Between and within breed variation in lamb survival and the risk factors associated with major causes of mortality in indigenous Horro and Menz sheep in Ethiopia

E. Mukasa-Mugerwaa,1, A. Lahlou-Kassi a,2, D. Anindo a,3, J.E.O. Rege a, S. Tembely a,4, Markos Tibbo a, R.L. Baker b,*

aInternational Livestock Research Institute (ILRI), P.O. Box 5689, Addis Ababa, Ethiopia
bILRI, P.O. Box 30709, Nairobi, Kenya

Accepted 10 December 1999

Abstract

Data collected on 3256 lambs born to Horro and Menz breed ewes single-sire mated to 71 rams at the International Livestock Research Institute (ILRI) Debre Berhan station between September 1992 and June 1996 were analysed for rates of survival and growth from birth to weaning. A significantly lower proportion of Menz lambs died before 1 year of age (28%) than the Horro lambs (59%). Least squares means for pre- and post-weaning mortality were 8.8 and 19.3%, respectively in Menz, and 25.3 and 34.2% for Horro sheep. Major causes of death were similar in Horro versus Menz lambs and were pneumonia (53 vs. 54%, respectively), digestive problems (14 vs. 12%), endoparasite infections (9 vs. 13%), starvation–mismothering–exposure (SME) complex (10 vs. 7%) and septicemia (3 vs. 2%). Relationships among causes of mortality with breed, birth weight (BWT), season of birth, parity, litter size and lamb health category (number of times a lamb was sick between birth and 1 year of age) were determined. The impact of these factors on mortality varied with lamb age. Lambs that were born with <2 kg BWT had a greater risk of dying from any cause except pneumonia. But, even though Horro lambs were heavier than Menz at birth (2.4 vs. 2.1 kg, respectively), twice as many died before 1 year of age. The cause of mortality was further influenced by season of birth, lamb sex and health category. In addition, sires were a significant source of variation for progeny survival at 6, 9 and 12 months of age, but not at the younger ages. The best and worst Horro ram sired progeny groups that had mortality rates up to 1 year of age of 22 vs. 80%, respectively. The same estimates in Menz rams were 11 and 48%, respectively. Reduced mortality rate would significantly increase lamb output. However, isolated efforts to solve this problem are likely to have limited impact. Instead, an integrated approach to minimise the impact of underlying factors is advocated. Farm (animal) management routines that could be introduced in the short or longer term are discussed. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Lamb mortality; Causes; Risk factors; Sheep; Ethiopia

*Corresponding author. Tel.: +254-2-630743; fax: +254-2-631499. E-mail address: l.baker@cgiar.org (R.L. Baker)

1Present address: P.O. Box 3987, Kampala, Uganda.
2Present address: Institut Agronomique et Vétérinaire, Hassan II, B.P 6202 Instituts 10101, Rabat, Morocco.
3Present address: American Breeders Service International, P.O. Box 14821, Nairobi, Kenya.
4Present address: Central Veterinary Laboratory, BP 2295, Bamako, Mali.

0921-4488/00/$ – see front matter © 2000 Elsevier Science B.V. All rights reserved.
PH: S0921-4488(99)00152-2
1. Introduction

Sheep and goats (small ruminants) help to provide extra income and support survival for many farmers in the tropics and sub-tropics. It is projected that by the year 2025 small ruminants will account for half the red meat production in sub-Saharan Africa (Winrock, 1992). Reproductive performance in terms of the number of lambs weaned per ewe a year affects off-take rate and profitability since most animals are sold primarily for meat production. Compared with animals in temperate regions, the productivity of tropical sheep is currently low. This is partly because up to 50% of the lambs born can die before weaning (Gatenby, 1986; Wilson et al., 1993).

Lamb losses can be high during the perinatal period (Scales et al., 1986) due to adaptation failure, dystocia, cold stress, starvation and mismothering (Hinch et al., 1985). Older lambs also die from various infections causing pneumonia and diarrhea, malnutrition, predation and lethal congenital malformations. Diseases are a major cause of lamb mortality and low productivity in sheep (Yapi et al., 1990; Haughey, 1991). Inadequate nutrition influences the severity of several infections, particularly in young animals (MacRea, 1993; Van Houtert et al., 1995). Sheep in the tropics primarily graze natural pastures or utilise crop residues and their by-products, whose supply and quality fluctuate seasonally. Lamb mortality may vary due to location, birth type, year and season of birth (Traore et al., 1985; Wilson and Murayi, 1988), between and within breeds (Smith, 1977; Dalton et al., 1980) and among sire progeny groups (Knight et al., 1979). There are, however, no known published data on the variability in lamb survival among sire progeny groups in tropical sheep breeds.

The objectives of this study were to: (1) identify the major causes of ill-health and mortality for Menz and Horro lambs at the ILRI research station in the Ethiopian highlands; (2) determine the relationship between these causes and breed, birth weight, season of birth, season, dam parity, litter size, lamb sex and health category; and (3) investigate the association between mortality as a sire trait and lamb performance. This study was part of a larger experiment investigating genetic resistance to gastrointestinal nematode parasites in Menz and Horro sheep (ewes and lambs) synchronised to lamb in the wet or dry seasons (Tembely et al., 1998; Baker et al., 1998; Mukasa-Mugerwa et al., 2000).

