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Synchronization of oestrus in Nubian goats

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Abstract

In a randomized block design, 34 Nubian goats were allocated for the purpose of studying the efficiency of different hormonal treatments in inducing and synchronizing oestrus. The animals were selected and grouped according to age so that each age group was represented under each group. The control group (A) consisted of four females while the rest of the groups (each consisting of 10 females) were randomly assigned to three different treatments. These treatments included a double Cloprostenol intramuscular injection (125 μg) (treatment B); intravaginal sponges impregnated with progesterone (40 mg) inserted for a 16-day period (treatment C) and treatment C plus an intramuscular injection of pregnant mare serum (300 IU) two days before sponge removal (treatment D). A vasectomized and a spermatic buck was introduced to all groups immediately after termination of each treatment for detection of oestrus. Does were monitored for the time interval from end of treatment to the onset of oestrus, oestrous signs and the duration of oestrus. They were then artificially inseminated at 24 and 48 h following termination of treatments. Those returning to oestrus were handmated. The control group was handmated. Conception rates were determined by non-return rates and by radioimmunoassay (RIA) used to monitor serum progesterone concentration 3–10 weeks after insemination. Late pregnancy was diagnosed by abdominal palpation after Day 90–110. The obtained results indicated that all the employed treatments were capable of inducing and synchronizing oestrus in Sudanese Nubian goats. Treatment B was significantly ($P<0.05$) more efficient than the other two treatments. The percentage of does responding to treatment B by showing oestrus was 100%, followed by D (77.7%) and C (70%). Duration of the induced oestrous period was shortest ($P<0.05$) in treatment C (38.6±7.1 h) followed by D (52±7.8 h) and B (52.6±4.8 h). Pregnancy rates were higher ($P<0.05$) with treatment B (77.8%) followed by C (70%) and D (55.5%). The overall pregnancy rate diagnosed by RIA was 37.5% less than that diagnosed by abdominal palpation (64%). However, kidding confirmed the accuracy of RIA as a pregnancy diagnosis.

Keywords: Oestrous synchronization; Nubian goats; Kidding rates

1. Introduction

The Nubian goat, together with other indigenous goats (Desert, Nilotic, Dwarf and Tagari) is the only really acknowledged goat in Sudan (Hassan and El Derani, 1990), and among the best dairy goats in Africa (Devendra and McLeory, 1982). The Nubian goats constitute 2.5 million of the 18.7 million head of goats in Sudan (FAO, 1992; AOAD, 1994) and their distribution is throughout the arid areas, essentially

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along rivers and in urban areas in the northern parts of Sudan. The milk yield and lactation period are 73.5 kg and 143 days respectively, with a yield of 1.5–2.0 kg/day (Sulieman and El Shafei, 1984).

Evidence of prostaglandin ($PGF_{2\alpha}$) synthesis and release from the endometrium was first revealed by Goding (1974). Several workers used a dose of 5 mg $PGF_{2\alpha}$ in goats (Debendetti et al., 1982; Akusu and Egbunike, 1984; Pandey et al., 1985). The percentage of goats that showed oestrus were 88, 80–100 and 70–100%, respectively. Variable doses of 62.5, 125, 250 μg Cloprostenol, given twice at an interval of 10 days, resulted in 87.5, 93.8 and 100% of females showing oestrus. Administration of exogenous progesterone in the early days of the oestrous cycle markedly affects the development of corpus luteum and may affect its activity (Thwaites, 1971). Ishwar and Pandey (1992), obtained 100% synchronization efficiency with progesterone impregnated sponges in Black Bengal goats. The authors reported an interval range of 95–137 h from the treatment to onset of oestrus. In the topics, progesterone intravaginal sponges gave a response of 35–50% in goats (Rosnina et al., 1992). Pregnant mare serum gonadotrophin (PMSG), usually used in conjunction with progesterone or progestagan intravaginal sponges before or after removal of the sponge in anoestrous and cycling goats (Corteel, 1975; Boshoff, 1980). This is to induce a mild superovulation, thus stimulating the twinning percentage of less prolific breeds of goats and sheep to an acceptable level (Gordon, 1975). A dose range of 375–750 I.U. of PMSG is recommended to synchronize oestrus. Any increase beyond this will depress rather than enhance conception rate. However, a dose of 300 I.U. has been reported to synchronize oestrus in goats (Bongso et al., 1982).

