ovulation rate.

Flushed ewes had a significantly higher ovulation rate (2.6) than non-flushed ewes (1.8).

Ovulation rate may also be related to the stocking rate. Ewes stocked at five ewes/ha had a higher ovulation rate than those at 7.5 and 10 ewes/ha.

The ovulation rate is higher in late summer and fall, and declines progressively during the late fall. Ewes joined in April had a higher ovulation rate (1.7) than ewes joined in February (1.49). However, Merino ewes are capable of ovulating throughout the year, and the incidence did not fall below 0.78 in Australia in a semi-arid tropical condition, the same trend was found in D'man ewes.

Stress factors such as fasting, cold, and premating stress may also affect ovulation rate. Scottish Blackface ewes maintained in a simulated heavy rainfall had a lower ovulation rate than ewes maintained in non-stressful condition. Fasting or shearing had no apparent effect on ovulation rate. However, a significant supression of behavioural estrus was observed. Stress caused by harassing with a dog or soaking in a spray dipper did not affect significantly the ovulation rate.

MATERIALS AND METHODS

Duration, location and climate

This study was carried out over a three year period (April 1981 - March 1984) at the La Raya Experiment Station, Cusco, Peru (4200 m elevation, 15°S latitude and 70° W longitude). The average annual rainfall during the four year period from January 1981 to December 1984 was 799.3 mm, and was mainly concentrated from December to March. There was no rainfall during June, July and August.

The temperature varied from a minimum of -6.6°C at night to a maximum of 15.8°C during the day. The annual average temperature was 6.4°C.

Management of the animals

The animals were maintained and grazed entirely on native pasture and did not receive any nutritional supplement. They were allowed to graze from 7 a.m. to 5 p.m. during the day, and were kept in a portable pen during the nights. This pen was moved whenever it was considered necessary specially in the rainy season. Drenching for internal parasites was done twice a year, before and after the rainy season. Shearing was performed every year the first week of March. The nutritional value of the range forages on the Southern Altiplano is usually adequate during and shortly after the rainy season, but the quality of

the forage decreases during the dry season (Tapia, 1984).

Experimental animals

Two breeds of sheep, the Corriedale and Criollo were used. The Corriedale breed is a medium wool type sheep (54's - 58's Bradford scale) with adult live body weight of 30-35 kg for ewes, and 45-50 kg for adult rams. The Criollo breed is smaller in size with a mean body weight of 25 - 30 kg for adult ewe, and 40-45 kg for adult rams. The wool is coarse (common), ununiform, and sometimes multicolored. Fleece and carcass weight average 1-1.5 kg, and 12-15 kg, respectively.

The Corriedale sheep were obtained from two co-operatives (Picotani and Marangani). Criollo sheep were obtained primarily from community flocks around the La Raya Experiment Station and a small proportion from the Rio Grande co-operative.

The data dealing with puberty (objective 1) were collected from 82 ewe lambs (37 Corriedale and 45 Criollo, Table 1). During the second year of the study three Corriedale ewe lambs died before they attained puberty, and during the third year seven Corriedale ewe lambs did not reach puberty by the end of the study. These ewes were eliminated from the study to facilitate statistical analysis which results in a younger and less variable age at puberty for the Corriedale than actually existed.

The number of ewes by breed, age and years is shown in Table 1. Fifteen ewes were assigned to each breed, age and year to provide data on body weight, incidence of estrus, and incidence and rate of ovulation throughout the year. However, during the second year a 1.5 year old Corriedale ewe died and was not replaced. Also during the third year of the study two 1.5 year old Criollo ewes died and were not replaced. No losses were observed during the first year of observation (1981-82).

Table 1. Number of experimental ewes by breed, year and age.

	Corriedale Age[1]					Criollo Age[1]					
Years	0.5	1.5	2.5	3.5	Sub-total	0.5	1.5	2.5	3.5	Sub-total	Total.
1981-82	15	15	15	15	60	15	15	15	15	60	120
1982-83	12	14	15	15	56	15	15	15	15	60	116
1983-84	10	15	15	15	55	15	13	15	15	58	113
Total	37	44	45	45	171	45	43	45	45	178	349

[1]Estimated age at the begining of the year, and based on the presence of permanent incisor teeth.

Estimation of age

Age at puberty was determined only during the second year because the lambs were born in the experiment station and date of birth was available. Lambs for the first and

third year were purchased from producers and their exact birthdates were not known, but were assumed to be midway during lambing season, October 1st to November 15th, or October 23rd.

For the second objective, the ages of the ewes were determined by the number of permanent incisor teeth; 2, 4 and 6 teeth for 1.5, 2.5, and 3.5 year olds, respectively. At the beginning of the second, and third years of study the oldest group of ewes were discarded and 1.5 year old ewes added and the 1.5 and 2.5 year old animals of the previous year were advanced to 2.5 and 3.5 year old groups for the following year of the experiment. It was necessary to retain these groups because of financial restrictions and lack of availability of animals. Such a procedure confounded the between and within ewe variability within subgroups and may influence the error term. Tests for heterogeneity of variance were made as appropriate.

Measurements obtained

Puberty. Ewe lambs were continuously exposed to vasectomized rams with painted brisket. The occurrence of estrus was checked each morning. A ewe lamb was considered puberal when she showed her first standing estrus. The date and live body weight of the ewe lambs were recorded to estimate the age and body weight at puberal estrus. The age at puberty was accurate only from lambs of the second year

because of known lambing date. Body weight at puberty was determined and analyzed during each of the three years. Laparoscopy was performed 5-6 days post puberal estrus detection to establish the occurrence and rate of ovulation.

Incidence of estrus (Ewes showing estrus/total ewes observed).- Ewes in estrus were recorded daily at 6 a.m. with the use of painted vasectomized rams. A ewe was considered in estrus when her rump was painted and the mating behavior was positively established by additional teaser rams. Three teams of six vasectomized rams each were provided. The rams were rotated at two week intervals. Three colors red, green and blue were used for consecutive two week periods. During the second year five teaser rams were replaced by new younger vasectomized rams.

Incidence of ovulation (Number of females ovulating/ females observed).- One third of each sub-group were examined each month with all ewes being laparoscopied once every three months.

The ovulation rate (Number of corpora lutea/ ewes ovulating).- Rate of ovulation was determined once each month on the ewes assigned for determining the incidence of ovulation. The schedule of laparoscopies appears in Table 2.

Laparoscopies were performed after ewes were fasted for 16-24 hs. The area anterior to the udder was clipped,

scrubbed and a sterilizing agent applied. The telescope and the forceps to locate the ovary were introduced through canulae. The occurrence of ovulation and number of corpora lutea were recorded for each ovary.

Table 2. Laparoscopy schedule by months.

		Corriedale Age			Criollo Age			
Quarters	Months	1.5	2.5	3.5	1.5	2.5	3.5	Total
1	April	5[1]	5	5	5	5	5	30
	May	5	5	5	5	5	5	30
	June	5	5	5	5	5	5	30
2	July	5	5	5	5	5	5	30
	August	5	5	5	5	5	5	30
	September	5	5	5	5	5	5	30
3	October	5	5	5	5	5	5	30
	November	5	5	5	5	5	5	30
	December	5	5	5	5	5	5	30
4	January	5	5	5	5	5	5	30
	February	5	5	5	5	5	5	30
	March	5	5	5	5	5	5	30
Total		60	60	60	60	60	60	360

[1]The number of ewes laparoscopied each month for each group and breed. Each ewe was observed once each three month period.

Live body weight.- Monthly body weight was recorded to the nearest 0.5 kg for all ewes. The ewes were not fasted before weighing. A predicted growth curve using a quadratic model ($\hat{y} = a + bx_1 + bx_1^2$) was calculated for each breed using the oberved values from 0.5 to 4.5 years of age combining years. The age at puberty was determined from the

observed data the second year. Age at physical maturity was considered to occur when the maximal weight was obtained on the predicted curve. The ewes were then categorized for analysis as physically immature (from puberty to physical maturity) and physically mature (physical maturity to 4.5 years of age).

Statistical analysis

The "t" test with unequal number of observations and unequal variances was used to analyze the age at puberty among breeds. Body weigth at puberty and all variables of response for the second objective (body weight, incidence of estrus and incidence and rate of ovulation) were analysed using least square analysis of variance with unequal number of observations (Rummage II; Scott, et al 1983).

