Research article

Litter size, litter weight, and lamb survivability of Doyogena sheep managed under community-based breeding program in Ethiopia

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ABSTRACT

Increasing litter size and weight during the marketing time by decreasing mortality among lambs per ewe is the objective of the community-based breeding program (CBBP). This study aims to find out litter size, litter weight per ewe, and preweaning lamb mortality of Doyogena sheep managed under CBBP. The study analyzed the data records of 4530 animals for 8 years from 2013 to 2020. A logistic regression procedure was used to analyze preweaning lamb survival rates. Results showed that the overall least-squares means of litter size at birth (LSB), litter size at weaning (LSW), total litter weight at birth (TLWB), and total litter weight at weaning (TLWW) were 1.57 ± 0.02 lambs, 1.50 ± 0.02 lambs, 5.24 ± 0.09 kg, and 24.14 ± 0.69 kg respectively. The incidence of preweaning lamb mortality was 4.72%. Year and breeder cooperative vary were observed for pre-weaning lamb losses. Females had lower odds of survival as compared to males. Odds of survival were low for triplets, quadruplets, and low birth weight (<2 kg) born lambs. The ongoing selection program which aims to improve reproductive and growth performance had a positive influence on the survival rate of lambs. Improvement of the environment in the flock, special care for multiple-born and care for small lambs would lead to further lamb survival improvements.

1. Introduction

Small ruminants, particularly indigenous breed types, play a substantial role in the livelihoods of a considerable part of the human population in the tropics from socio-economic aspects (Ahsani et al., 2010; Mohammadabadi 2021; Masoudzadeh et al., 2020a). Thus, combined trials with emphasis on administration and genetic progress to improve their outputs are of decisive significance (Masoudzadeh et al., 2020b; Mohammadabadi et al., 2017). Economical and biological efficiency of sheep production enterprises generally improves by increasing the productivity and reproductive performance of ewes (Zamani et al., 2015; Mohammadabadi 2016; Amiri Roudbar et al., 2017, 2018; Ghotbaldini et al., 2019).

CBBP has become an encouraging small ruminant genetic improvement option (Haile et al., 2020; Wilson et al., 2021). CBBP was adopted in the Doyogena district of Ethiopia to improve Doyogena sheep. Doyogena sheep are found in the Enset crop-livestock production system of southern Ethiopia (Taye et al., 2016). Doyogena ewes are prolific with high incidences of multiple births with an occasional incidence of triplets and quadruplets (Abebe, 2018). In the report of Kebede (2019), from the total birth of 2990 lambs, 53% and 11% of lambs born were twins and triplets. To date, more than 1500 elite breeding rams have been produced from breeder cooperatives and have been sold as breeding animals to neighboring communities. These figures indicate the vital role of Doyogena sheep as a source of an improved genotype and the benefits for smallholder participant farmers.

The efficiency of CBBP or selection could be improved by increasing the number of lambs per ewe (marketable lambs). This could be achieved by improving litter size and survival rate traits (Tesema et al., 2020; Getachew et al., 2015). These two traits affect the overall production rates, objective reproductive traits, and profitability of the breeding program. However, mortality rates are a major problem as litter size increase substantially. As indicated by Sodiq et al. (2011) litter size, litter weight, and lamb survival have been the objective of many studies previously (Baneh and Hafezian, 2009; Duguma et al., 2002).

Improving litter size and reduction of lamb mortalities can be achieved by identifying the specific causes of losses and minimizing the influences of these losses. Thus, understanding management and environmental factors affecting these traits is a must for successful selective breeding programs. However, there is limited information...
regarding the survival rates of multiple Doyogena lambs. To date, objective data on litter size, litter weight traits, and survival rate of Doyogena sheep are unavailable. Hence, reliable information for these traits is needed for optimizing the ongoing CBBP. Thus, the objective of this study was to determine pre-weaning litter size, litter weight, and pre-weaning lamb survivability for Doyogena sheep, as well as to identify the effects of the non-genetic factors on litter size and lamb survival of Doyogena sheep CBBP.