Despite the sizable contribution of the Nubian goats to the national economy, little effort has been undertaken to improve their reproductive performance. Synchronization of oestrus will allow the farmer to predict the time of oestrus with reasonable accuracy (Britt, 1984) and, hence, reduce the time used for detection of oestrus. Other benefits of synchronization include feeding animals in uniform groups with diets according to stage of production. Also, the facilitating of supervision of kidding does, thus reducing neonatal mortality and helping in the organization of the weaning and fattening and marketing of kids. The study was thus carried out with the following objectives:

1. to test the efficiency of different hormonal methods in inducing and synchronizing oestrus in indigenous Nubian goats; and
2. to assess Nubian goat fertility as a result of synchronization, following a fixed time of artificial insemination (AI).

2. Material and methods

From a flock of 150 Nubian goats, 34 females were selected. The ages ranged from one-and-a-half to five years and body weights from 10–28 kg. Age was estimated by dentition (McNitt, 1983). The female goats were randomly allocated to four groups so that different age groups were represented in each group. One group (A) consisted of four animals serving as a control group. The other three groups, each consisting of 10 animals, were randomly allocated to three different synchronization treatments as follows:

Treatment (B): Each female in this group received a double intramuscular injection of 125 μg (0.5 ml), Estrumate (Cloprostenol: Cooper) at a 13-day interval.

Treatment (C): Intravaginal progesterone impregnated sponges (40 mg; Alverta, GMPH) inserted by using a disposable syringe as described by Evans and Maxwell (1987) for a 16-day period.

Treatment (D): Intravaginal progesterone impregnated sponges were administered as in treatment (C), plus an intramuscular injection of 300 I.U. PMSG (Folligon; Intervet) two days before sponge removal.

The number of females retaining their sponges until removal/second injection to oestrus, oestrous signs and duration of the induced oestrous periods were recorded for treatments B, C and D. A vasectomized Nubian buck and aspermatic active Saanen buck were introduced for the control and treated groups following the termination of each treatment period for determining the onset of oestrus and detection of females in oestrus. The control group was handmated, by taking females in oestrus to male, while the

synchronized does (whether observed in oestrus or not) were artificially inseminated 24 and 48 h after the termination of treatments. Sites of semen deposition was intra cervical or uterine as far as the cervix could allow the passage of the straw. A volume of 0.5 ml fresh semen containing 200×10^6 active spermatozoa was used. Inseminated does were monitored for return to oestrus 21–60 days following AI with the aid of a vasectomized buck. Those does returning to oestrus were again inseminated. Conception rates based on non-return rates following the double insemination were determined 30–60 days following AI and abdominal palpation.

Other parameters investigated were:

1. Fertility rate=(kidded does/does inseminated (AI))×100
2. Fecundity rate=(kids born alive/does inseminated (AI))×100
3. Prolificacy rate=(kids born alive/kidded does) ×100
4. Kidding rate=(kidded does/pregnant does)×100
5. Litter size=number of kids per female

The above parameters were calculated according to Charring et al. (1992).

Blood samples (10 ml) were taken by jugular venipuncture from 10 goats per group using non-heparinized vacutainers. Times of sample collection were: after AI, and from week 3–10 at weekly intervals. Progesterone concentration in serum samples was measured using the progesterone RIA kit supplied by the International Atomic Energy Agency, Vienna. The standards used were 0.0; 0.3; 1.6; 6.4; 15.9; 31.8; 63.6; 12.58 nmol/1 with low- and high-quality controls. An intra-assay coefficient of variation (CV) of 3.85% was obtained from duplicate determination of control in the same assay. An inter-assay CV of 8.45% was obtained from two duplicate determinations in eight different assays.