Data dealing with puberty were analysed using the following experimental model:

$$Y_{ij} = u + B_i + C_j + B_iC_j + E$$

where: u = overall mean

Y_{ij} = body weight at puberty.

B_i = breed effect,

C_j = year effect,

E = the overall error term for the model.

Some analyses were made to investigate differences between the groups of animals with no significant differen-

ces detected. The data for incidence of estrus, incidence of ovulation and ovulation rate were analysed as a completely randomized 2x2x3x12 factorial experiment. The main effects were breed (2), age group (2), years (3), and month (12). Because separate groups of animals were used for each month within the three month period for incidence and rate of ovulation between and within ewe variation was confounded for subgroups. For purposes of analysis these two sources of variation were assumed to be the same. The model used for each response was:

$$Y_{ijkl} = u + B_i + A_j + C_k + M_l + B_iA_j + B_iC_k + A_jC_k + B_iA_jC_k + B_iM_l + A_jM_l + C_kM_l + B_iA_jM_l + A_jC_kM_l + B_iC_kM_l + B_iA_jC_kM_l + E$$

where: u = overall mean

B_i = breed effect,

A_j = age effect,

C_k = year effect,

M_l = month effect,

E = the overall error for the model.

MS (mean square) and SEM (standard error of the mean) were rounded to two decimal points, and the mean values ($\bar{x}$) were rounded to one decimal point. The Least Significant Difference (LSD) analysis was applied to determine differences among means within main effects or interactions.

RESULTS AND DISCUSSION

Puberty

Data were available for age at puberty during the second year (1982-83) of the study only. The Corriedale breed attained puberty at a significantly (P<.01) older age (693.6 ± 24.5 days, 23.1 months) than the Criollo (483.3 ± 21.9 days, 16.1 months).

The least square analysis of variance for live body weight is presented in Table 3, and the corresponding means by years, breeds and their interactions are presented in Table 4. The Corriedale breed was significantly (P<.05) heavier (27.2 kg) than the Criollo (25.3 kg). The heavier weight in Corriedale was due to larger mature size and/or older age at which puberal estrus was observed.

Table 3. ANOVA for body weight at puberty

Source	df	MS	F
Breed	1	67.02	11.22**
Year	2	138.72	23.22**
Breed-year	2	82.84	13.86**
Error	76	5.97	

**(P<.01)

A negative relationship is often reported in the lite-

rature between live body weight and age at puberty (Dyrmundsson 1973, 1983; Dickerson and Laster 1975). However this usually occurs among animals within a comparable mature size where faster growing, heavier ewe lambs reach puberty at a younger age.

Table 4. Least square means ± s.e.m. for bodyweight at puberty (kg)[1]

Years	n	Corriedale	n	Criollo	n	Years
81-82	15	30.4± .63[d]	15	25.2± .63[ab]	30	27.8± .45[a]
82-83	12	28.4± .71[c]	15	26.3± .63[b]	27	27.3± .47[a]
83-84	10	22.7± .77[a]	15	24.5± .63[a]	25	23.6± .50[b]
Breeds	37	27.2± .41[b]	45	25.3± .37[a]	82	26.4±3.45

[1]$P<.05$ for means with different superscript letters among breeds, years and breed-year.

Five (42 %) of the Corriedale ewe lambs used in this study reached puberty at ages greater than 18 months which is the oldest age when ewes are first placed in breeding in Peru. Consequently only 58 % of the Corriedale breed attained puberty at the age when first exposed for breeding compared to 100 % of the Criollo breed.

The difference between the Corriedale and Criollo is primarily genetic. Such differences among breeds are common (Hafez, 1952; Dyrmundsson 1973, 1983; Dickerson and Laster,

1975, and Naranjo and Sabogal, 1978). However, the older age at puberty and the delay of some Corriedale ewes to attain puberty may have been influenced by a counfounding effect of seasonal anoestrus.

Body weights at puberty during the first and second year were significantly heavier ($P<.05$) from the weights of ewes during the third year. These differences seem to be influenced by five Corriedale ewe lambs which did not attain puberty by the completion of the experiment (March 31, 1984), and were not included in the analysis.

A positive correlation between age and body weight at puberty was calculated, for Corriedale ($r=0.64$) and for Criollo ($r=0.19$) during the one year when data for which age at puberty were available, and the difference between the indices of correlation was significant ($P<.05$). These values are not as high as those reported elsewhere, especially for the Criollo (Dyrmundsson 1973, 1983).

The body weight at puberty was 78.3 and 79.6 % for Corriedale and Criollo, respectively of the adult weight of ewes in this experiment. These proportions are higher than those reported by Dyrmundsson (1973); Quirke, et al (1981), and Dyrmundsson (1983), presumably because the ewe lambs in this report reached puberty at an older age. A major factor in this case is likely to be the low level of nutrition and related environmental conditions existing in the highlands of Peru.

Body weight

Data provide measures of body weight response by breed for ages, years and periods within years. Estimates were made for growth curves to puberty, from puberty to physical maturity, and during physical maturity. Information is also provided on monthly variations throughout the year and among years as a reflection primarily of the climatic and nutritional environment, and the interactions of breed, age, years and months. These body weights were used for the purpose of reporting and interpreting reproductive performance relating to estrus and ovulation. They also represent the first published data on growth, mature body weight, and seasonal and annual variations for these breeds in the Andean Highlands.

Significant ($P<.05$) differences in weight occurred among the main effects of breed, age, years, months and some of their interactions (Tables 5 and 6, Figures 1 and 2). The Corriedale breed attained a mature body weight at approximately 39 months and Criollo ewes at approximately 36 months. This difference was significant ($P<.05$). One major (July) and minor (February) peak in body weight occurred each year. These waves or fluctuations are related to climate and resulting feed availability.

The breeds were similar in body weight ($P>.05$) at 0.5 years of age (Criollo 19.0 and Corriedale 17.1 kg) when the

study was initiated. However, the growth curve of the Corriedale was steeper resulting in a significantly heavier body weight at maturity (35.0 kg vs 31.8 kg for the Corriedale and Criollo). The breed difference in body weight was maintained ($P<.05$) to 48 months of age. This differential growth between breeds is reponsible for many of the interactions measured.

Reproductive performance was analyzed in terms of weight and age at puberty (first estrus); the incidence of estrus, and incidence and rate of ovulation during the period from puberty to physical maturity; and the same variables in the physically mature animals. Reproductive performance is also interpreted in terms of monthly and semiannual (combined over years) body weight changes. Photoperiod is also considered in interpretation although it varied only approximately two hour annually because of the close proximity to the equator.

Incidence of estrus and ovulation, and ovulation rate

Reproductive performance in terms of incidence of estrus, and incidence and rate of ovulation are presented in Tables 5,7,8,9,10 and 11. Breed, age, year and months showed statistically significant differences ($P<.01$) for incidence of estrus and incidence of ovulation, but not for ovulation rate. Most of the two-way interactions for incidence of estrus were significant ($P<.05$), but not for

incidence and rate of ovulation (P>.05).

The overall incidence of estrus, incidence and rate of ovulation was 58.36 ± 4.99 %, 50.88 ± 4.98 %, and 1.01 ± 0.13, respectively (Fig. 3 and 4).

From puberty to physical maturity (physically immature), the mean incidence of estrus for the Criollo (measured as 1.5 to 3.5 years of age) and Corriedale (measured as 2.5 years to 3.5 years of age) was 67.1, and 45.4 % (P<.05), respectively (Fig. 5). The incidence of ovulation was 58.5, and 39.6 % (P<.05), for Criollo and Corriedale, respectively during the same period (Fig. 6). There was no significant difference (P>.05) between the ovulation rate for the two breeds (Corriedale 1.00, and Criollo 1.03).

The incidence of estrus during the period of physical immaturity for Corriedale ewes (Fig. 5) was higher from March (93.2 %) through July (60.0 %; five months) and lower from September (15.7 %) through January (8.9 %; five months). August and February were transitional months. The Criollo breed demonstrated the same annual changes during the year but with a higher incidence during a long period. The higher incidences occurred for eight months, from February (72.3 %) through September (62.9 %), and the lower values for only two months (November and December, 38.4 and 38.0 %). January and October were transitional months. The incidence of estrus during the lower months was higher for the Criollo than the Corriedale (P<.05).

