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Level and Effect of Inbreeding in a Flock of Horro Sheep at Bako Research Center

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Abstract

Levels of inbreeding were calculated in a flock of Horro sheep kept at Bako Research Center during the period 1978-1997. Using regression methods, the effect of lamb and dam inbreeding level on weight at birth (BW), at weaning (WW), at six month (6MW) and one year (YW) of age, on survival to different ages (3 and 7 days and one, three, six and 12 months) and on litter size at birth were studied. Flock average inbreeding coefficient during the study increased to more than 2% in the year 1991 and decreased thereafter. Proportion of inbred animals also increased to about 81%. Regression of performance on inbreeding showed that 1% increase in inbreeding coefficient of the lamb resulted in a decrease in weight of -4, 6, 31 and 103g in BW, WW, 6MW, and YW, respectively. Except for YW which approached significant level (p=0.06) all effects were not significant. A percent increase in inbreeding coefficient of the dam has also resulted in a decrease in BW, WW, 6MW, and YW of -1, -4, 33 and 33g, respectively. All were not significant. The effect of individual and dam inbreeding on litter size at birth was also not significant (p>0.05). Significant (p<0.05) negative effect of both individual and dam inbreeding was observed on survival to 30 days of age. Dam inbreeding has also a significant (p<0.05) effect on survival to yearling. Effects on survival to other growth stages were all non significant. Analysis from categorization of inbreeding levels indicated that higher levels of inbreeding are detrimental. In spite of the low level of inbreeding in the current study there are some significant and non-significant negative trends due to inbreeding. Thus it is advisable to avoid particularly higher levels of inbreeding.

Keywords: Inbreeding level, inbreeding depression, growth traits, survival, litter size.

Introduction

In the smallholder sheep production keeping rams in small flocks to which they are related is common. Due to this it is likely that there exists high level of inbreeding. Economic importance of inbreeding in sheep has been shown in a number of works (e.g. Lamberson and Thomas, 1984; Ercanbrack and Knight, 1991). Under the management conditions existing in the smallholder production system selection within the indigenous breed seem better means of improvement than importing exotic germ plasm. Selection increases inbreeding. There exists breed variation in the effect of inbreeding on different traits (Ercanbrack and Knight, 1991; Boujenane and Chami, 1997).

Work on characterization of Horro sheep breed has been since 1977 at Bako Research Center. Though effort was made to avoid close inbreeding, due to the small size of the flock and due to the flock being closed for a long period of time it was not possible to avoid inbreeding completely. Recent work (Solomon and Gemeda, 2000) on analysis of the data from the Horro sheep characterization study has shown that there are declines, though not systematic, in growth performance, survival and reproductive performance. This study was done to determine the level and effects of inbreeding on early growth performance, survival and litter size.

Materials and Methods

Animals and Management

Data used in this study was collected from a flock of Horro sheep kept at Bako research center during the period 1978-1998. The flock was established with 100 ewe lambs (all milk teeth but some of them were pregnant when procured) and 4 rams purchased from different local markets around Shambo, Western Ethiopia. The sheep management was semi-intensive in that sheep grazed out-doors during the day (08:00 a.m.-08:00 p.m.) and were housed during the night in pens with bamboo walls and corrugated metal sheet roofs. The flock grazed natural pasture throughout the year with the exception of the mating period when they were kept indoor and fed on concentrates and hay.