2. Materials and methods

2.1. Animal types and study location

Data were collected on 3256 lambs born to Horro and Menz ewes from June 1992 to September 1996 at the ILRI Debre Berhan research station located 9°36’N and 39°38’E, 120 km north-east of Addis Ababa, Ethiopia at an altitude of 2780 m. The climate is characterised by a long rainy season (June to September) accounting for 75% of the annual rainfall, a short rainy season (February/March to April/May) and a dry season (October to January). Annual rainfall recorded at the station, averaged 970 mm over the study period. Mean, minimum and maximum temperatures were 6.2 and 18.8°C, respectively, and relative humidity was 60%. Ewes were 1–6 years old at mating with a mean body weight of 22.8 kg and a mean condition score of 2.5 on a 0–5 scale (Hossamo et al., 1986).

2.2. Animal nutrition, reproduction and health management

Ewes grazed together during the day on pastures dominated by Andropogon, Festuca and Pennisetum grasses mixed with Trifolium semense (a legume). Animals were housed at night in covered pens with free access to grass hay, water and mineral lick blocks. Ewes received 200 g/hd per day of a concentrate mixture comprising 33% noug cake (Guizotia abyssinica), 65.5% wheat bran, 1.0% limestone and 0.5% salt. The allowance was increased to 400 g/hd per day during the third trimester of pregnancy and during the peak of the dry season (from November to January). Before weaning, lambs had no access to feed other than what was fed to their dams. After weaning lambs grazed in separate sex groups and were fed 50–150 g/hd per day of the same concentrate until they were able to graze actively.

Ewes were mated after synchronised oestrus to deliver their lambs either in the wet (June to August) or dry (October to December) season. Ewes were mated in single-sire groups of 20–25 ewes to a ram.
of the same breed. Rams were subjected to a breeding soundness examination prior to each mating season. Each ram was used to produce progeny in one wet and one dry season and then ≈75% of the rams of each breed were replaced with new rams. Ten rams of each breed were used at each mating.

Sick animals were attended to and the date and cause of sickness recorded. This permitted the number of times lambs fell sick (health category) to be calculated. Animals were regularly drenched for liver flukes using either Fasinex® (Triclabendazole; Ciba Geigy, Switzerland) or Ranide® (Rafloxanide, MSD AgVet, Holland) and were vaccinated for pox, pasteurellosis and clostridial infection. Faecal samples collected monthly were used to determine worm eggs per gram (epg) counts and individual lambs with ≥2000 epg were treated with Panacur® (Fenbendazole, Hoechst, Germany) prior to weaning. At weaning all lambs were drenched. Between weaning and 1 year of age all lambs were drenched only when the mean faecal egg count for a group of monitor lambs exceeded 2000 epg. A resident veterinarian performed necropsies on dead animals.

2.3. Data collection and measurements

At the time of lambing, birth weight (BWT), sex, and litter size were recorded and lambs were ear-tagged. Lambs with BWT of ≤2, 2–3 and ≥3 kg were respectively categorised as light, medium and heavy. Causes of sickness or death were grouped into six categories as follows. (1) Starvation: related to starvation, mismothering and exposure (SME) complex and stillbirths. (2) Digestive: included gastro-enteritis, impaction, liver abscesses, peritonitis and bloat. (3) Respiratory: pneumonia and lung abscesses. (4) Endoparasites: included gastro-intestinal nematode parasites, coenurosis, fascioliasis and monesiasis. (5) Septicaemia: involved systemic infections and navel infection. (6) Other: included problems not specified above plus undiagnosed or unknown causes.

Lamb mortality rate was assessed as: (1) cumulative mortality — lambs born which died by 3 days, 7 days, 3 months, 6 months, 9 months and 12 months; and (2) survivor mortality — lambs that died of those surviving at the beginning of a given age period (0–3, 3–6, 6–9 and 9–12 months of age).

2.4. Statistical analysis

Lamb performance for BWT, average daily gain (ADG) from birth to weaning, weaning weight (WWT) and mortality (a binomial trait — alive or dead) at 3 and 7 days, 1, 3, 6, 9 and 12 months of age were analysed by mixed model least squares procedures (SAS, 1987). The statistical model included the fixed effects of breed (2 levels), parity (4 levels), year (4 levels), season of birth (2 levels), lamb sex (2 levels), litter size (2 levels) and sire within breed fitted as a random effect. Two way interaction terms were included in the final model when significant (p<0.05). In addition, lamb birth date and lamb age were fitted as linear covariates for BWT and WWT, respectively. Lamb mortality was calculated only for lambs born alive. Odds ratios (Yapi et al., 1990) were computed for lambs of a given breed, parity, litter, lamb sex, birth weight and health category (explanatory variables) likely to die from the different causes: starvation digestive; respiratory; endoparasitism; septicemia; and other (response variables).

3. Results

3.1. Lamb pre-weaning growth performance

Horro lambs were heavier than Menz lambs (2.4 vs. 2.1 kg, p<0.001) at birth. They also grew faster pre-weaning (67 vs. 61 g per day, p<0.001) and were heavier at weaning (9.4 vs. 7.9 kg, p<0.001). BWT increased significantly (p<0.001) from the first to third parity (2.0, 2.3 and 2.5 kg, respectively), was higher for lambs born as singles than multiples (2.6 vs. 2.0 kg, p<0.001) and was heavier for male than female lambs (2.3 vs. 2.2 kg, p<0.001). BWT did not vary significantly (p>0.05) among years but was higher for lambs born in the wet than dry season (2.5 vs. 2.1 kg, p<0.05).