Each group was accommodated separately in pens of 8×5 m. The animals were allowed an adaptation period of three weeks and were fed a concentrate diet at the rate of 0.5 kg/head/day according to the recommendations for feed concentrates to yearling and pregnant does (Devendra and McLeory, 1982). The concentrate diet consisted of soybean (46.8%), yellow corn (25%), wheat bran (25.2%), mineral mixture (2%) and salt (1%). Green fodder was offered adlibitum and the animals had free access to a salt lick and clean water.

Analysis of variance was used in randomized complete block design. Duncan's multiple range test was used to test significance between treatment means (Snedecor and Cochran, 1967).

3. Results

3.1. Oestrous parameters

The responses of does to different hormonal treatments are shown in Table 1. Following the administration of the first injection of Cloprostenol (Treatment B) six (60%) of the 10 does responded by showing oestrus, while one doe aborted. Following the second dose administration, all the remaining does (three) responded. Oestrus was observed in 70% of does (n=10) following removal of impregnated progesterone sponges (Treatment C) on Day 16. Similarly, 77.7% (n=10) showed oestrus following termination of progesterone and PMSG treatment (Treatment D). All of the does (n=4) in the control group (A) showed spontaneous oestrus. There were significant differences ($P<0.05$) in oestrous responses between treatments.

The mean interval from termination of treatments to first signs of oestrus was not statistically significant between treatment groups. However, there were significant ($P<0.05$) differences between treatment groups in the duration of the induced oestrous periods. The control (A) and Treatment C showed shorter durations than treatments B and D. The return to oestrus from Day 30–60 following AI/mating and conception rates following AI were not significant between treatments. However, the mean pregnancy rates differed significantly ($P<0.05$) between treatment groups (Table 2). Conception rates were highest in Treatment B followed by treatments C and D. Fertility and fecundity rates (%) were highest in Treatment B followed by C and D, whereas the prolificacy rate (%) was highest in Treatment D followed by treatments B and C. The kidding rate was shown to be 100%, while the litter size was higher with treatments B and D (1.6) than Treatment C (1.5) (Table 3).

Table 1
Does responding to treatments: mean interval from treatment to onset of oestrus and mean duration of oestrous period (h) following synchronization with Cloprostenol (B), progesterone impregnated sponges (C), C+PMSG (D)

Parameter	Age group (year)	Control A	Treatments		
			B	C	D
No. of does responding to treatments	1.5–2	1	3	2	3
	2–3	2	3	3	2
	4–5	1	3	2	2
Number responded (%)		4(100%) [a]	9(100%) [a]	7(70%) [c]	7(77.7%) [b]
Mean interval from treatment end to onset of oestrus (h)	1.5–2		54	36	64
	2–3		48	64	48
	4–5		56	60	44
Mean±standard error			52.6±11.1	53.3±17.5	52.3±14.3
Mean duration of oestrous period (h)	1.5–2	20	54	36	64
	2–3	42	48	20	48
	4–5	48	56	60	44
Mean±standard error		36.6±3.2 [b]	52.6±48 [a]	36.6±7.1 [b]	52±7.8 [a]

[a,b,c] Values in rows denoted by different superscripts differ significantly ($P<0.05$).
[d] Not measured.

Table 2
Number of does inseminated, returning to oestrus, conception and pregnancy rates, and does exhibiting oestrous in pregnancy following: synchronization with Cloprostenol (B), progesterone impregnated sponges (C), C+PMSG (D)

Parameter	Age group (year)	Control A	Treatments		
			B	C	D
No. of does inseminated/handmated		4	9	10	9
Does returning to service (Day 30–60 after insemination)	1.5–2	—	1	2	—
	2–3	—	—	1	—
	4–5	1	1	—	1
Mean for group (%)		1(25%)	2(22.2%)	3(30%)	1(11.1%)
Conception rates (Day 30–60 after insemination)	1.5–2	1	2	2	4
	2–3	2	2	2	1
	4–5	—	3	3	3
Mean for group (%)		3(75%)	7(77.8%)	7(70%)	8(88.9%)
Pregnancy rates (3–10 weeks RIA)	1.5–2	—	1	—	—
	2–3	—	2	2	1
	4–5	—	2	2	2
Mean for group (%)		—	5(55.6%) [a]	4(40%) [b]	3(11.1%) [a]

[a,b] Values in row denoted by different superscripts differ significantly ($P<0.05$).