Except during mating periods the ewe and ram flocks were housed and herded separately. Throughout the period of this study (1977-1997), controlled single-sire mating was practiced. The mating period usually lasted for about 42 days (minimum of two oestrous cycles). With the exception of part of the flock mated thrice during the years1982 to 1985 for study on frequency of lambing and another subset mated at nine months intervals between 1989 and 1991 for selection on yearling weight, mating generally occurred from mid November to early January for lambing in April and May. During mating, about 20 (occasionally 10-25) ewes were assigned to each ram based on a random procedure after they were stratified by age. With the exception of 1989 to 1990, there was no genetic selection. In the years 1989 and 1990 two groups of rams were used: one group comprised rams selected for yearling weight (to be mated with selection group ewes) while the other comprised rams of medium yearling weight (to be mated with a control group of ewes). The selection differential was low (2 to 3 kg) due to the small number of rams available for selection (low intensity of selection). Additionally correction of the data was done only for type of birth. Ewe lambs were culled and rams were also chosen before mating based on visual appraisal. At times, rams kept as stand-by were used to replace those with poor libido. The pedigree of each ram was checked for close relationships (closer relation than great grand parent) with the ewes in their respective groups. When such relationships exist ewes were switched between groups based on similarity in age and weight. The introduction of stand by rams, at times, resulted in some relationships to occur between some of the ewes in that group and the newly introduced ram. The flock was largely closed until 1994 when rams and some ewe replacements were bought from outside. Ewes were culled if they were found to be chronically sick, or aged. But culling for infertility or other lamb production traits was not practiced. Except in the first two years when rams were used for the second year all rams were used only once. Ewes were used repeatedly until they were culled or dead.

Data Collection

A total of 4031 lambing records from 184 sires and 904 ewes were used in this study. Body weight measurement was taken once every four weeks for the total flock and fortnightly for lambs up to weaning age. All body weight measurements were taken in the morning after fasting the animals overnight (13-15 hr.). With the exception of monthly weights for three consecutive months in 1991 (which were not available), growth, reproduction and survival data recorded during the period 1978 to 1997 was used. Weaning weights were recorded at an average age of 92.5±0.13 days with a range of 70 to 110 days while six month weights were taken at the age of 184.4±0.26 days with a range of 150 to 210 days. For yearling weight the average age was 366.3± 0.31 days with a range of 322 and 408 days.

A score of unity or two was given to the ewe, which gave birth to single or multiples (twins or triplets), respectively. Triplets were rare in the data (33 out of 4031 lamb records) and were put in the same category along with twins. Type of rearing was scored as 1 for lambs born single and reared as single, 2 for lambs born twin and reared with the twin mate at least to 45 days of age and 3 for lambs born twin and the twin mate died before the age of 45 days. Ewe age was categorised into 7 classes in the analysis of litter size while parity was categorized into 5 classes in the analysis of survival and growth performance. Survival was coded as 0 for lambs died before a specified age and 1 otherwise.

Statistical Analysis

Inbreeding coefficients were calculated from the relationship matrix used in animal model analysis by the Average Information Restricted Maximum Likelihood (AIREML) program of Gilmour et al. (1995). All animals present in 1978 were assumed to be unrelated. Inbreeding coefficients of lambs and dams were merged in the data analysis of lamb growth, survival and birth type. Effects of inbreeding were estimated by analysing performance data with inclusion of inbreeding coefficients of the lamb and the ewe in the model as linear covariates. The model used to analyse the effects of inbreeding on growth performance included the fixed effects of year, parity, type of rearing (litter size for birth weight) and sex, and age at measurement (Julian birth day for birth weight) and inbreeding coefficient of the lamb and the dam as covariates. In the analysis of litter size fixed effects of year of birth and ewe age were included in the model along with inbreeding coefficients of the individual lamb (foetus) and dam. A model similar to that of growth performance was used in the analysis of survival to different ages but parity was replaced by ewe age, and BW was included as covariate and litter size was used in all cases. In a separate analysis inbreeding coefficients of the lamb and the ewe were categorised into two ($F=0$ and $F>0$) classes. To see the effect of different levels of inbreeding, inbreeding coefficients of the lamb and the dam were categorised into 3 classes ($F=0$, $0<F\leq3$, and $F>3$).

Results

Level of Inbreeding

Average inbreeding coefficients during the study period are shown in Table 1. The overall average inbreeding coefficient was 0.78% and the annual average increased to more than 2% in the year 1991 and decreased thereafter. The proportion of inbred animals in each year also showed increase to as high as 81 per cent in 1990 and then decreased to zero in the year 1996. Annual increases in average inbreeding coefficient of the total and inbred animals, and in the proportion of inbred animals was 0.07 ± 0.0129, 0.37 ± 0.173 and 3.04 ± 0.6 per cent, respectively. All of the values were statistically significant ($p<0.05$).