Factors that significantly influenced BWT were also found to affect ADG and WWT. In particular, lambs born in the wet season grew faster (74 vs. 54 g per day, p<0.001) than their contemporaries born in the dry period and they also had heavier WWT (9.4 vs. 7.9 kg, p<0.001).

There was a breed×lambing season interaction for ADG and WWT (p<0.001), the ADG differences for Horro lambs born in the wet compared to the dry
interval being greater (80 vs. 54 g per day) than for the Menz (68 vs. 54 g per day) breed. In a similar manner, the difference in WWT for Horro lambs born in the wet relative to the dry season was about twice as large (10.7 vs. 8.1 kg) as that observed for Menz sheep (9.1 vs. 7.7 kg). Within breed, sires were a significant source of variation for BWT, ADG and WWT ($p < 0.001$).

### 3.2. Lamb survival

Overall, 1.6% of the lambs (53/3256) recorded were stillborn and a further 41.8% (1360/3256) died before they reached 1 year of age. Analyses for cumulative mortality to different lamb ages are shown in Table 1. Mortality rate was influenced by many factors whose importance varied with lamb age. The overall flock

| Table 1 Least squares means (%) for breed, parity, year, season of birth, litter size, birth weight and lamb sex for lamb mortality during the perinatal and postnatal periods |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Number of lambs born            | Perinatal mortality | Cumulative postnatal mortality |
|                                 | Up to 3 days | Up to 7 days | Up to 1 month | Up to 2 months | Up to 3 months | Up to 6 months | Up to 9 months | Up to 12 months |
| Overall mean                    | 4.7          | 7.1           | 11.1          | 15.9           | 20.3           | 34.9           | 41.3           | 44.2           |
| RSD                            | 2.0          | 2.5           | 2.9           | 3.4            | 3.6            | 4.2            | 4.4            | 4.5            |
| **Factor**                      |              |               |               |                |                |                |                |                |
| Breed                           |              |               |               |                |                |                |                |                |
| Menz                            | 4.0          | 5.0           | 6.8           | 8.4            | 8.8            | 19.1           | 24.3           | 28.2           |
| Horro                           | 7.8          | 10.8          | 15.9          | 21.3           | 25.3           | 48.9           | 56.2           | 59.5           |
| Dam Parity                      |              |               |               |                |                |                |                |                |
| 1 lambing                       | 4.2          | 7.5           | 11.9          | 16.8           | 21.3           | 39.5           | 46.5           | 49.9           |
| 2 lambings                      | 6.8          | 7.6           | 11.3          | 13.5           | 14.4           | 32.3           | 39.1           | 41.9           |
| 3 lambings                      | 6.6          | 6.9           | 9.5           | 14.1           | 14.9           | 30.5           | 36.9           | 40.0           |
| 4 lambings or more              | 6.3          | 9.5           | 12.9          | 15.2           | 17.6           | 33.9           | 38.2           | 43.5           |
| Year                            |              |               |               |                |                |                |                |                |
| 1992/1993                       | 1.2          | 3.6           | 4.5           | 3.7            | 5.6            | 20.1           | 29.2           | 35.4           |
| 1993/1994                       | 8.5          | 11.4          | 17.9          | 25.1           | 32.3           | 41.5           | 49.3           | 52.7           |
| 1994/1995                       | 6.9          | 9.8           | 13.4          | 16.9           | 18.4           | 36.1           | 43.1           | 45.4           |
| 1995/1996                       | 7.2          | 6.8           | 9.8           | 12.9           | 11.9           | 38.5           | 39.3           | 41.9           |
| Litter size                     |              |               |               |                |                |                |                |                |
| Single                          | 4.6          | 6.6           | 9.9           | 11.1           | 10.3           | 29.0           | 37.5           | 41.0           |
| Multiple                        | 7.4          | 9.1           | 12.9          | 18.7           | 23.9           | 39.1           | 42.9           | 46.7           |
| Under 2 kg                      | 2294         | 6.2           | 7.9           | 10.7           | 12.6           | 13.9           | 25.9           | 31.6           | 34.9           |
| 2–3 kg                          | 950          | 5.7           | 7.9           | 12.1           | 17.2           | 20.2           | 42.1           | 48.8           | 52.8           |
| Over 3 kg                       | 426          | 17.1          | 22.1          | 26.9           | 28.9           | 32.5           | 48.3           | 52.9           | 54.9           |
| Over 3 kg                       | 2545         | 0.6           | 1.9           | 5.3            | 11.3           | 15.5           | 32.9           | 38.8           | 42.8           |
| Over 3 kg                       | 285          | 0.2           | 0.7           | 1.9            | 4.4            | 3.2            | 20.9           | 28.8           | 33.8           |
| Lamb sex                        |              |               |               |                |                |                |                |                |
| Female                          | 4.6          | 6.1           | 10.4          | 13.5           | 15.6           | 30.8           | 35.2           | 38.6           |
| Male                            | 1675         | 7.4           | 9.7           | 12.4           | 16.3           | 18.6           | 37.3           | 45.2           | 49.1           |

*a Residual standard deviation.