Table 3
Number of does inseminated, returning to oestrus, conception rates pregnancy rates and does exhibiting oestrous in pregnancy following: synchronization with Cloprostenol (B), progesterone impregnated sponges (C), C+PMSG (D)

Parameter	Age group (year)	Control A	Treatments		
			B	C	D
No. of does inseminated/handmated		4	9	10	9
Does returning to service (Day 30–60 after insemination)	1.5–2	—	1	2	—
	2–3	—	—	1	—
	4–5	1	1	—	1
Mean for group (%)		1(25%)	2(22.2%)	3(30%)	1(11.1%)
Conception rates (Day 30–60 after insemination)	1.5–2	1	2	2	4
	2–3	2	2	2	1
Mean for group (%)	4–5	3(75%)	7(77.8%)	7(70.35%)	8(88.9%)
Pregnancy rates (3–10 weeks RIA)	1.5–2	—	1	—	—
	2–3	—	2	2	1
	4–5	—			
Mean for group (%)			5(55.6%) [a]	4(40%) [b]	3(11.1%) [a]
Fertility rate(%)			55.5	40	33
Fecundity rate (%)			88.8	60	55.5
Prolificacy rate			160.0	150	166.6
Kidding rate			100	100	10
Litter size			1.6	1.5	1.6

[a,b] Values in rows denoted by different superscripts differ significantly ($P<0.05$).

The patterns of progesterone concentration in the serum of does following insemination were determined using RIA kits. In the pregnant does, the serum progesterone level began at 2 ng/ml, then increased to 13.2 and 23.6 ng/ml. However, this technique could not distinguish between pseudopregnancy and prolonged luteal phase. On the other hand, progesterone profile of non-pregnant cycling does began like that of the pregnant ones, but fell sharply ($\leq$2 ng/ml) indicating the return to oestrus. The profile of cyclic does showed low progesterone concentration (0.03 ng/ml) which was maintained throughout the period of observation (10 weeks).

4. Discussion

The three treatments used in this study were found to induce oestrus in Sudanese Nubian goats. The 100% response obtained with Treatment B (Cloprostenol) could be attributed to the rapid fall of progesterone concentration as suggested by Acritopoulou et al. (1977). These results were in agreement with those obtained in goats (93.8%) by Fairnie et al. (1977). However, the dose (125 μg) in this study was lower than the 250 μg recommended. Synchronization of oestrus using impregnated progesterone sponges (Treatment C) showed similar results (oestrous response, 70%) obtained in sheep (Gordon, 1975). However, the response in Black Bengal goats was 100% (Ishwar and Pandey, 1992), indicating other managerial factors and not only dose progesterone concentration in the intravaginal sponge as synchronization criteria. Optimal fertility was likely to be associated with minimal doses of 30–100 mg progesterone (Lamond, 1964; Gordon, 1971).

The aim of injecting PMSG (300 I.U.) in treatment D, was to synchronize and induce ovulation. It resulted in a 77.7% oestrous response, which was better than that reported by Rosnina et al. (1992) in

tropical goats during the rainy months (50%) and dry months (37%). The use of PMSG in this study resulted in a more predictable occurrence of oestrus which was consistent with the observation of Bongso et al. (1982).

The interval from the end of the second injection of Cloprostenol treatment to the onset of oestrus obtained in the present study (52 h) was in line with that reported (55 h) by Greyling and VanNiekerk (1980) at a 14-day interval. However, other studies showed longer (100 h) intervals (Pandey et al., 1985) or shorter (37–43 h) durations (Akusu and Egbunike, 1990) at 11-day intervals between injections.