Effect of Inbreeding

Further analysis on the effect of individual and dam inbreeding on lamb growth, lamb survival and on litter size showed that 1% increase in inbreeding coefficients of the lamb resulted in an increase of 4 g in birth weight and a decrease of 6, 31 and 103 g in weaning, six month and yearling weight (Table 2). With the exception of yearling weight which approached significant level ($p=0.06$) all the effects were non-significant. A per cent increase in inbreeding coefficients of the dam has also resulted an increase of 1 and 4 g in birth and weaning weight, respectively, and a decrease of 33 g in each of 6MWT and YWT. All effects were non-significant ($p>0.05$). The effect of individual lamb (foetal) and dam inbreeding on litter size at birth was also found to be non-significant. Survival to 30 days of age was found to be significantly affected by both individual ($p<0.05$) and dam ($p<0.01$) inbreeding coefficients while survival to 1 year of age was also affected by dam regression coefficient (p<0.05). Survival to other ages studied was not affected by either of the coefficients.

Table 1. Annual average coefficient of inbreeding for the total flock, and for the inbred animals and proportion of inbred animals in each year (1978-1997)

Year of birth	No. of animals	Average inbreeding coefficient (%)	Proportion of inbred animals (%)	Average inbreeding Coefficient of inbred animals (%)
Overall average	3697	0.78	31.6	2.5(3.25)
1978	96	0.00	0.00	0.0
1979	184	0.14	0.54	25.0(-)
1980	218	0.46	2.75	16.7(6.45)
1981	286	0.26	4.20	6.3 (2.31)
1982	267	0.95	11.24	8.6(5.55)
1983	207	0.44	8.70	5.1(3.17)
1984	162	0.43	12.96	3.3(2.89)
1985	116	0.81	35.34	2.3(2.28)
1986	203	0.93	43.35	2.2(1.73)
1987	170	0.81	64.71	1.2(1.32)
1988	253	1.13	71.94	1.6(1.76)
1989	273	1.56	68.50	2.3(2.86)
1990	367	1.86	80.65	2.3(2.53)
1991	122	2.18	64.75	3.4(4.93)
1992	147	1.14	63.54	2.7(3.64)
1993	118	1.34	61.86	2.2(2.15)
1994	98	0.74	60.20	1.2(0.99)
1995	103	0.05	4.85	1.5(0.67)
1996	134	0.00	0.00	0.0
1997	173	0.13	0.58	25.0(-)
P-value [a)]		0.001	0.001	0.047
Regression (± S.E.) on year		0.070 ±0.0129	3.044 ±0.6002	0.366 ±0.1727

[a)] = F-test for effect of year

Table 2. Partial regression coefficients (±S.E.) of weights at different stages, litter size and survival to different growth stages on lamb and dam inbreeding

Trait	N	Lamb regression coefficient	Dam regression Coefficient
Birth weight (kg)	3696	0.0035±0.0040	0.0012±0.0048
Weaning weight (kg)	2801	-0.0063±0.0230	0.0036±0.0253
Six month weight (kg)	2220	-0.0308±0.0324	-0.0330±0.0332
Yearling weight (kg)	1440	-0.103±0.0534	-0.0329±0.0541
Litter size	3697	0.0009±0.0035	-0.0016±0.0041
Survival to 3 days	3657	-0.0003±0.0018	0.00005±0.0021
Survival to 7 days	3657	-0.0009±0.002	-0.0020±0.0024
Survival to 30 days	3656	-0.0054±0.0024*	-0.0084±0.0028**
Survival to weaning	3627	0.0009±0.0029	0.0054±0.0035
Survival to 6 month	3485	0.0014±0.0034	-0.0040±0.0039
Survival to 1 yr of age	2912	0.0013±0.0036	-0.0103±0.0043*

* P<0.05 ** P<0.01 for means within a row.