*b Lambs weaned at an average of 3 months of age.

*c Not significant ($p>0.05$).

*p < 0.05; **p < 0.01; ***p < 0.001.
pre- and post-weaning mortality averaged 20 and 24%, respectively, leading to a flock mortality rate of 44% (1413/3256 — i.e. includes stillbirths) up to 1 year of age. From birth up to 1 year of age losses were significantly higher for Horro than Menz lambs (Table 1). The pre- and post-weaning death rates were 25.3 and 34.2%, respectively, for Horro in contrast to 8.8 and 19.3% for Menz sheep. As a consequence, mortality up to 1 year of age was about twice as high for Horro than Menz lambs (59 vs. 28%, respectively).

There was no significant difference in lamb mortality attributable to dam parity until they were three months old ($p>0.05$). Up to this age mortality rate followed the expected trend with more losses involving the progeny of maiden compared to ewes that had given birth previously. Lamb losses varied among years but there was no clear trend across the 4 years of the study; the highest number of deaths were recorded in 1993/1994. However, lambs born in the wet season (June/August) experienced higher mortality than those born in the dry season (October/December). No significant difference ($p>0.05$) was observed in the death rate of lambs of single or multiple births during the first month after lambing. However, thereafter, multiple-born lambs experienced a higher rate of mortality ($p<0.001$). In addition, male lambs were found to have a higher death rate than females, particularly during the perinatal period and after the age of 6 months.

There was a positive relationship between BWT and lamb survival at all ages ($p<0.001$). Losses for lambs born <2 kg BWT (light) were at least 15% higher than for young born with 2–3 kg BWT (medium). Likewise, mortality rate in lambs with medium BWT was higher than that of lambs weighing 3 kg BWT or more (heavy), the differences being most evident after weaning. Overall, 75, 16, 6, 2, 1 and 0.5% of failures to rear lambs were by ewes that lost their lambs one to six times, respectively.

The mortality rate declined as survivor lambs grew older. When considered as a total flock 20% of the lambs died within 3 months of birth; 18% of survivors died between 3 and 6 months; 10% of those left died from 6 to 9 months; while 5% of the rest died between 9 and 12 months of age. The trend in survivor mortality was similar in both breeds but had greater magnitude in Horro (25, 30, 17 and 7%) than in Menz (8, 10, 7 and 4%) lambs.

### 3.3. Causes of mortality

Out of the 1413 lambs that died (including stillbirths) before they were 1 year old 485, 209, 57 and 18 had fallen sick one to four times, respectively. The remaining 644 died with no prior illness including the 53 stillbirths (Table 2). Necropsy examinations revealed pneumonia to be the most widespread cause of mortality, accounting for 54.0% of all deaths (Table 2).

Causes of mortality were similar in the two breeds and about half of the deaths in Horro and Menz lambs were attributed to pneumonia (53.4 vs. 54.2%, respec-

<table>
<thead>
<tr>
<th>Cause of mortality</th>
<th>Number of times the lambs fell sick prior to death</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Starvation</td>
<td>101 (15.6)</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>305 (47.4)</td>
</tr>
<tr>
<td>Digestive</td>
<td>51 (7.9)</td>
</tr>
<tr>
<td>Endoparasitism</td>
<td>54 (8.4)</td>
</tr>
<tr>
<td>Septicaemia</td>
<td>10 (1.6)</td>
</tr>
<tr>
<td>Stillbirth</td>
<td>53 (8.2)</td>
</tr>
<tr>
<td>Joint illness</td>
<td>3 (0.5)</td>
</tr>
<tr>
<td>Trauma/accident</td>
<td>7 (1.1)</td>
</tr>
<tr>
<td>Unknown causes</td>
<td>60 (9.3)</td>
</tr>
<tr>
<td>Total</td>
<td>644 (45.6)</td>
</tr>
</tbody>
</table>

*a As a percentage of the 1413 lambs which died.*
tively), followed by losses ascribed to digestive and gastro-intestinal problems (14.4 vs. 11.5%), endoparasitism (8.7 vs. 13.1%), the SME complex (9.7 vs. 7.3%), septicemia (3.4 vs. 1.6%), stillbirths (2.5 vs. 5.6%) and undetermined causes (6.6 vs. 5.1%). Irrespectively of the number of times lambs were sick, the largest proportion succumbed to pneumonia (Table 2). This was followed by losses due to digestive problems and endoparasitism in lambs that had previously been sick, while the SME syndrome was the second-most important cause of death among lambs that died without previous clinical sickness.

Non-parasitic illnesses (pneumonia, GI problems, septicemia, joint-illness) accounted for most deaths in both breeds. The next most important ailments were linked to non-infectious causes (SME, malnutrition, physical injury, stillbirth). Endoparasite infections as a cause of mortality was of limited importance in both breeds and was primarily confined to infections from tapeworms (Moniezia spp.) in very young lambs, and liver flukes (Fasciola hepatica) and verminous pneumonia (Dictyocaulus filaria) in older lambs.