The interval from removal of intravaginal progesterone impregnated sponges to onset of oestrus in this study (53 h) was found to be much shorter, when compared to those reported by Ishwar and Pandey (1992) in Black Bengal goats (95–137 h) and by Doijode et al. (1992) in Angora goats (80 h). These variations might be due to breed effect (Thorburn et al., 1969; Bindon et al., 1975; Quirke and Gosling, 1976) as well as nutrition (Lamond et al., 1972) which are both known to have an influence on progesterone level (Karsch et al., 1983).

The mean duration of the induced oestrous periods ranged between 38 h (Treatment C) and 52 h (treatments B and D). Variation between treatments regarding duration of oestrus might be due to the amount of oestrogen in the blood produced by induced luteolysis (Treatment B) or mild superovulation (Treatment D) as oestrogen level in blood is presumed to bring the animal into oestrus and has a depressing effect on progesterone (Mirskaria et al., 1941). As such, it appeared that high levels of serum oestrogen concentrations might be responsible for the prolonged duration of oestrus observed in this study. This result was consistent with the one previously reported by Kudouda (1985) in Sudanese Nubian goats (912–48 h) and was within the mean duration oestrus period of the goats in the tropics (17–48 h) reported by Devendra and Burns (1970).

Conception rates obtained in Treatment B (Cloprostenol) were in agreement to those reported by other authors (Costa et al., 1983; Akusu and Egbunike, 1984; Pandey et al., 1985) by administration of two injections Cloprostenol 14 days apart, but were contradictory to results obtained by Simplicio and Machado (1991) when the two injections were given 11 days apart. The interval between injection of Cloprostenol and its ability to lower progesterone concentration within a few hours (Acritopoulou et al., 1977) might stand as a reasonable justification for the fertility results obtained in the current study.

The treatments employed in the present study had a significant ($P<0.05$) effect on the pregnancy rate obtained. However, the lower pregnancy rate encountered with Treatment D (55.5%) at Day 90–100 following AI compared with the high conception rate monitored at Day 30–60 following AI (88.9%) might be attributed to high embryonic resorption. These losses might have occurred due to the inability of the uterus to support more than the limited number of embryos (Robinson, 1989).

Monitoring the circulating serum progesterone levels of post-inseminated goats using RIA was indicative of the reproductive status of the does. Does that exhibited serum progesterone concentrations $\approx$2 ng/ml and maintained these elevated levels during the prescribed period (3–10 weeks post-insemination) were considered to be pregnant and confirmed to be so after kidding. However, the RIA results were less reliable (37.5%) than the pregnancy rate diagnosed by abdominal palpation (64%). The serum progesterone concentration considered for positive pregnancy diagnosis is 2 ng/ml as reported by Restall et al. (1990) and Llewelyn et al. (1995). It can, thus, be concluded that the RIA technique in monitoring serum progesterone profiles could give satisfactory information about the reproductive performance in Nubian goats. However, it cannot differentiate between pseudopregnancy or an extended luteal phase.

This study confirmed that all the treatments employed induced and synchronized oestrus in the Sudanese Nubian goats with Cloprostenol treatment showing significant ($P<0.05$) response. The Interval from treatment to onset of oestrus did not differ much from treatments; and the durations of oestrus period were significantly different between treatments ($P<0.05$), but close to the mean range of goats in the tropics. Furthermore, the characteristic reliable signs of oestrus and the frequencies of their manifestation were not altered by the treatments applied.

The application of Cloprostenol in two doses of 125 μg given 13 days apart was easier to use and can be applied by an ordinary goat keeper. It has the merit of being easily applicable to a large flock of variable

ages with minimal time and labour. Intravaginal progesterone impregnated sponges with, or without PMSG were easier to apply in parous females than non-parous ones, however, they involved both labour and strict hygienic measures during application. The actual pregnancy rate diagnosed by RIA and verified by kidding (12–37.5%) was less than that obtained by abdominal palpation (22–64%). The type of kidding showed the possibility of getting twins and triplets in older than in younger does. Fertility, fecundity and prolificacy rates have shown far better reproductive performance with Treatment B compared to that of treatments C or D.