Categorising the data into inbred and non-inbred classes has shown that, although most of these were not statistically significant, inbred lambs had better performance than non inbred lambs in almost all the traits considered and lambs from inbred dams had slightly lower performance than lambs from non-inbred dams in some of the traits (Table 3). The regression of performance on inbreeding coefficient was always very small in value and in most cases negative. This was found to contradict the result of the analysis from categorizing the data into inbred and non-inbred animals. An explanation for the contradiction was sought through a separate analysis where inbreeding coefficient of the lamb and the dam was categorised into three. This analysis showed that in most cases the effect of inbreeding of the lamb was positive at low levels and negative at higher levels (Table 4). There was no systematic effect in the case of dam inbreeding levels (Table 5).

Table 3. Least square means (±S.E.) of performance of inbred and non-inbred lambs and lambs from inbred and non-inbred dams.

Trait	N	Lamb		Ewe	
		Non-Inbred	Inbred	Non-Inbred	Inbred
Birth weight (kg)	3696	2.57±0.013	2.68±0.020**	2.63±0.012	2.61±0.022
Weaning weight (kg)	2801	11.78±0.108	12.02±0.13	11.82±0.09	11.99±0.14
Six month weight (kg)	2220	15.44±0.16	15.48±0.19	15.57±0.14	15.4±0.20
Yearling weight (kg)	1440	23.99±0.27	24.18±0.32	23.8±0.24	24.4±0.35
Litter size	3697	1.44±0.012	1.49±0.017*	1.46±0.012	1.47±0.018
Survival to 3 days	3657	0.93±0.007	0.94±0.009	0.94±0.006	0.93±0.009
Survival to 7 days	3657	0.91±0.007	0.93±0.010	0.92±0.007	0.91±0.011
Survival to 30 days	3656	0.87±0.008	0.86±0.012	0.88±0.008	0.86±0.013
Survival to weaning	3627	0.73±0.011	0.77±0.015*	0.76±0.01	0.74±0.015
Survival to 6 month	3485	0.59±0.012	0.65±0.017**	0.64±0.012	0.61±0.017
Survival to 1 yr of age	2912	0.44±0.014	0.50±0.019*	0.49±0.013	0.44±0.019*

* P<0.05 **P<0.01 for means within a row.

Table 4. Least square means (±S.E.) of performance of lambs of different inbreeding levels

Trait	Class of lamb inbreeding[a b]		
	1 (N)	2 (N)	3 (N)
Birth weight (kg)	2.63±0.019 (2423)	2.75±0.026 (972)	2.66±0.037*** (301)
Weaning weight (kg)	11.8±0.12 (1844)	12.1±0.15 (740)	11.7±0.20* (217)
Six month weight (kg)	15.4±0.17 (1511)	15.7±0.22 (538)	14.9±0.288* (171)
Yearling weight (kg)	24.0±0.30 (888)	24.6±0.37 (428)	23.4±0.47* (134)
Litter size	1.44±0.015 (2424)	1.50±0.021 (972)	1.45±0.03* (301)
Survival to 3 days	0.93±0.008 (2390)	0.95±0.01 (968)	0.93±0.02 (299)
Survival to 7 days	0.90±0.009 (2390)	0.94±0.012 (968)	0.89±0.017* (299)
Survival to 30 days	0.85±0.011 (2389)	0.87±0.015 (968)	0.81±0.020* (299)
Survival to weaning	0.72±0.013 (2367)	0.77±0.018 (963)	0.72±0.025* (297)
Survival to 6 month	0.58±0.015 (2261)	0.65±0.020 (934)	0.61±0.028** (290)
Survival to 1 yr of age	0.42±0.016 (1812)	0.49±0.023 (843)	0.46±0.031* (257)

[a] 1) F=0 2) 0<F≤3 3) F>3 [b] number of lambs within a class in parenthesis

* P<0.05 ** P<0.01 *** P<0.001 for means within a row.