2. Materials and methods

2.1. Description of study area

The study was carried out in the Doyogena district located in Kem-bata Tembaro Zone (Figure 1) at a distance of 258 km to the Southwest of Addis Ababa (the national capital) and 171 km from Hawassa (the regional capital of Ethiopia). The study area has an altitude ranges from 1900 to 2800 m above sea level (m.a.s.l). The district has both highland 70% (> 2300 m. a.s.l) and midland 30% (> 1500 to < 2300 m. a.s.l) agro-ecologies. The common agricultural practice of the district is a mixed crop-livestock production system (Kebede, 2019).

2.2. Modality of the breeding program

In 2012/13 CBBP was adopted in the Doyogena district to improve Doyogena sheep. Participant farmers were involved in every stage, from planning to the operation of the breeding program (Mueller et al., 2015; Haile et al., 2019).

Initially, the program was started in two breeder cooperatives with 148 male-headed and 24 female-headed households. Currently, eight breeder cooperatives (3 new and 5 older) CBBPs cooperatives are underway and were involved in this study. More than 811 households directly participated in this breeding program. Animal identification and performance recording were carried out by field data collectors with close supervision by researchers. The breeding rams were selected based on their six months’ weight (6WT) and estimated breeding values (EBVs) incorporating farmers’ criteria namely physical appearance, tail type, absence or presence of horn, twinning rate, mothering ability, and coat color. Understanding the community view, animal/trait preference, environments, and trait priorities are important for the success of indigenous small ruminant genetic improvement (Gizaw et al., 2013).

First-ranked (top 10%) breeding rams were retained within the flock while second-ranked rams were (60%) sold for breeding purposes to other communities. The third-ranked (30%) were culled from the CBBP to prevent unwanted mating. After one year of service, the breeding rams were sold to other areas of the region.

2.3. Animal management

All animals were identified with an individual plastic ear tag. Each CBBP cooperative has its own code of identification number. The ear tag contains a cooperative code, animal ID, and year of birth. All the data were recorded in a recording longhand book. The content of the recording book included baseline record, lamb record, and ewe’s record. Newly joined animals were recorded in a baseline-recorded format. The recorded data formulated from the owners’ names, animals ID, dams ID, sires ID, birth weights, birth dates, birth types, animal sex, ewe parity, animal coat color (block coat color not preferred), weaning weight (at three months age), 6-months weight, and culling reasons.

2.3.1. Feeding

The main feed sources for animals included false banana/enset (Ensete ventricosum) products of Amicho (fresh parts of corms of enset could be cooked like potatoes) and corm (swollen underground parts of enset, which are important to feed to sheep), crop residue, improved forage/grass, kitchen leftover, and commercial concentrates. The major improved forage crops adopted by participant farmers were Desho grass (Pennisetum pedicellatum), elephant grass (Pennisetum purpureum), oat (Avena sativa), and vetch (genus Vicia) and treelucerne (Chamaecytisus palmensis L.). Flocks graze with tethering in a small private land area. The feeding of ewes and lambs was relatively the same as the feeding of the other flocks. Feeding in the daytime and housing at night were practiced.

![Figure 1. Location of the study site.](image)
2.3.2. Housing and watering system

Participant farmers house their sheep throughout the year to protect them from cold, rain, predators, and theft. Often one big house is utilized and constructed from bamboo or locally available materials. Usually, sheep are housed together with other livestock inside the main house which is separated by a woodlot. Participant farmers regularly clean animal waste. Some farmers also removed the waste through a small drainage system behind the main house. All participant farmers offered their sheep water once a day. The primary sources of water were small rivers and water from pipe water.