References

Acritopoulou, S., Haresign, W., Foster, J.P., Lamming, G.E., 1977. Plasma progesterone and LH concentration in ewes after injection of an analogue of prostaglandin. J. Reprod. Fertil. 49, 337–340.

Akusu M.O., Egbunike, G.N., 1984. Fertility of the West-African Dwarf goat in its native environment following $PGF_{2\alpha}$ induced oestrous. Vet. Quart. 6(3), 173–176 (Abst).

Akusu, M.O., Egbunike, G.N., 1990. Effects on oestrous duration of West-African Dwarf goats. Small Rumin. Res. 3, 413–418.

AOAD, 1994. Volume 14, AOAD Printing Press – Khartoum.

Bindon, B.M., Blanc, M.R., Pelletier, J., Terqui, M., Thiomonier, J., 1975. Preovulatory gonadotrophin and ovarian steroid changes in French sheep breeds different in fecundity. Does FSH Stimulate follicles. Proc. Endoc. Soc. Aust. 18th Annual Meeting 18, 64.

Bongso, T.A., Fatimah, I., Dass, S., 1982. Synchronization of Oestrous of goats treated with progestagen-impregnated intravaginal sponges and PMSG, and reproductive performance following natural mating or A.I. with frozen semen. J. Anim. Reprod. Sci. 5, 111–116.

Boshoff, D.A., 1980. Limitation of multiple ovulations in Karakul ewes after the use of PMSG. Ph.D. Thesis. (Cited by Bongso et al. 1982).

Britt, J.H., 1984. Limitation on the pharmacological control of reproduction, proc. 10th Inter. Congr. of Anim. Reprod. and A.I., IV-31.

Charring, J., Humbert, J.M., Levis, J., 1992. Manual of Sheep Production in the Humid Tropics of Africa. C.A.B. International, pp. 144.

Corteel, J.M., 1975. The use of progestagens to control the oestrous cycle of the dairy goat. Ann. Biol. Animal Biochem. Biophys. 15, 353–363 (Cited by Bongso, et al., 1982).

Costa, S.A.D.A., Francsa, M.P., Vinha, N.A., 1983. A.I. of indigenous goats with frozen semen following oestrous synchronization with $PGF_{2\alpha}$. Anim. Breed Abst. 51, 1–12.

Debendetti, A., Lucaroni, A., Malfatti, A., 1982. Induction of Synchronized oestrous in goats following the introduction of males after a period of separation (Buck effect). Anim. Breed. Abst. 54, 1–2.

Devendra, C., Burns, M., 1970. Goat production in the tropics. Commonwealth Bureaux of Animal Breed and Genetics, Tech. Comm. No. 19.

Devendra, C., McLeory, G.B., 1982. Goats and sheep production in the tropics. Longman Singapore Publishers London, UK, pp. 26, 37–45, 71.

Doijode, S.V., Bakshi, S.V., Bakshi, S.A., Pargaonkar, O.R., Markandeya, N.M., 1992. Studies on synchronization of oestrous in does. Anim. Breed. Abst. 60(9), 5811.

Evans, G., Maxwell, W.M.C., 1987. Salamon's artificial insemination of goat and sheep. Butterworths 75, 85–116.

Fairnie, I.J., Wales, R.G., Gherardi, P.B., 1977. Time of ovulation, fertilization rate and blastocyst formation in ewes following treatment with prostaglandin analogue ICI 80996. Theriogenology 8, 183–185.

FAO, 1992. Production year book, Volume 46. Statistical series no. 112 ISSN, 7118-0071, Rome, Italy.

Goding, J.R., 1974. Demonstration that $PGF_{2\alpha}$ is the Uterine Luteolysing agent in the ewe. J. Reprod. Fertil. 38, 261–271.

Gordon, I., 1971. Induction of early breeding in sheep by Standard and Modified Progestagen PMSG treatment. J. Agric. Sci. (Camb.) 76, 337–342.