Table 5. Least square means (±S.E.) of performance of dams of different inbreeding levels

Trait	Class of dam inbreeding[a b]		
	1 (N)	2 (N)	3 (N)
Birth weight(kg)	2.69±0.016 (2828)	2.67±0.029 (671)	2.68±0.039 (218)
Weaning weight(kg)	11.8±0.11 (2208)	12.1±0.17 (443)	11.8±0.21 (150)
Six month weight(kg)	15.5±0.16 (1820)	15.3±0.24 (291)	15.2±0.293 (109)
Yearling weight(kg)	23.6±0.26 (1137)	24.3±0.43 (228)	24.1±0.51 (77)
Litter size	1.44±0.015 (2828)	1.50±0.021 (671)	1.45±0.03* (218)
Survival to 3 days	0.94±0.008 (2828)	0.93±0.011 (671)	0.93±0.02 (218)
Survival to 7 days	0.92±0.008 (2828)	0.91±0.013 (671)	0.90±0.019 (218)
Survival to 30 days	0.87±0.010 (2827)	0.86±0.015 (671)	0.80±0.023* (218)
Survival to weaning	0.75±0.012 (2779)	0.75±0.019 (635)	0.72±0.028 (213)
Survival to 6 month	0.64±0.014 (2659)	0.62±0.021 (615)	0.59±0.031 (211)
Survival to 1 yr of age	0.49±0.016 (2185)	0.46±0.023 (544)	0.42±0.034* (183)

[a] 1) F=0 2) 0<F≤3 3) F>3 [b] Number of records from dams in a class in parenthesis

* P<0.05 for means within a row.

Discussion

Overall the level of inbreeding was low. However the proportion of inbred animals has risen to more than 80%. This is due to the mating design followed where pedigrees were checked for close relationship. The flock was kept closed until 1994 when some ewe and ram replacements were purchased from outside. Due to the small size of the flock and because it was kept closed for long, some relationship in most of the mates was likely to exist. The low level of inbreeding may explain why the effect of inbreeding in most cases was not significant. From a number of studies (Boujenane and Chami, 1997; Wiener et al., 1992a; Ercanbrack and Knight, 1991) it was shown that individual inbreeding could have sizeable effect when inbreeding levels are greater than 15%. In the current study the inbreeding level for inbred animals was 2.5%.

The regression analysis showed that there were non-significant effects (mostly negative) of inbreeding on performances evaluated. Values ranging from –14 to –2 g have been reported by Ercanbrack and Knight (1991) for the effects of individual inbreeding on lamb birth weight in Rambouillet, Targhee, and Columbia breeds. Boujenane and Chami (1997) reported values of 0.1 g and -6.1 g for effect of one percent of individual level of inbreeding on birth weight in Sardi and Beni Guil sheep, respectively, while Van Wyk et al. (1993) reported a reduction of 8 g in BW of Dormer sheep for 1% increase in level of inbreeding of the individual lamb. Analla et al. (1998) reported 11 to 76 g reduction in BW of various lines of Merino sheep. A review by Lamberson and Thomas (1984) revealed a range of -29 to 22g reduction in BW by one per cent rise in individual level of inbreeding. In the current study the figure obtained was low and positive but falls within the range reported by Lamberson and Thomas (1984). Other studies in sheep (Analla et al., 1999; Mirza et al., 1999) and in cattle (Pariacote et al., 1998) also reported on the effect of individual inbreeding on WW. Van Wyk et al. (1993) reported a reduction of 99g in WW in Dormer sheep while Boujenane and Chami (1997) reported an increase of 6g and a decrease of 45g per 1% rise in inbreeding in Sardi and Beni Guil sheep, respectively. Ercanbrack and Knight (1991) reported that there was a decrease of 59g for each 1% increase in inbreeding coefficients. The result in the current study showed lower decrease in WW than in most reports but in similar direction and it also falls within the range of –177g to 36g reported in the review of Lamberson and Thomas (1984).