2.3.3. Veterinary service

Free veterinary service was provided for CBBP participant farmers. Employed health professionals gave basic animal health services to all the animals. Sheep were de-wormed for gastrointestinal parasites and lungworms twice a year in February and July. Sheep were administered ivermectin for prophylaxis and control of external parasitism. Vaccination against ovine Pasteurellosis (February and August, twice a year), sheep Pox (April, once a year), Peste des Petits Ruminants (October once a year), Anthrax (June, once a year), Foot and Mouth Disease, and enterotoxaemia have been administered. The vaccines were administered to all animals above three months of age. Animals were injected with broad-spectrum antibiotics (Oxytetracycline long act) as a prophylactic against secondary bacterial infections. These procedures were usually carried out before and after the rains. The animals were offered injectable forms of multivitamins during the challenging time if needed.

2.4. Data source and management

Data were obtained from the ongoing Doyogena sheep CBBP operational in the Doyogena districts under Areka Agricultural Research Center (AARC). Enumerators were employed to record specified biological data on the sheep flocks owned by members. The research staff of the program from AARC and other associated institutes were carrying out a regular follow-ups on both functions of the cooperatives and the record-keeping practices of the enumerators. At the start of the CBBP, 10660 sheep flock was recorded and grouped into 64 mating groups by 64 elite breeding rams. The data routinely collected by the enumerators were recorded at the time of the event. At birth, the relevant information about newborn lambs such as owners’ names, birth dates, lamb sex, birth type, lamb birth weight, dam parity, sire ID, and dam ID was recorded.

Data used for lamb litter size at birth, and at weaning, with their corresponding weights were 3167, and 2463 respectively. Data from 4530 individual lambs representing progeny of 2080 dams and 530 sires were used for analyzing survival rates. The data were collected from 2013 to 2020. Recruited data collectors collect mortality data at the time of the event. Lambs were scored one (1) for lambs surviving and zero (0) for those who died earlier than 90 days (weaning age). The fixed effect included factors like the year of birth/lambing (2013–2020), seasons (main rainy season, small rainy, and dry season), sex (male and female), parity (1, 2, 3, 4, 5, 6 and ≥7), birth type (single, twin, triplet and, above), and cooperatives (Ancha, Begedamo, Gamora, Hawora, Lemi, Murasa, Serera, and women breeder cooperative). Members of breeder cooperatives were both male and female except for women breeder cooperative.

2.5. Statistical analysis

LSB, LSW, TLWB, and TLWW data were calculated and analyzed by using R software. LSD test was used to compare more than two means. For mean separation agncorrelu and emmeans packages were used (R Core Team, 2019). The statistical models were shown in the following Eqs. (1) and (2).

2.6. The model for litter size at birth and litter size at weaning

\[ Y_{ijklm} = \mu + \beta_i + C_j + Y_k + S_l + (Y_k \times S_l) + e_{ijklm} \]  

(1)

where:

- \( Y_{ijklm} = \) litter size traits,
- \( \beta_i = \) ith parity (i = 1, 2, 3, 4, 5, ≥6),
- \( C_j = \) jth cooperative (j = Ancha, Begedamo, Gamora, Hawora, Lemi, Murasa Serera and women breeder cooperative),
- \( Y_k = \) kth year (k-2014 -2020)
- \( S_l = \) lth season (l = main rainy season, small shower falls, dry season)
- \( Y_k \times S_l = \) the interaction between lambing year and lambing season;
- \( e_{ijklm} = \) random error.

litter weight at birth and litter weight at weaning:

\[ Y_{ijklm} = \mu + \beta_i + C_j + Y_k + S_l + B_m + (Y_k \times S_l) + e_{ijklm} \]  

(2)

where:

- \( Y_{ijklm} = \) reproductive trait for each animal
- \( \mu = \) overall mean,
- \( \beta_i = \) ith parity (i = 1, 2, 3, 4, 5,6 and ≥7)
- \( C_j = \) jth cooperatives (j = Ancha, Begedamo, Gamora, Hawora, Lemi, Murasa, Serera and women breeder cooperatives)
- \( Y_k = \) kth year (k-2014 -2020)
- \( S_l = \) lth season (l = main rainy season, Small shower falls, dry season)
- \( B_m = \) mth birth type (m = single, twin, triplet and, above)
- \( Y_k \times S_l = \) the interaction between year and lambing season;
- \( e_{ijklm} = \) random error