Seasonal changes also occurred in the incidence of ovulation in both breed and were greatest in the Corriedale. The incidence of ovulation in physically immature Corriedale ewes (Fig. 6) averaged 39.7 % for the twelve months of the year. The higher values were observed from May (73.3 %) through August (86.7 %), and lower values from November (13.3 %) through March (6.7 %). In this case the transitional months from low to high were April (56.7 %), and the transition from high to low September and October (41.7, and 41.1 %). In the Criollo the months with the higher incidence of ovulation were May (81.2 %) through November (66.7 %). The months with lower incidence of ovulation were December (37.6 %) through March (40.0 %). April was considered a transitional month (53.3 %). The difference between Corriedale and Criollo in the number of months with a higher level of incidence of ovulation was significant (4 vs 8 months; $P<.05$).

In the physically mature ewes the mean annual incidence of estrus for Corriedale and Criollo (Fig. 8) was 47.2 and 68.7 % ($P<.05$), respectively. A significant ($P<.05$) difference occurred among months for the two breeds. Corriedale mature ewes showed a marked seasonality with higher values occurring during the six month period from March (91.1 %) through August (53.3 %). The months with lower values were November (8.9 %) through January (8.9 %). The transitional months from low to high was February (33.3 %), and from

high to low, September (26.7 %) and October (20.0 %).

Physically mature Criollo ewes showed higher estrus activity from February (71.1 %) through October (60.0 %), which represents nine months of estrus activity in contrast to six months in the Corriedale. The highest value was in March (88.9 %). Lower values were shown from November (44.4 %), through January (37.8 %). Using this classification there were no transitional months.

The mean annual incidence of ovulation in the mature ewes (Fig. 9) also differed between breeds ($P<.05$). Criollo (56.7 %) was higher than the Corriedale (39.5 %). The months with higher proportion of Corriedale ewes ovulating were June (73.3 %) through September (66.7 %) The months with lower values were December (13.3 %) through March (6.7 %). The rest of the months were considered as transitional. In the Criollo the higher proportion of ewes ovulating was from May (60.0 %) through November (60.0 %), with the highest values in June through September (73.3 %). The higher values extend over a seven months period compared to four months in the Corriedale ($P<.05$).

The predicted values for incidence of estrus and ovulation were calculated by breed and for the two stages of development in body weight (physically immature and mature). These profiles are shown in Fig. 10 through 17. There were no statistical differences ($P>.05$) in the predicted values for incidence of estrus and ovulation. For the

nature of the predicted values the models were trigonometric. The regression equation for incidence of estrus and ovulation in the Corriedale was $\hat{y} = -29.6 + 27$ month $- 1.96$ month$^2 + 3.68$ age $- 10.9 \cos(2\pi$ month$/12) + 32.5 \sin(2\pi$ month$/12)$, $R^2 = .92$, and $\hat{y} = 34.2 + 2.2$ month $- 0.163$ month$^2 - 27.5 \cos(2\pi$ month$/12) - 19.8 \sin(2\pi$ month$/12) - 0.37$ age, $R^2 = 0.84$, respectively. In the Criollo the corresponding equations were $\hat{y} = 34.1 + 15.3$ month $- 1.25$ month$^2 + 2.44 - 2.83 \cos(2\pi$ month$/12) + 8.15 \sin(2\pi$ month$/12)$, $R^2 = 0.81$ for incidence of estrus, and $\hat{y} = 5.8 + 26.1$ month $- 2.15$ month$^2 + 18.3 \cos(2\pi$ month$/12) - 10.6 \sin(2\pi$ month$/12) - 0.52$ age, $R^2 = 0.85$ for incidence of ovulation.

These results indicate that the incidence of estrus is higher than that of ovulation particularly at the begining of the period of increased activity and the mean incidence of estrus is higher than ovulation. In general the estrus or ovulation did not occur in all ewes or did not fall to occur in all ewes during any month of the year.

These results provide evidence for several differences in response of estrus and ovulation to genetics and environment. The results obtained were consistent among years which justified combining years and increases the confidence in the results.

Clear differences exist between breeds for age at puberty and for seasonal differences during the year for both

the incidence of estrus and ovulation. The Criollo attains puberty at a younger age and the occurrence of estrus and ovulation is less seasonal than the Corriedale. There are many references in the literature for differences due to genetics in seasonality of the breeding season in areas where photoperiod is clearly involved (Hafez, 1952; Hulet et al, 1974; Wheeler and Land, 1977; Robertson, 1977; Valencia, et al 1978; Ward, 1980; De Lucas, et al, 1984). Seasonal and breed differences have also been demonstrated in areas closer to the equator (Cardozo and Foote, 1968 in Bolivia; Naranjo and Sabogal, 1978 in Colombia; and Irazqui and Menvielle, 1982 in Argentina).

In this study the native Criollo breed demonstrated better adaptation to the environment of the Peruvian Southern Highlands than the Corriedale. Similar results were also found in the Central highlands of Peru (Vivanco et al, 1984) for difference among breeds as well as incidence and seasonal patterns of estrus and ovulation.

The reason for the seasonal variation cannot be specifically defined from this study but are related generally to changes in rainfall and feed production. It is not likely that photoperiod is involved since there is a variation of approximately only two hours in day length throughout the year.

The seasonal patterns in estrus and ovulation were similar for physically immature and mature ewes except that

the incidence for each breed was higher in the mature ewes which reflects sexual development of those traits.

Estrus and ovulation did not occur in all ewes of either breed during any period of the year. Most studies reporting seasonal changes in these traits indicate periods during which all ewes show estrus and ovulation, and periods when none of the ewes demonstrate estrus and ovulation. In this study it was expected that all or virtually all, ewes would show estrus and ovulate during some period of the year. It is possible; however, that this does not occur under the conditions that this study was conducted. This possibility should be considered but it is not possible to specifically determine the cause for the seasonal changes.

The ewes were carefully checked for estrus daily using sexually active marked rams which were rotated regularly. Ovulation was checked by direct visualization of the ovary for the presence of corpora lutea as evidence of ovulation via the laparoscope at monthly intervals. One third of the ewes were observed each month with each ewe being observed every three months. This provided a smaller sample of ewes for determinig incidence of ovulation compared to estrus. Also the ewes were not observed for ovulation at a set number of days following estrus and therefore it is possible that some ewes that were experiencing ovulation cycles were observed during periods when the corpus luteum was not

present. The method of estrus used is judged adequate to provide accurate measures of this trait. It is possible that ovulation occurred in some cases without it being observed. Any limitations to observing estrus and ovulation are not of a magnitude to substantially affect the incidence observed. A possible explanation to this decreased incidences may be the continual presence of the ram. Schinckel (1954), has reported that continual presence of the ram, as was the case in this study, reduced the incidence of estrus in Australia.

Particularly at the beginning of the breeding season ovulation in sheep has been reported to often occur without estrus followed by ovulation with estrus (Hafez, 1952; Hulet, et al, 1974; Wheeler and Land, 1977; Valencia et al, 1978; Irazqui and Menvielle, 1982; De Lucas et al, 1984). This did not appear to be the case in this study. The mean incidence of ovulation was less than that of estrus, particularly at the beginning of the breeding season or period when an increase in incidence of estrus occurred. This overall reduced incidence of ovulation might be explained in part by the chance observing of ovaries in ewes that were ovulating at a time when the corpus luteum was not present as noted above.

The ovulation rate in the mature ewes was similar to physically immature ewes. There was no significant difference ($P>.05$) by breeds or month. These results agree with

those reported by Cardozo and Foote (1968) comparing the Criollo and Corriedale in Bolivia. Besides the genetic factors, nutrition influences the level of ovulation rate, Gunn and Doney (1975); Kelly et al (1976); Cumming (1977); Haresign (1981); Gunn (1983), and Montgomery et al (1985). Ewes in this study did not receive nutritional supplementation. Because of the relatively low level of nutrition the genetic potential for ovulation rate was not measured.

Even though Criollo ewes did not have a higher ovulation rate, than the Corriedale they were less subject to seasonal variations in the incidence of estrus and ovulation. The most important finding seems to be that the Criollo reached puberty earlier than the Corriedale, and demonstrated an extended period of estrus and ovarian activity with less variation in their incidence.