Numerically the effect of dam inbreeding on WW in the current study was positive, though statistically not significant, but with relatively small value while the effect of individual inbreeding was negative. The effect of inbreeding of the dam on lamb growth is largely a result of a poorer supply of milk to their lambs (Wiener et al., 1992a). The positive effect of dam inbreeding on WW in the current study is inexplicable and could be a result of chance occurrence due to the low level of inbreeding. Lax and brown (1967; cited by Lamberson and Thomas, 1984) reported similar small positive effect of dam and larger negative effect of individual inbreeding for female Merino sheep. Effects of individual and dam inbreeding on 6-month weight were reductions of 31 and 33g, respectively, while for yearling weight the reductions were 103 and 33g, respectively. From a review work on a number of sheep breeds Lamberson and Thomas (1984) reported reductions of 25 to 272g in post-weaning body weight per 1% increase in individual inbreeding; the inbreeding depression on six month and yearling weight in the current study for individual inbreeding falls in this range. Reports of dam inbreeding depression on post-weaning weight are rare in the literature. In the review of Lmaberson and Thomas (1984) there was only one source (Lax and Brown, 1967) who reported reduction in post-weaning weight male animals but increase of this variable in female animals. Doney (1966) reported lower mean values for weight from birth to about 4½ years of age of inbred than non-inbred Blackface sheep.

With the exception of survival to 30 days and to 1 year of age, inbreeding depression due to individual and dam inbreeding on litter size and other categories of survival was non-significant. Inbreeding affects fitness traits (reproduction and survival) more than it does on production traits, which is also reflected in the present study (Tables 2 and 3), whereby the effect of individual and dam inbreeding on some of the traits was found to be significant even at this low level of inbreeding while the effect on growth traits was not significant. Similarly, Galal et al. (1981) reported significant effect of lamb inbreeding on survival to 7 and 120 days of age. Even though the average level of lamb inbreeding in the work of Galal et al. (1981) was 12% which is much higher than the level of inbreeding in the current study, there was similarity in the presence of significant inbreeding depression on survival to weaning. Significant inbreeding depression of dam on survival of lambs to 1 month of age was observed in ewe groups with inbreeding coefficients of greater than 3%. Krystyna et al. (1990) also observed increase in lamb losses during the first month of their life in the group of ewes with inbreeding levels of over 5%. In the same work the effects of dam inbreeding on survival to different ages have shown a negative trend but all were non-significant, unlike the observations in the current study. Van Wyk et al. (1993) and Boujenane and Chami (1997) reported non-significant linear effect of individual (foetus) and dam inbreeding on pre-weaning lamb survival and litter size.

Evidence from Coltman et al. (1999) suggests that inbred animals are more susceptible to parasites. In the current study the effect of individual inbreeding was significant only on survival to one month of age. Lambs are hardly grazing to the age of one month and difference in susceptibility to parasite as a result of inbreeding cannot explain the significant effect of individual inbreeding on survival. With respect to litter size, Wiener et al. (1992b) reported significant effect of dam inbreeding on litter size but the level of inbreeding was much higher (F_D>0.25) than the level of inbreeding in this study.

The apparently better but statistically non-significant performance of inbred than non-inbred animals shows that the level of inbreeding in the current study is below the critical range. This was confirmed by the out come of the re-analysis of the data set after the inbreeding level was categorized into three levels (Tables 4 and 5). A similar higher performance of inbred than non-inbred animals in terms of milk production and BW was reported for Sahiwal cattle in Kenya (Rege and Wakhungu, 1992). The trend in performance on growth and viability observed in Table 4 that performance tends to improve at the medium level of inbreeding and drop at the high level suggests a curvilinear relationship between level of inbreeding and performance in growth and viability. A similar curvilinearity in the effect of inbreeding on economic traits was reported in beef cattle (Dinckel et al., 1968). Krystyna et al. (1990) also found decreased ewe prolificacy and lamb survival in the group of ewes with a highest inbreeding (>5% Vs. 2%-5% and =2%) though the results were not statistically significant.

Conclusion

The level of inbreeding in the current study is low and the effects were in most cases not significant. However, even at this low level there are indications that YW and survival could be negatively affected by inbreeding levels of the lamb and the dam. Under the traditional smallholder sheep production system, it is common that breeding rams came from the same flock. Due to small flock sizes the chance of build up of inbreeding is high, the consequences of which are hardly noticed in the production system. A system of ram exchange between villages and farmers could be considered as a remedial measure. While inbreeding depression at very low levels of inbreeding may have no or slightly positive effects, high levels of inbreeding are detrimental to production. The low levels of inbreeding are difficult to maintain at farm level since kinship is very close in small flocks. Thus, ram exchange should receive due attention and the exchange should take place before rams reach sexual maturity. Effects of inbreeding at levels which are expected to occur in the small flocks of the smallholder farmers are worth investigating.