Gordon, I., 1975. The use of progestagen in sheep breed by natural and A.I. Ann. Biol., Anim. Bioch. Biophys. 15, 303–316.

Greyling, J.P.C., VanNiekerk, C.H., 1980. Synchronization of oestrous in the Boer goat doe: Dose effect of $PGI_{2\alpha}$ in the double injection regime. S. Africa J. Anim. Sci. 6, 146–150 (Abst).

Hassan, N.I., El Derani, O.H., 1990. Goat resources in the Arab World 2. Republic of Sudan.

Ishwar, A.K., Pandey, J.N., 1992. Oestrus synchronization and fertility in Black Benegal goats following administration of progesterone and govadotropins. Res. Vet. Sci. 52(2), 141–146.

Karsch, F.J., Foster, D.L., Bittman, E.L., Goodoman, R.L., 1983. A role of oestradiol in enhancing luteinizing hormone pulse frequency during oestrous cycle in sheep. Endocr. 113, 1333–1339.

Kudouda, M.M., 1985. Growth, Reproduction and Productive Performance of Sudanese Nubian Goats. M.V.Sc. Thesis. University of Khartoum.

Lamond, D.R., 1964. Synchronization of ovarian cycle in sheep and cattle. Anim. Breed. Abst. 32, 269–285.

Lamond, D.R., Gaddy, R.G., Kennedy, S.W., 1972. Influence of season and nutrition on plasma progesterone in rambouillet ewes. J. Anim. Sci. 34, 626–629.

Llewelyn, C.A., Ogoa, J.S., Obwolo, M.J., 1995. Influence of season and housing on ovarian activity of indigenous goats in Zhimbabwe. Trop. Anim. Hlth & Prod. 27, 175–185.

McNitt, J.I., 1983. Livestock, Husbandry Techniques. Granada. Publ. Ltd. Frogmore St. Albans and London, pp. 95.

Mirskaria, L.M., Smirnov, Ugrjumov, D.V., 1941. Heat during pregnancy, Vet. Rec. 55(31) 297–298.

Pandey, J.N., Ishwar, A.K., Singh, R.A., 1985. Oestrous synchronization in goats using prostaglandin (lutealyse). Indian. J. Anim. Sci. 55(7), 551–552.

Quirke, J.F., Gosling, J., 1976. Progesterone levels throughout the oestrous cycle in three ewe breeds with different ovulation rates. Proc. 8th, Intern. Congr. Anim. Reprod. A.I., Kracow.

Restall, B.J., Milton, J.T.B., Klong-Yutti, P., Kochapokde, S., 1990. Pregnancy diagnosis in Thai native goats, Anim. Breed. Abst. 58(12).

Robinson, T.J., 1989. Programmed year round sheep breeding. Aust. J. Exp. Agric. Anim. Husb. 20, 667–673.

Rosnina, V., Jainudeen, M.R., Nahayah, M., 1992. Superovulation and egg recovery in goats in the tropics. Vet. Res. 130(5), 97–99.

Simplicio, A.A., Machado, R., 1991. Fertility of dairy goats subjected to oestrous synchronization and insemination at a predetermined time. Ann. IX Congr. of Brazilian Anim. Reprod., vol. II, pp. 351.

Snedecor, G.W.L., Cochran, W.G., 1967. Statistical methods (6th edn.), Iowa: the Iowa State University Press, 593 pp.

Sulieman, A.H., El Shafei, S.A., 1984. A note on the performance of Sudanese Nubian Goats compared with exotic group of British dairy goats. Sud. J. Vet. Sci. Anim. Husb. 24, 101–104.

Thorburn, G.D., Bassett, J.M., Smith, I.D., 1969. Progesterone concentration in the peripheral plasma of sheep during the oestrous cycle. J. Endocr. 45, 459–469.

Thwaites, C.J., 1971. Exogenous progesterone and oestrous cycle length in the ewe. J. Agric. Sci. Camb. 77, 147–149.