SUMMARY AND CONCLUSIONS

This experiment was carried out in the Peruvian Southern Highlands, at the La Raya experiment station (4200 m elevation, 15°S latitude, and 70°W longitude). Puberty, body weight, incidence of estrus, and incidence and rate of ovulation were measured for three consecutive years (1981-1982, 1982-1983, and 1983-1984) in a flock of 60 Corriedale and 60 Criollo ewes. Information was obtained on four different age groups within each breed; 0.5-1.5, 1.5-2.5, 2.5-3.5, and 3.5-4.5. Ewes were managed on a natural grazing pasture, without receiving any nutritional supplement.

Puberty was considered as the time when a ewe lamb showed her first estrus. Age at puberty were recorded during one year (1982-1983). Body weight was measured each month. Incidence of estrus was observed on a daily basis with the aid of three teams of six vasectomized painted rams which were rotated every two weeks. Incidence of ovulation (number of females ovulating/females observed) was observed on a monthly basis, for this purpose every month five ewes of each age (1.5, 2.5, and 3.5) and breed (Corriedale and Criollo) were observed with the laparoscope. The ovulation rate (number of corpora lutea/ ewe ovulating) was calculated on a monthly basis. Ewes were fasted for 16-24 hs before to laparoscopy. Puberty data

were analyzed using the "t" test. Body weight, incidence of estrus and ovulation, and ovulation rate were analyzed using Rummage II, a statistical computer program designed for performing least squares analysis of variance with unequal number of observations. The data were treated as a factorial design. The main factors were breed (2), age groups (2), years (3), and months (12); the corresponding interactions were also calculated. Whenever statistical differences were found, the LSD (least significant difference) technique was applied to determine differences between selected means.

The age at puberty (measured in 1982-83 only) for Corriedale was 693.6 days (23.1 months), and for Criollo 483.3 days (16.1 months). The body weight at puberty age was 27.2 kg for Corriedale, and 25.3 kg for Criollo. The correlation between between age and body weight was positive for the two breeds, r=0.64 for Corriedale, and r = 0.19 for Criollo ($P<.05$). Criollo was more precocious than Corriedale, the difference was seven months (210 days). Ewes are usually exposed for breeding at 15-17 months of age in Peru. One hundred percent of the Criollo ewes attained puberty at this age, in contrast to only 58 % of the Corriedale ewe lambs. The body weight at puberty in relation to adult liveweight was 78.3 % for Corriedale, and 79.6 % for Criollo.

Body weight tended to show a seasonal and annual varia-

tion, a major peak was observed in July and a minor in February. There was a significant difference ($P<.05$) in the attainment of physical maturity, 39 months of age for Corriedale and 36 months for Criollo, the corresponding body weights at these ages were 35.0 and 31.8 kg for Corriedale and Criollo, respectively. The regression equation for body weight was $\hat{y} = 16.6 + 0.947$ month-age $- 0.0122$ month-age^2, $R^2 = 0.78$, and $\hat{y} = 19.3 + 0.697$ month-age $- 0.0097$ month-age^2, $R^2 = 0.69$ for Corriedale and Criollo, respectively.

Incidence of estrus, and incidence and rate of ovulation were related to physical development; puberty to physical maturity (physically immature and physically mature ewes.

The Corriedale breed showed a lower overall incidence of estrus than the Criollo, 45.4 and 67.1 %, respectively. Within year immature Corriedale ewes showed higher values during five months, from March (93.2 %) through July (60 %), in contrast to eight months in the Criollo, from February (72.3 %) through September (62.9 %). The lower incidence of estrus in the immature Corriedale lasted for five months, from September (15.7 %) through January (8.9 %), compared to only two months in the Criollo, November (38.4 %) and December (38.0 %).

In the mature ewes the proportion of ewes showing higher estrus activity in Corriedale were from March (91.1 %) through August (53.3 %). The Criollo breed showed the

higher values for nine months, February (71.1 %) through October (60.0 %). The period of time of lower estrus activity was similar for the Corriedale and Criollo (three months), November through January; however, the values were different, 8.9 % in the Corriedale and 37.8 - 44.4 % in the Criollo.

The incidence of ovulation was significantly different ($P<.05$) among the two breeds, 58.5 % in the Criollo, and 39.6 % in the Corriedale. Physically immature Corriedale ewes showed higher proportion of ewes ovulating for four months, from May (73.3 %) through August (86.7 %). On the other hand Criollo ewes showed higher values for 8 months, April (53.3 %) through November (66.7 %).

In the mature ewes the incidence of ovulation differed ($P<.05$) between breeds. Corriedale ewes ovulated at a higher incidence for four months, June (73.3 %) through September (66.7 %), in contrast to seven months in the Criollo, from May (60.0 %) through November (60.0 %). Physically mature ewes showed a higher incidence of estrus than physically immature ewes. The incidence of estrus and ovulation through the three consecutive years of the study differed. The overall incidence for the Criollo ewes for all ages was 67 %. Physically immature Corriedale ewes demonstrated a lower ($P<.05$) incidence of estrus (43.6 %), and mature ewes showed a rise in incidence of estrus to 47.2 % both of which were less than the Criollo (66.3 and

68.7 % for physically immature and mature ewes).

There was no difference (P>.05) in the ovulation rate for Corriedale (1.00) and Criollo (1.03) ewes, the same pattern was observed by age, years, and months.

The conclusions of this study can be state as follows; (1) The Criollo breed reached puberty seven months earlier than the Corriedale. The liveweight at puberty was 25.3 and 27.2 kg for the two breeds, respectively. (2) At 15-17 months of age, which is the first breeding age in the sheep industry in Peru, 100 % of the Criollo had attained puberty, compared to only 58 % of the Corriedale. (3) Body weight showed seasonal and annual variations, a major peak was observed in July, and another minor peak in February. (4) Physical maturity was three months earlier in the Criollo (36 months) than in the Corriedale (39 months); body weight at physical maturity was 31.8 and 35.0 kg for the two breeds, respectively. (5) The Corriedale breed demonstrated a marked seasonality in the proportion of ewes showing higher incidence of estrus (5- 6 months, March through August), compared to 8 - 9 months (February to October) in the Criollo. (6) The same trend was observed in the incidence of ovulation, although the higher proportion of ewes ovulating started later than the incidence of estrus. (7) The ovulation rate was approximately 1.0 (1.0 - 1.03) in the two breeds for all ages, years and months.

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APPENDIX

Table 5. ANOVA for body weight and incidence of estrus

		Body weight		Incidence of Estrus	
Source	d.f.	M.S.	F	M.S.	F
Breed	1	3622.88	191.76**	63.78	395.68**
Age	2	3800.04	201.14**	4.04	25.08**
Year	2	1267.22	67.08**	5.61	34.78**
Month	11	498.61	26.39**	13.68	84.88**
B x A	2	603.12	31.92**	3.05	18.93**
B x Y	2	1.82	0.09	0.06	0.38
A x Y	4	673.60	35.65**	0.50	3.10**
BxAxY	4	354.04	18.74**	0.16	0.98
B x M	11	3.22	0.17	1.25	7.23**
A x M	22	31.16	1.65*	0.40	2.46**
Y x M	22	192.68	10.19**	0.89	5.50**
BxAxM	22	0.82	0.04	0.42	2.58**
BxYxM	22	4.50	0.24	0.42	2.61**
AxYxM	44	1.73	0.09	0.15	0.93
BxAxYxM	44	3.58	0.19	0.17	1.04
Error	2995	18.89		0.16	

* P <.05
** P <.01

Table 6. Least square means ± s.e.m. for body weight (kg)

Breed/age[3]	YEARS 1981-82	1982-83	1983-84	Overall[2]
Corriedale				
0.5 yrs.	25.8 ± .32	19.9 ± .32	19.6 ± .32	21.7 ± .19[a]
1.5 yrs.	29.1 ± .32	32.7 ± .33	27.8 ± .32	29.9 ± .19[b]
2.5 yrs.	32.6 ± .34	33.8 ± .32	35.9 ± .33	34.1 ± .19[c]
3.5 yrs.	33.2 ± .32	34.7 ± .32	36.4 ± .32	34.8 ± .19[d]
Subtotal[1]	30.2 ± .19[b]	30.3 ± .19[b]	30.2 ± .19[b]	30.3 ± .11[b]
Criollo				
0.5 yrs.	26.0 ± .34	20.6 ± .32	22.6 ± .34	23.1 ± .19[a]
1.5 yrs.	29.1 ± .34	30.3 ± .32	29.1 ± .34	29.5 ± .19[b]
2.5 yrs	30.8 ± .32	31.1 ± .32	31.2 ± .32	31.1 ± .19[b]
3.5 yrs.	28.9 ± .32	33.4 ± .32	33.1 ± .32	31.8 ± .19[b]
Subtotal[1]	28.7 ± .19[a]	28.9 ± .19[a]	29.0 ± .19[a]	28.9 ± .11[a]
Combined				
0.5 yrs.	25.9 ± .23[b]	20.3 ± .23[a]	21.1 ± .23[a]	22.4 ± .13[a]
1.5 yrs.	29.1 ± .23[c]	31.5 ± .23[d]	28.5 ± .24[c]	29.7 ± .13[b]
2.5 yrs.	31.7 ± .23[d]	32.1 ± .23[e]	33.6 ± .23[e]	32.6 ± .13[c]
3.5 yrs.	31.0 ± .23[d]	34.0 ± .23[f]	34.8 ± .23[f]	33.3 ± .13[c]
Overall[1]	29.4 ± .13[a]	29.5 ± .13[a]	29.5 ± .13[a]	29.5 ± 5.20

[1] $P<.05$ for means with different superscript letters between years for breed, physical development and overall.