### 3.4. Relationship between causes of mortality and breed and environmental factors

Table 3 gives the 95% confidence intervals for odds ratios by breed, birth weight category, season of birth, dam parity, litter size, lamb sex and health category associated with the major cause of death relative to being alive at 1 year of age. Considering odds ratios significantly different from the value of 1.0 (the value representing no association), Horro lambs had a greater risk of dying of any cause than Menz lambs. For example, Horro lambs were at a higher risk of dying from SME/malnutrition, digestive and septicemia causes than Menz lambs (odds ratios of 2.57, 2.46 and 3.87, respectively, Table 3). BWT was also a major risk factor for pre-weaning mortality. In comparison to heavy weight lambs, lambs born light had a bigger risk of dying from SME/malnutrition, endoparasitism or septicemia (odds ratios of 0.36, 0.55 and 0.63, respectively). This was in agreement with the observation that lambs born multiple, the lambs born lighter, were also more likely to die of any cause than singles except those suffering from septicemia. Likewise, lambs born in the dry season were more likely to die from the SME complex, endoparasitism and septicemia than contemporaries born in the wet period. In addition, males had a bigger risk of succumbing to the SME complex, respiratory and endoparasitic ailments than females. Lastly, relative to lambs that fell sick only once, those that fell sick two or more times were at a greater risk of dying from respiratory and endoparasitic disease.

### 3.5. The influence of sires on lamb mortality

The 3256 lambs in the investigation were the progeny of 71 rams (sires). Sires were a significant source of variation for lamb mortality at 6, 9 and 12 months (p<0.05–0.001) but not earlier (p>0.05). The data were analysed only from the 63 sires that had been used for mating for at least a year (i.e. in two or more mating seasons). It was found that the best and worst Horro ram sired progeny groups that had mortality rates up to 1 year of age of 22 vs. 80%, respectively. The same estimates in Menz rams were 11 and 48%, respectively. The Menz rams were categorized as being low, moderate and high mortality sires if <23 24–30 and >30%, respectively, of their progeny had died by 1 year of age. Horro rams were classified similarly if <44, 45–50 and >50%, respectively, of their offspring died before a year of age. The distribution of sires by breed and level of progeny mortality is shown in Table 4. There was a fairly normal distribution of sires for lamb mortality but this was shifted towards inferior performance among Horro rams.

The relationship between mortality as a sire trait and lamb performance had a number of interesting components (Table 5). Firstly, deaths to 1 year of age averaged only 16% for a quarter of Menz rams, 28% for one-fifth of the rams while mortality for the remaining 55% of sires was under 40%. In contrast, only one-tenth of Horro rams had an annual mortality rate of <30%, 16% of the sires in this breed lost a half of their progeny while death rate for the remaining three-quarters of the rams was 66%. Secondly, within breed, mean BWT was very similar (2.5 kg for Horro and 2.3 kg for Menz) across the three sire mortality groups (low, moderate and high). It was after lambing that BWT, ADG and WWT were considerably lower for lambs that subsequently died than for survivors. Thirdly, within breed, the BWT for lambs that died was very similar across the three sire groups, ca. 2.4 kg for Horro and 2.1 kg for Menz lambs. Fourthly,
### Table 3