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References

Analla, M., Montilla, J.M. and Serradilla, J.M. 1998. Analysis of lamb weight and ewe litter size in various lines of Spanish Merino sheep. *Small Rumin. Res.* 29:255-259.

Boujenane, I. and Chami, A. 1997. Effects of inbreeding on reproduction, weights and survival of Sardi and Beni Guil sheep. *J. Anim. Breed. Genet.* 114:23-31.

Coltman, D.W.; Pilkington, J.G.; Smith, J.A. and Pemberton, J.M. 1999. Parasites mediated selection against inbred Soay sheep in a free-living island population. *Evolution.* 53:1259-1267.

Dinckel, C.A.; Bush, D.A.; Minyard, J.A. and Trevillian, W.P. 1968. Effect of inbreeding on growth and conformation of beef cattle. *J.Anim. Sci.* 27:313-322.

Doney, J.M. 1966. Inbreeding depression in grazing Blackface sheep. Anim. Prod. 8:261-266.

Ercanbrack, S.K. and Knight, A.D. 1991. Effects of inbreeding on reproduction and wool production of Rambouliet, Targhee and Columbia ewes. *J. Anim. Sci.* 69:4734-4744.

Galal, E.S.E.; Afifi, E.A.; El-Kimaray, I.S.; Ahmad, I.A. and Shawar, A.F. 1981. Lamb survival as affected by inbreeding and cross breeding. *J. Agric. Sci.* 96:1-5.

Gilmour, A.R.; Thompson, R. and Culis B.R. 1995: Average information REML, An efficient algorithm for variance parameter estimation in linear mixed models. *Biometrics.* 51: 1440-1450.

Krystyna Charon , M., Qlech Wanda and Lewczuk Jarslaw. 1990. The effect of inbreeding on productivity of Polish Lowland sheep of the Zelana variety. *Proc. 4th Wld. Congr. Gen. Applied Livest. Prod.* XV:84

Lamberson, R.W., and Thomas, D.L. 1984. Effects of inbreeding in sheep: a review. *Anim. Breed. Abstr.* 52:287-297.

Lax, J. and Brown, G.H. 1967. The influence of maternal handicap, inbreeding and ewe's body weights at 15-16 months of age on reproduction rate in Australian Merinos. *Aust. J. Agric. Res*. 19:433.

Mirza, R.H.; Muhammed Abdullah; Intizar Ali and Riaz Hussain. 1999. Effect of inbreeding on body weight in Lohi sheep. *J. Animal and Plant Sciences* 9:25-27.

Pariacote, F.; Vleck, L.D.van and MacNeil, M.D. 1998. Effects of inbreeding and heterozygosity on preweaning traits in a closed population of Herefords under selection. *J. Anim. Sci*. 76(5):1303-1310.

Rege, J.E.O. and Wakhungu, J.W. 1992. An evaluation of long-term breeding programme in a closed Sahiwal herd in Kenya II. Genetic and Phenotypic trends and levels of inbreeding. *J. Anim. Breed. Genet*. 109(1992):374-384.

Solomon Abegaz and Gemeda Duguma. 2000. Genetic and phenotypic parameters of growth, reproductive and survival performance of Horro sheep at Bako Research Center. *Research fellowship report*. International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia.

Van Wyk, J.B., Erasmus, G.J. and Konstantinov, K.V. 1993. Inbreeding in the Elsenburg Dormer sheep stud. *S. Afr. J. Anim. Sci*. 23:77-80.

Wiener, G., Lee, G.J. and Woolliams, J.A. 1992a. Effects of rapid inbreeding and of crossbreeding of inbred lines on the body weight growth of sheep. *Anim. Prod*. 55:89-99.

Wiener, G., Lee, G.J. and Woolliams, J.A. 1992b. Effects of rapid inbreeding and of crossbreeding of inbred lines on conception rate, prolificacy and ewe survival in sheep. *Anim. Prod*. 55:115-121.