[2] $P<.05$ for means with different superscript letters between age within breed, between breeds, and between physical development.

[3] Denotes for physical development (Physically immature and physically mature ewes).

Table 7. Least square means ± s.e.m. by months for all the variables.

Months	Body weight kg	Estrus Incid. %	Ovul. Incid. %	Ovul. Rate
Apr.	26.6 ± .26[a]	73.78 ± 2.44[fg]	50.01 ± 4.58[bc]	1.01 ± .03[a]
May.	27.7 ± .26[b]	83.29 ± 2.44[h]	67.58 ± 4.61[ef]	1.03 ± .02[a]
Jun.	29.8 ± .26[d]	79.12 ± 2.44[h]	75.45 ± 4.58[f]	1.00 ± .02[a]
Jul.	31.3 ± .27[g]	77.03 ± 2.46[g]	72.00 ± 4.55[f]	1.00 ± .02[a]
Aug.	30.9 ± .27[f]	67.87 ± 2.46[ef]	73.34 ± 4.55[f]	1.01 ± .02[a]
Sep.	30.1 ± .27[d]	45.03 ± 2.46[c]	62.67 ± 4.55[e]	1.03 ± .02[a]
Oct.	29.2 ± .27[cd]	37.11 ± 2.46[bc]	54.89 ± 4.55[cd]	1.03 ± .02[a]
Nov.	28.1 ± .27[c]	28.21 ± 2.46[a]	49.96 ± 4.56[bc]	1.00 ± .02[a]
Dec.	28.5 ± .27[b]	27.15 ± 2.46[a]	23.02 ± 4.61[a]	1.00 ± .02[a]
Jan.	30.2 ± .27[d]	32.47 ± 2.46[ab]	25.42 ± 4.55[a]	1.00 ± .02[a]
Feb.	30.8 ± .27[ef]	57.00 ± 2.46[d]	24.02 ± 4.61[a]	1.00 ± .02[a]
Mar.	30.5 ± .27[e]	91.02 ± 2.46[i]	27.84 ± 4.58[a]	1.00 ± .02[a]

$P<.05$ for means with different superscript letters between months within column.

Table 8. Least square means ± s.e.m. for incidence of estrus (%)

Breed/age[3]	Years 1981-82	1982-83	1983-84	Overall[2]
Corriedale:				
Immature	51.67 ± 2.99	36.67 ± 2.99	42.30 ± 3.06	43.55 ± 1.74[a]
Mature	55.00 ± 2.99	41.67 ± 2.99	45.00 ± 2.99	47.22 ± 1.73[b]
Subtotal[1]	53.34 ± 1.73[c]	39.17 ± 1.73[a]	43.68 ± 1.74[b]	45.39 ± 1.00[a]
Criollo:				
Immature	71.67 ± 2.99	58.33 ± 2.99	68.33 ± 2.99	66.28 ± 1.73[c]
Mature	73.89 ± 2.99	65.56 ± 2.99	66.67 ± 2.99	68.70 ± 1.73[c]
Subtotal[1]	72.41 ± 1.73[e]	60.74 ± 1.73[d]	66.76 ± 1.76[d]	67.10 ± 1.00[b]
Combined:[1]				
Immature	65.00 ± 2.12[c]	51.11 ± 2.12[a]	59.62 ± 2.18[b]	58.62 ± 1.24[a]
Mature	64.45 ± 2.12[c]	53.62 ± 2.12[a]	55.84 ± 2.14[b]	57.96 ± 1.23[a]
Overall	64.78 ± 1.22[c]	52.11 ± 1.22[a]	58.06 ± 1.22[b]	58.36 ± 2.50

[1]$P<.05$ for means with different superscript letters between years for breed, physical development and overall.
[2]$P<.05$ for means with different superscript letters between age within breed, between breed, and between physical development.
[3] Denotes physical development (physically immature and physically mature ewes).

Table 9. ANOVA for incidence and rate of ovulation

		Ovulation incidence		Ovulation rate	
Source	d.f.	M.S.	F	M.S.	F
Breed	1	17.28	92.71**	0.04	2.19
Age	2	0.58	3.13**	0.02	0.28
Year	2	1.66	8.89**	0.02	0.97
Month	11	3.59	19.27**	0.01	0.58
B x A	2	1.63	8.76**	0.05	2.72
B x Y	2	0.36	1.93	0.003	0.14
A x Y	4	0.23	1.22	0.01	0.66
BxAxY	4	0.28	1.49	--	--
B x M	11	0.28	1.50	0.006	0.37
A x M	22	0.19	0.42	0.02	1.24
Y x M	22	0.22	1.18	0.02	1.41
BxAxM	22	0.24	1.27	--	--
BxYxM	22	0.23	1.21	--	--
AxYxM	44	0.20	1.08	--	--
BxAxYxM	44	0.19	1.04	--	--
Error	855	0.19	--	0.02	--

** $P<.01$

Table 10. Least square means ± s.e.m. for incidence of ovulation (%)

Breed/age[3]	Years			Overall[2]
	1981-82	1982-83	1983-84	
Corriedale:				
Immature	51.94 ± 5.60	35.00 ± 5.57	30.83 ± 5.69	39.67 ± 3.24[a]
Mature	51.67 ± 5.57	31.67 ± 5.57	35.00 ± 5.57	39.45 ± 3.22[a]
Subtotal[1]	51.81 ± 3.22[b]	33.34 ± 3.23[a]	32.95 ± 3.24[a]	39.56 ± 1.87[a]
Criollo:				
Immature	56.67 ± 5.57	58.34 ± 5.57	57.89 ± 5.91	59.42 ± 3.29[b]
Mature	63.33 ± 5.57	50.00 ± 5.57	56.67 ± 5.57	56.67 ± 3.22[b]
Subtotal[1]	58.89 ± 3.22[c]	55.56 ± 3.22[b]	57.22 ± 3.28[c]	58.49 ± 1.87[b]
Combined:				
Immature	55.09 ± 3.94[d]	50.56 ± 3.96[c]	48.77 ± 4.06[c]	51.51 ± 2.30[a]
Mature	57.50 ± 3.94[d]	40.83 ± 3.94[a]	45.83 ± 3.94[b]	48.06 ± 2.28[a]
Overall[1]	56.05 ± 2.28[b]	46.67 ± 2.28[a]	47.57 ± 2.31[a]	50.88 ± 4.97

[1]$P<.05$ for means with different superscript letters between years for breed, physical development and overall.

[2]$P<.05$ for means with different superscript letters between physical maturity within breed, between breeds, and between physical development.

[3]Denotes for physical development (physically immature and physically mature ewes).

Table 11. Least square means ± s.e.m. for ovulation rate

Breed	Years 1981-82	1982-83	1983-84	Overall
Corried.	1.00 ± .02	1.00 ± .03	1.00 ± .03	1.00 ± .02[a]
Criollo	1.04 ± .02	1.02 ± .02	1.01 ± .02	1.03 ± .01[a]
Overall	1.03 ± .01[a]	1.00 ± .02[a]	1.00 ± .02[a]	1.01 ± .13[a]

[a]P>.05 for mean with the same superscript letters among means.