Odds ratios and the 95% confidence intervals in parenthesis for the causes of lamb mortality by breed, birth weight, season of birth, parity, litter size, lamb sex and health category up to 1 year of age.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Comparisons</th>
<th>Major cause of mortality up to 1 year of age</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SME/Malnutrition</td>
<td>Digestive</td>
<td>Respiratory</td>
<td>Endoparasitic</td>
<td>Septicaemia</td>
</tr>
<tr>
<td>Breed</td>
<td>Horro vs. menz</td>
<td>2.57 (1.76,3.78)</td>
<td>2.46 (1.80,3.35)</td>
<td>2.26 (1.91,2.68)</td>
<td>1.24 (0.89,1.73)</td>
<td>3.87 (1.83,8.19)</td>
</tr>
<tr>
<td>Birth weight</td>
<td>Medium vs. light</td>
<td>0.65 (0.41,1.02)</td>
<td>1.03 (0.66,1.62)</td>
<td>1.30 (0.99,1.71)</td>
<td>0.80 (0.51,1.27)</td>
<td>0.87 (0.35,2.16)</td>
</tr>
<tr>
<td></td>
<td>Heavy vs. light</td>
<td>0.36 (0.21,0.64)</td>
<td>0.81 (0.50,1.33)</td>
<td>1.66 (1.25,2.21)</td>
<td>0.55 (0.33,0.92)</td>
<td>0.63 (0.23,1.75)</td>
</tr>
<tr>
<td></td>
<td>Heavy vs. medium</td>
<td>0.57 (0.36,0.89)</td>
<td>0.79 (0.56,1.10)</td>
<td>1.28 (1.07,1.53)</td>
<td>0.68 (0.46,1.01)</td>
<td>0.72 (0.34,1.54)</td>
</tr>
<tr>
<td>Seasona</td>
<td>Dry vs. wet</td>
<td>1.13 (0.79,1.63)</td>
<td>0.88 (0.65,1.19)</td>
<td>0.91 (0.77,1.00)</td>
<td>1.48 (1.07,2.07)</td>
<td>3.30 (1.63,6.67)</td>
</tr>
<tr>
<td>Parity</td>
<td>2 vs. 1 lambing</td>
<td>0.96 (0.62,1.46)</td>
<td>0.70 (0.49,1.01)</td>
<td>0.93 (0.75,1.14)</td>
<td>0.82 (0.54,1.25)</td>
<td>0.56 (0.26,1.20)</td>
</tr>
<tr>
<td></td>
<td>3 vs. 1 lambing</td>
<td>0.70 (0.42,1.18)</td>
<td>0.64 (0.42,0.97)</td>
<td>1.09 (0.87,1.36)</td>
<td>0.91 (0.57,1.43)</td>
<td>0.48 (0.19,1.19)</td>
</tr>
<tr>
<td></td>
<td>4 vs. 1 lambing</td>
<td>0.57 (0.31,1.06)</td>
<td>0.57 (0.35,0.93)</td>
<td>0.93 (0.72,1.19)</td>
<td>0.87 (0.53,1.31)</td>
<td>0.11 (0.01,0.78)</td>
</tr>
<tr>
<td></td>
<td>3 vs. 2 lambing</td>
<td>0.74 (0.43,1.26)</td>
<td>0.91 (0.57,1.43)</td>
<td>1.17 (0.93,1.48)</td>
<td>1.10 (0.68,1.79)</td>
<td>0.85 (0.31,2.36)</td>
</tr>
<tr>
<td></td>
<td>4 vs. 2 lambing</td>
<td>0.60 (0.32,1.13)</td>
<td>0.81 (0.49,1.36)</td>
<td>0.99 (0.76,1.29)</td>
<td>1.06 (0.62,1.81)</td>
<td>0.19 (0.02,1.46)</td>
</tr>
<tr>
<td></td>
<td>4 vs. 3 lambing</td>
<td>0.8 (0.40,1.64)</td>
<td>0.90 (0.52,1.57)</td>
<td>0.85 (0.65,1.12)</td>
<td>0.97 (0.55,1.69)</td>
<td>0.22 (0.03,1.81)</td>
</tr>
<tr>
<td>Litter size</td>
<td>Multiples vs. single</td>
<td>2.31 (1.61,3.31)</td>
<td>1.42 (1.04,1.93)</td>
<td>1.48 (1.24,1.76)</td>
<td>1.76 (1.25,2.48)</td>
<td>0.62 (0.28,1.37)</td>
</tr>
<tr>
<td>Lamb sex</td>
<td>Male vs. female</td>
<td>1.36 (0.95,1.97)</td>
<td>1.07 (0.80,1.45)</td>
<td>1.32 (1.12,1.56)</td>
<td>1.23 (0.88,1.72)</td>
<td>0.66 (0.35,1.26)</td>
</tr>
<tr>
<td>Health category</td>
<td>Sick 2× vs. sick 1×</td>
<td>0.10 (0.01,0.75)</td>
<td>1.01 (0.66,1.54)</td>
<td>1.18 (0.85,1.65)</td>
<td>1.25 (0.78,2.02)</td>
<td>0.85 (0.35,2.05)</td>
</tr>
<tr>
<td></td>
<td>Sick 3× vs. sick 1×</td>
<td>0.96 (0.94,0.97)</td>
<td>1.08 (0.58,2.03)</td>
<td>1.60 (0.96,2.69)</td>
<td>0.65 (0.27,1.58)</td>
<td>0.67 (0.15,2.96)</td>
</tr>
<tr>
<td></td>
<td>Sick 3× vs. sick 2×</td>
<td>0.99 (0.98,1.01)</td>
<td>1.07 (0.55,2.13)</td>
<td>1.35 (0.77,2.36)</td>
<td>0.52 (0.21,1.32)</td>
<td>0.79 (0.16,3.93)</td>
</tr>
</tbody>
</table>

*a Season of birth: dry, October to December; and wet, May to July.
surviving lambs appeared to be those which attained a minimum threshold ADG of 78 g per day for Horro and 68 g per day in Menz sheep, and a minimum threshold WWT of 10 kg for Horro and 9 kg in Menz sheep. Finally, the differences between the average BWT, ADG and WWT of lambs that survived and those which died were on the whole larger, and perhaps more critical, in the Menz than in the Horro breed.

4. Discussion

Levels of lamb performance for BWT, ADG and WWT in this study were similar to those reported earlier for tropical sheep (Gatenby, 1986). The observations that BWT, ADG and WWT were higher for the larger Horro breed also concurred with previous results from this location (Gautsch, 1992) and other results from the present study (Mukasa-Mugerwa et al., 2000).

While the overall level of mortality of 44% from birth to 1 year of age is high, the main cause of this was the very high mortality in the Horro lambs (59%) vs. the Menz lambs (28%). Previous research at Debre Berhan (Gautsch, 1992) had also indicated much higher mortality rates in Horro versus Menz sheep (ewes and lambs). It was hypothesised at the start of this experiment that the large difference in mortality between these breeds may be at least partly related to a breed difference in resistance to gastro-intestinal nematode parasites. However, this was not true in the ewes (Tembely et al., 1998) and does not appear to be true in preliminary analyses of the lamb data (Baker et al., 1998). It is important to note that while both the breeds studied are indigenous to Ethiopia only the Menz sheep are indigenous to the study area. The Horro sheep were introduced to Debre Berhan as young ewes and rams (i.e. the parents of the lambs being evaluated) from the mid-altitude area in the western part of Ethiopia.