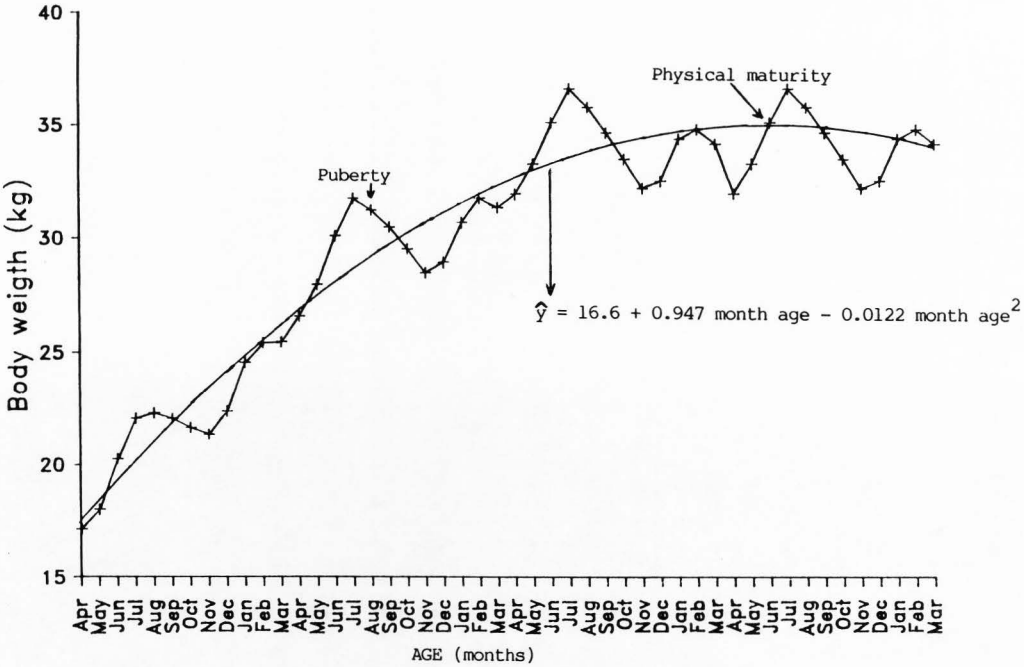

Figure 1. Body weight in Corriedale ewes with observed (—+—) and predicted (——) curves.

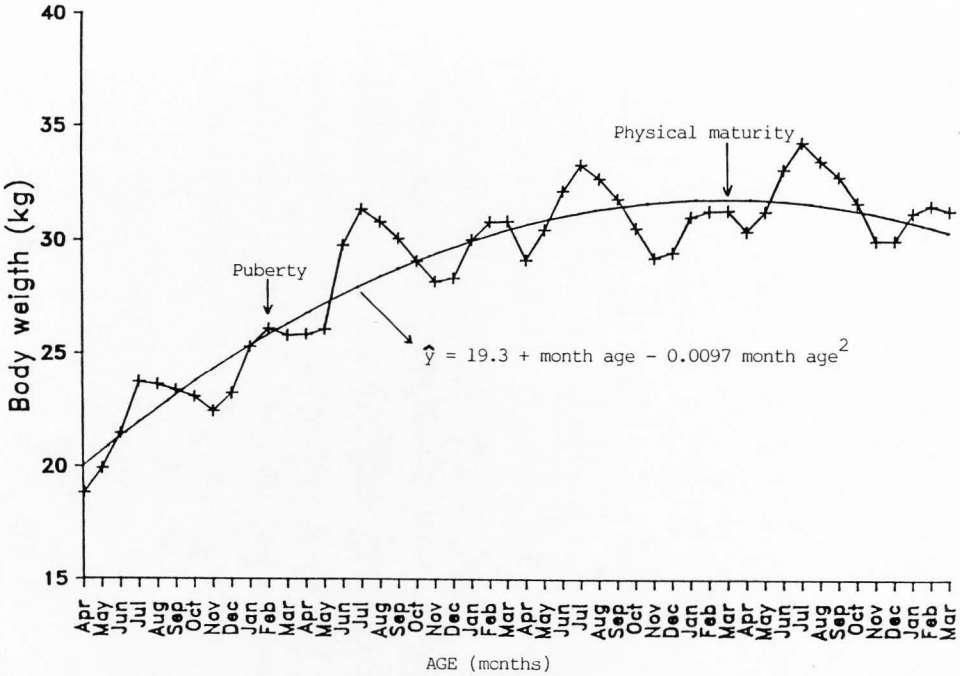

Figure 2. Body weight in Criollo ewes with observed (—+—) and predicted (——) curves.

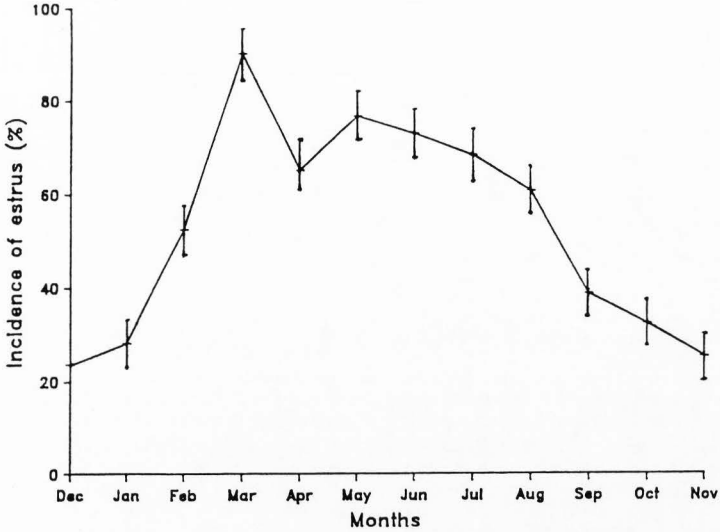

Figure 3. Incidence of estrus by months with breed, age and years combined.

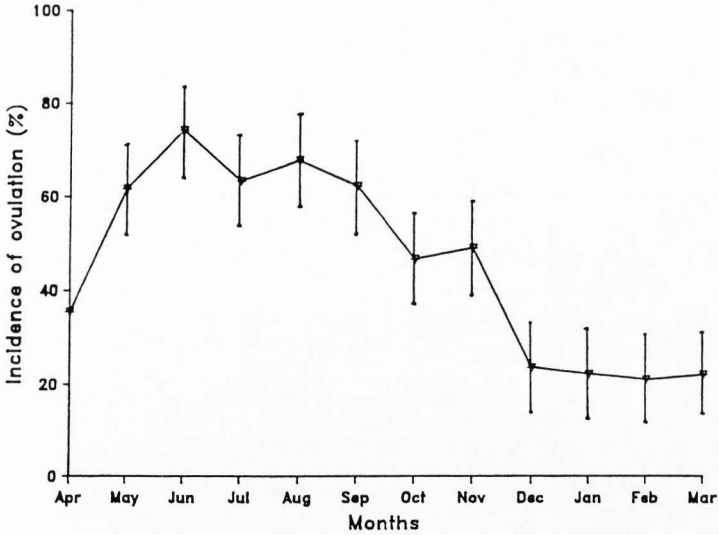

Figure 4. Incidence of ovulation by months with breed, age and years combined.

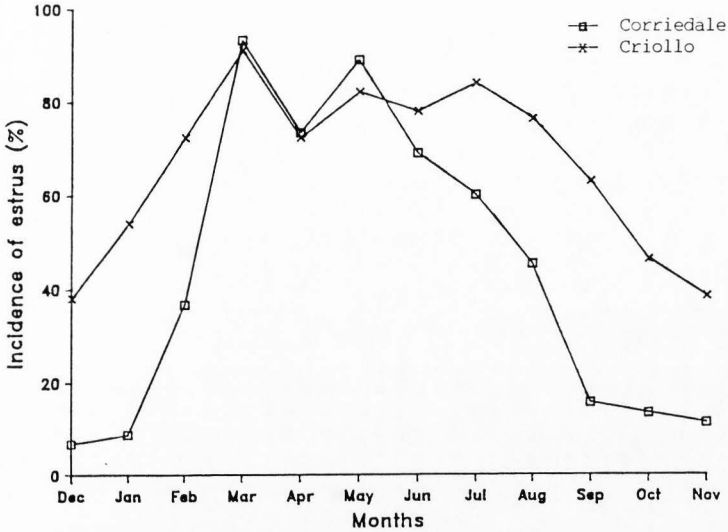

Figure 5. Incidence of estrus in physically immature ewes by breeds and months with years combined.