The overall pre-weaning mortality of 20% was within the 12–50% range for tropical sheep (Traore et al., 1985; Wilson et al., 1993) while the post-weaning death rate of 24% also agreed with previous findings by Fall et al. (1982). The effect of breed, birth type, season, parity and birth weight on survival has been reported previously (Meyer and Clarke, 1978; Dalton et al., 1980; Fall et al., 1982). However, annual lamb losses of 28% in Menz and 58% in Horro sheep indicated that mortality remains a major constraint to improving productivity, especially in Horro sheep in this environment. A few aspects of mortality in this study are emphasised below as they represent potential focal areas for strategies to reduce losses.

Perinatal deaths which occurred within seven days of birth accounted for 36% of pre-weaning mortality and 17% of the annual losses, results similar to those of Traore and Wilson (1988). Ewes generally produce one lamb and dam nutrition resources are mainly invested in the single lamb, which should limit losses. Birth weight is a risk factor for lamb survival (Meyer and Clarke, 1978; Dalton et al., 1980; Scales et al., 1986; Yapi et al., 1990; Mukasa-Mugerwa et al., 1994) in an inverted U-shaped relationship (i.e. lower survival of lambs with very small and very large BWT). BWT is influenced by ewe prenatal nutrition, litter size, placental size and foetal genotype (Haughey,
Table 5
Growth performance characteristics for the progeny sired by Horro and Menz rams having different lamb mortality rates from birth to 1 year of age

<table>
<thead>
<tr>
<th>Breed</th>
<th>Site mortality category</th>
<th>No. of rams</th>
<th>Percentage of rams</th>
<th>No. of lambs sired</th>
<th>No. of lambs dead by 12 months</th>
<th>Mortality rate (%)</th>
<th>Birth weight (kg)</th>
<th>Average daily gain (g per day)</th>
<th>Weaning weight, 3 months (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horro</td>
<td>low&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3</td>
<td>9</td>
<td>67</td>
<td>20</td>
<td>29.8</td>
<td>2.53</td>
<td>2.48</td>
<td>2.55</td>
</tr>
<tr>
<td></td>
<td>moderate&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5</td>
<td>16</td>
<td>198</td>
<td>100</td>
<td>50.5</td>
<td>2.51</td>
<td>2.40</td>
<td>2.63</td>
</tr>
<tr>
<td></td>
<td>high&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23</td>
<td>75</td>
<td>836</td>
<td>555</td>
<td>66.3</td>
<td>2.59</td>
<td>2.48</td>
<td>2.79</td>
</tr>
<tr>
<td></td>
<td>sub-total</td>
<td>31</td>
<td>100</td>
<td>1101</td>
<td>675</td>
<td>61.3</td>
<td>2.57</td>
<td>2.46</td>
<td>2.73</td>
</tr>
<tr>
<td>Menz</td>
<td>low&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8</td>
<td>25</td>
<td>210</td>
<td>34</td>
<td>16.1</td>
<td>2.38</td>
<td>2.10</td>
<td>2.43</td>
</tr>
<tr>
<td></td>
<td>moderate&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7</td>
<td>20</td>
<td>314</td>
<td>87</td>
<td>27.7</td>
<td>2.33</td>
<td>2.09</td>
<td>2.43</td>
</tr>
<tr>
<td></td>
<td>high&lt;sup&gt;b&lt;/sup&gt;</td>
<td>17</td>
<td>55</td>
<td>742</td>
<td>286</td>
<td>38.5</td>
<td>2.29</td>
<td>2.09</td>
<td>2.41</td>
</tr>
<tr>
<td></td>
<td>sub-total</td>
<td>32</td>
<td>100</td>
<td>1266</td>
<td>407</td>
<td>32.1</td>
<td>2.32</td>
<td>2.09</td>
<td>2.42</td>
</tr>
</tbody>
</table>

<sup>a</sup> Low, <44%; moderate, 45–50% and high, ≥50% annual lamb mortality.

<sup>b</sup> Low, ≤23%; moderate, 24–30%; and high ≥30% annual lamb mortality.
Factors which contribute to low BWT also tend to reduce foetal lipid reserves, limit neonatal vigour, impair colostrum production and restrict ewe milk production (Mellor and Murray, 1985a, b). As a consequence, lambs born light are also more susceptible to the SME complex (Table 3; Davis et al., 1981). Data on BWT consistent with optimal lamb survival in tropical breeds are scarce (Mukasa-Mugerwa et al., 1994). However, this information is vital to the design of strategies that are more appropriate for farmers who have a chronic shortage of supplementary feeds. These farmers need to know, for example, that indiscriminate supplementary feeding of ewes (the non-pregnant, the single- and twin-bearing ewes) is wasteful because they have varying needs.