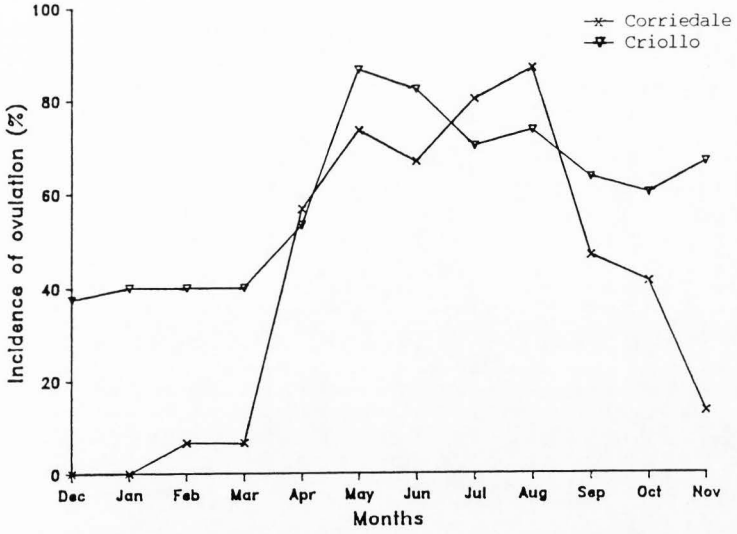

Figure 6. Incidence of ovulation in physically immature ewes by breeds and months with years combined.

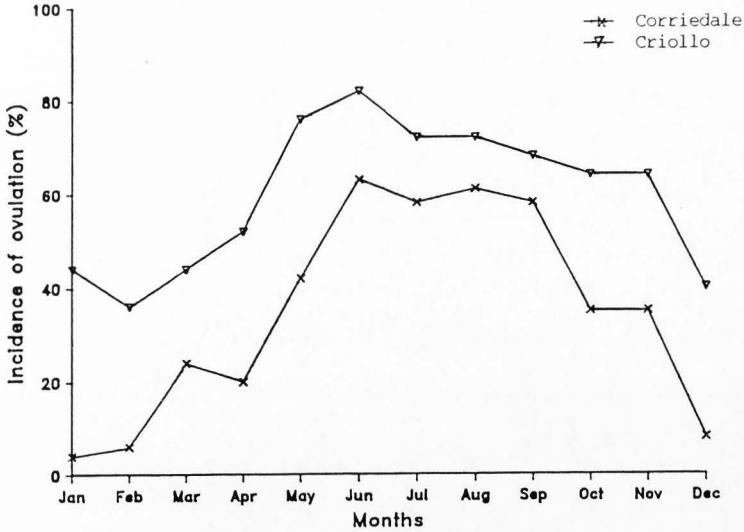

Figure 7. Incidence of ovulation by breeds and months with age and years combined.

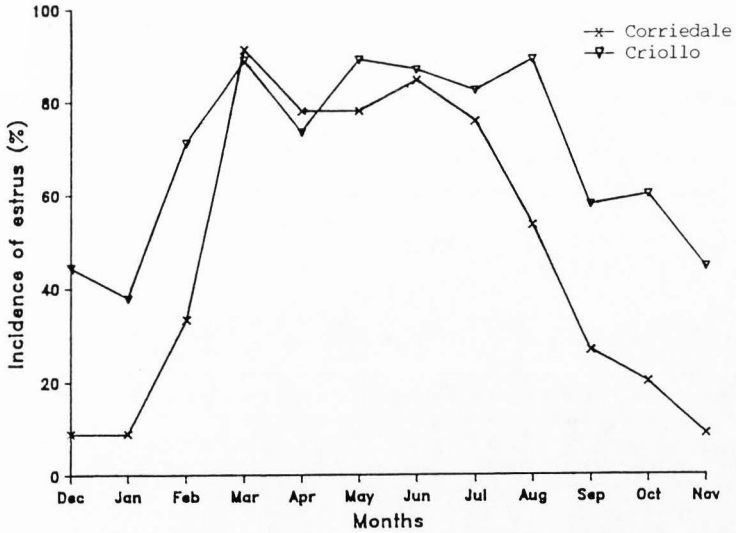

Figure 8. Incidence of estrus in mature ewes by breeds and months with years combined.

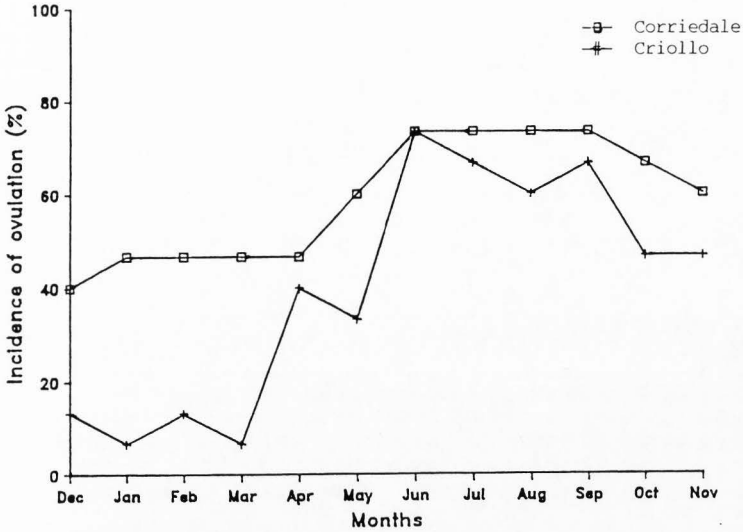

Figure 9. Incidence of ovulation in mature ewes by breeds and months with years combined.

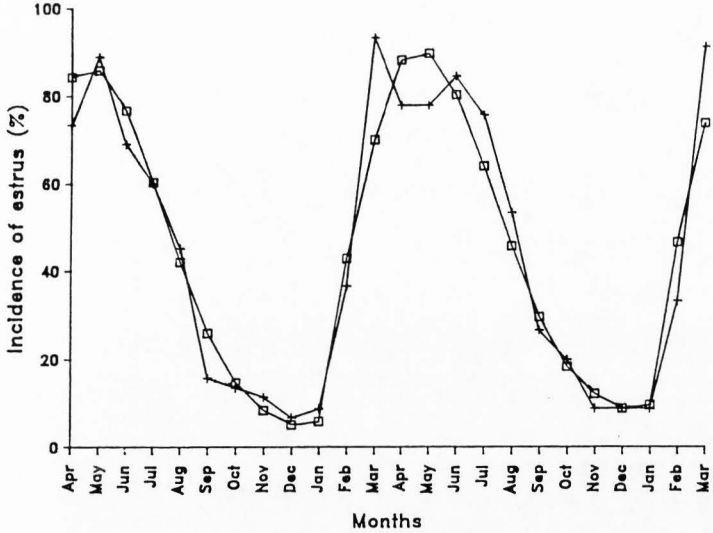

Figure 10. Incidence of estrus in Corriedale ewes with observed (—+—) and predicted (—□—) curves by months and age.

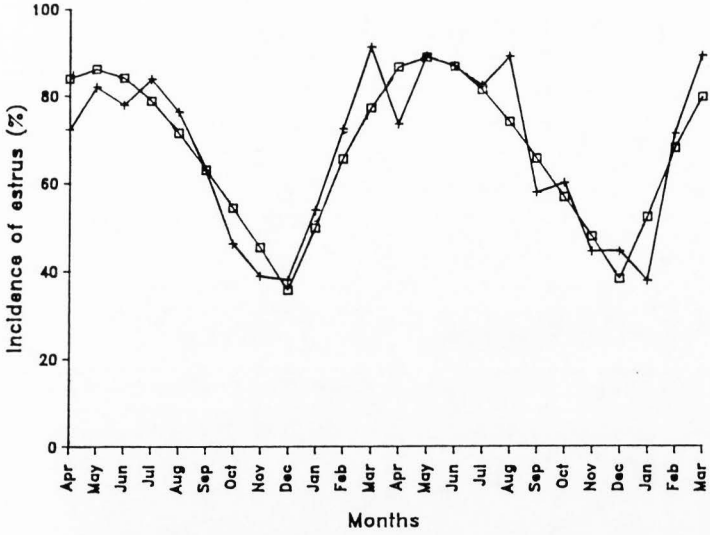

Figure 11. Incidence of estrus in Criollo ewes with observed (—+—) and predicted (—□—) curves by months and age.

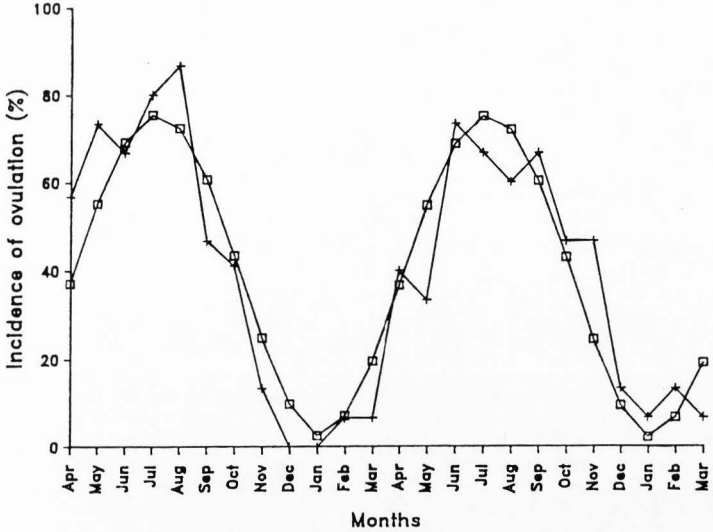

Figure 12. Incidence ovulation in Corriedale ewes with observed (—+—) and predicted (—□—) curves by months and age.

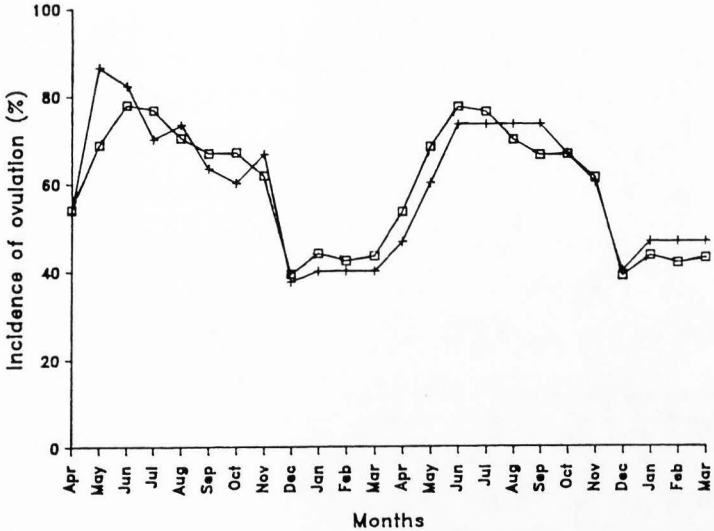

Figure 13. Incidence of ovulation in Criollo ewes with observed (—+—) and predicted (—□—) curves by months and age.

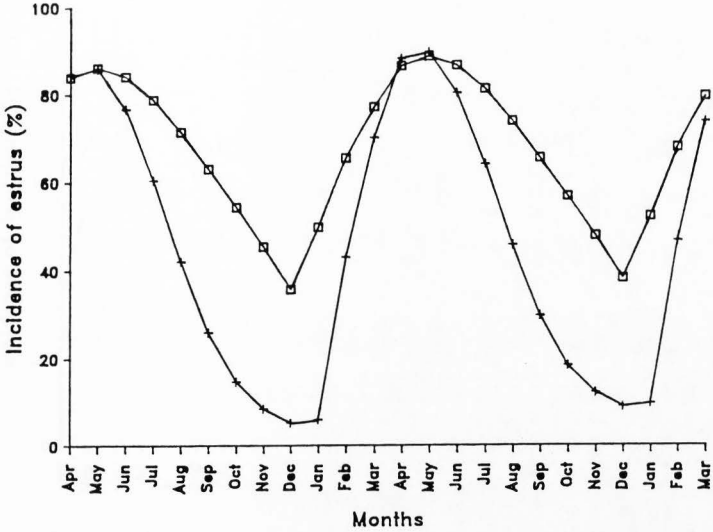

Figure 14. Predicted incidence of estrus in Corriedale (—+—) and Criollo (—□—) ewes by motnhs and age.

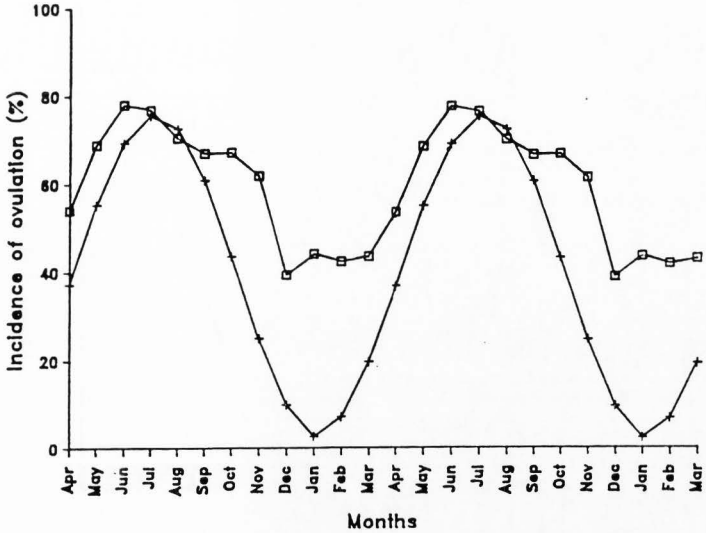

Figure 15. Predicted incidence of ovulation in Corriedale (—+—) and Criollo (—□—) ewes by months and age.

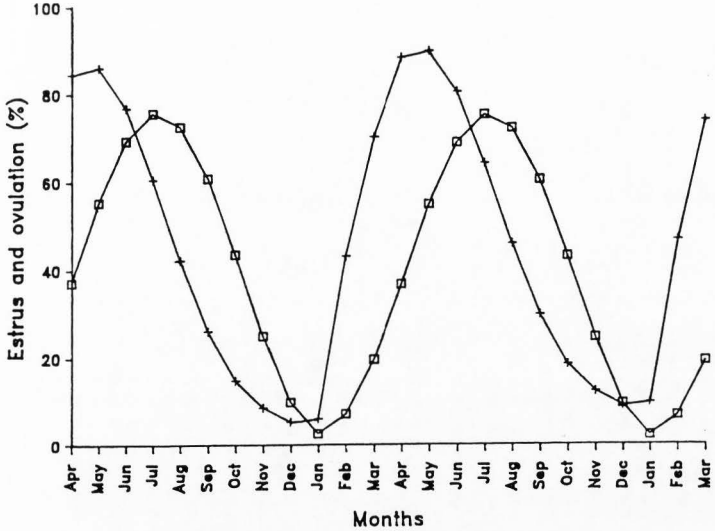

Figure 16. Predicted incidence of estrus (—+—) and ovulation (—□—) in Corriedale ewes by months and age.

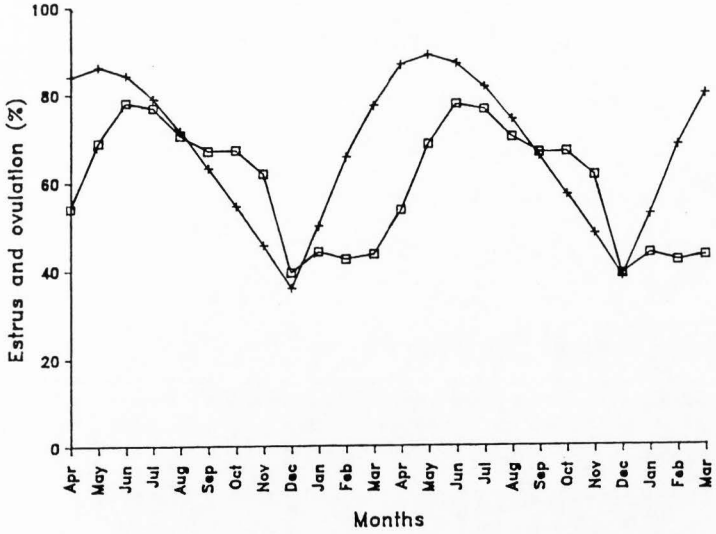

Figure 17. Predicted incidence of estrus (—+—) and ovulation (—□—) in Criollo ewes by months and age.