Perinatal lamb losses in temperate sheep ranged from 6.5 to 14% but as environmental conditions got worse survival rates tended to improve (Varley, 1992). This is because as conditions deteriorated management practices were provided which ensured better husbandry and hygiene, adequate immune acquisition, reduced climatic stresses (cold, wind, rain), limited malnutrition and starvation, and good contact between dams and lambs post-partum. These farm management practices are also relevant for tropical sheep production. In particular, since the relationship between BWT and survival is causative, it would be advisable to introduce farm (animal) management routines which can help to increase BWT. One option is to supplement ewes in the last trimester (Scales et al., 1986; Mukasa-Mugerwa et al., 1994), especially animals in poor body condition carrying twins since both the foetus and udder undergo rapid development during this period. After birth, steps need to be taken to reduce losses in low weight lambs. One option is to cross-foster or graft light, weak, orphan or abandoned lambs shortly after parturition. The rotation of twins during nursing can also help to ensure that each gets enough milk. Increased care for twins, which are more likely to suffer from the SME syndrome, might lead to a recognisable increase in lamb survival and flock productivity. Ensuring strong ewe-lamb bonding within 12–24 h of delivery also enhances colostrum production by dams and increased intake by lambs. Fortunately, many smallholder farmers in the tropics are good at this as they restrict ewes and their lambs to near the homestead for the first few days (and sometimes longer — e.g. 1–2 weeks) after lambing. This practice further helps to protect against chilly, windy, wet and harsh temperature conditions at a time when new-born lambs must adjust from a highly dependable intra-uterine to the more challenging external environment.

Patterns in lamb mortality with age were similar in both breeds but much higher for the Horro (Table 1). Moreover, most deaths resulted from non-parasitic infections, especially pneumonia (Table 2). Because lamb mortality arose from basically the same causes in both breeds, it is conceivable that poorer survival in Horro sheep reflected the breed’s lack of proper adaptability to major causes of ill-health, especially pneumonia and other non-parasitic infections, in the local environment. It is also pertinent to note that the Menz are a coarse wooled sheep and the Horro are a hair sheep which may affect the adaptability of the Horro to a relatively cold, high altitude environment. It is clear that the Menz sheep should be the preferred breed for sheep farmers in this region of Ethiopia, although at present the Horro breed does not have a significant presence in this region. However, the relatively small Menz sheep are sometimes perceived as being unproductive by local farm advisors, but this study clearly demonstrates that this is not the case. For example, Awassi sheep are currently being promoted as a suitable breed for this region of Ethiopia, with limited effort being put into evaluating their potential role and productivity compared to the locally adapted Menz sheep.

Variability in lamb survival among sire progeny groups within breed has been reported previously in temperate (Knight et al., 1979), but not in tropical sheep. The wide variation that was observed in lamb mortality rate among sires within breed was important. These results suggested that lamb survival could be enhanced if this parameter was adequately stressed in sheep genetic improvement programmes. This proposition is strongly supported by the findings of Knight et al. (1979) who recorded 8 and 17% improvements in lamb survival rate for single- and twin-born lambs sired by high survival versus low survival Romney rams. However, before embarking on within-breed genetic improvement programmes for lamb survival it is important that the genetic correlation of lamb survival with important associated traits (e.g. birth weight or litter size) are estimated and evaluated (Cundiff et al., 1982). For example, in cattle the
genetic correlations between calf survival and birth weight and between calf survival and calving difficulty are both strongly negative and therefore antagonistic (Cundiff et al., 1982). There is also evidence in sheep for an antagonistic genetic correlation between litter size and lamb survival (Cundiff et al., 1982). Therefore, gains from selection from one trait would tend to be offset by losses in the other. A subsequent paper utilising the full data set generated in this experiment (4361 lambs born from 83 sires and 1638 dams) will address this issue in more detail.

5. Conclusions

The number of lambs born and surviving to marketing is very critical to sheep production. Present data indicated that Menz and Horro sheep have good reproductive ability (Mukasa-Mugerwa et al., 2000), but high lamb mortality seriously constrains productivity, especially in the Horro breed. The causes of lamb mortality were largely linked to management since they mainly related to low birth weights, SME and non-parasitic disease (predominantly pneumonia). Isolated efforts to solve only one of these problems will only partly alleviate mortality. Instead, an integrated approach in which critical elements of major environmental and genetic factors are addressed would be more relevant. Firstly, farm routines need to be introduced that would increase BWT, reduce climatic stress, limit malnutrition, starvation and exposure, and promote maximum ewe–lamb contact during the first few days after birth. Secondly, the wide within breed sire variability in progeny mortality suggested that enough genetic diversity possibly exists which can be exploited more permanently. This can be organised through ram progeny tests in order to identify sires for producing harder lambs. These programmes (possibly nucleus breeding schemes) should involve the faster-growing weaner ram lambs selected from ewes with high rearing ability in farmer flocks within the same eco-region or production system. Pre-weaning lamb growth rate should be emphasised because it is an indicator of dam milking ability. However, since infectious causes were also critical to survival, it might be advantageous to develop tools or indictors to help in identifying lambs with better general resistance to infectious diseases. These indicators could be tested for during the performance tests or earlier. The best rams would be re-distributed to farmers as replacement sires while mediocre animals would be castrated or fattened for slaughter. In many tropical farming conditions, it will be very costly and time consuming to implement a fully integrated approach to reduce lamb mortality. In many cases, a more practical approach will be to concentrate, at least initially, on addressing a few (e.g. one or two) of the major causes of mortality, whether these be diseases or management issues.

Acknowledgements

The authors greatly thank staff of the ILRI Debre Berhan station and Mr. Amare Kelemu, Mr. Eshetu Zerihun and Mr. Yenesew Mekoya for contributions to animal care and data collection. Mr. Gizachew Tariku and Mr. Mesfin Shebru are thanked for computer data management and analysis, while Ms Anne Nyamu is appreciated for editorial comments on the manuscript. This is ILRI publication No. 990161.

References