To measure lamb mortalities, we calculated pre-weaning mortality rates as a proportion of lambs born alive at three-month ages. Pre-weaning survival rates were analyzed using the logistic regression procedure of SAS (2008) with a binary response variable, which was modeled as a binomial variable (yi). The dependent variable (yi) can assume the value of 1 with a probability of survival pi or the value of 0 with a probability of death 1-pi for observation i. Logistic regression model was used to study the association of various non-genetic factors on preweaning lamb mortality. The statistical model used is shown below (3):

\[ \ln \left( \frac{P_{ijklm}}{1 - P_{ijklm}} \right) = \beta_0 + \beta_1 S_i + \beta_2 P_i + \beta_3 C_j + \beta_4 S_l + \beta_5 B_m + \beta_6 BW_n + \beta_7 Y_k + e_{ijklm} \]  

(3)

where, \( P_{ijklm} \) is the probability that animal i survived until three months/weaning age; \( \beta_0 \) intercept; of lamb survival up to 3 months/weaning age; \( S_i \) is the effect of ith sex; \( P_i \) is the effect of jth parity, \( C_j \) is the effect of kth breeder cooperatives, \( S_l \) is the effect of lth season of birth, \( B_m \) is the effect of mth birth type, \( BW_n \) is the effect of nth lamb birth weight, \( Y_k \) is the effect of kth lambing year. Corresponding regression coefficients are indicated by \( \beta. e_{ijklm} \) is the residual error corresponding to responding variable. The birth weight of lambs was grouped into four (less than 2 kg, between 2.1-2.9 kg, between 3.0-3.9 kg, and greater than 4 kg levels. The odds ratios are presented with 95% confidence intervals (CI).

3. Results and discussion

3.1. Litter sizes at birth and at weaning

The overall least-squares means and their standard errors of litter size at birth (LSB) and litter size at weaning (LSW) of the Doyogena sheep are presented in Table 1. The mean values for LSB and LSW are 1.57 ± 0.02 and 1.50 ± 0.02 lambs/ewe respectively. The parity of ewes, breeder cooperatives, and year of lambing had a significant (P < 0.01) influence on LSB and LSW. In the current study, the lowest litter sizes were recorded in the first and second parity of ewes. However, the largest litter
was observed in ewes at their fifth parity (Table 1). The results indicated that there was a tendency for productivity improvement as ewe parity (ewe age) advanced and reached a maximum of fifth parity. This could be explained by the ewes’ physiological maturity with ewe age (Mengiste et al., 2010) in terms of ovulation rate, and uterine capacity. Several works of the literature indicated that maternal traits (maternal genetic and permanent environmental variance) affect the reproductive efficiency of the ewes (Kebede, 2019; Rashidi et al., 2011).

There was a significant (p < 0.05) variation in LSB and LSW across breeder cooperatives. Among the CBBP, Begadamu, Ancha, and Hawora had higher LSB which was 1.75 ± 0.03, 1.70 ± 0.02, and 1.61 ± 0.02 respectively. Similarly higher LSW were recorded from Begadamu (1.63 ± 0.03), and Lemi (1.62 ± 0.10). Low LSB and LSW were obtained from Murasa (5.79 kg), Hawora (5.69 kg), and Serera (5.71 kg) sheep breeds respectively. The present study was higher than the results sorted by Taye et al. (2010) and Abegezi (2002) for Washara (1.19) and Horro (1.3) sheep breeds respectively.

3.2. Total litter weight at birth and weaning

The least-square means and their standard errors of litter weight at birth and litter weight at weaning are presented in Table 2. The overall litter weights at birth and weaning age per ewe of the Doyogena ewes were 5.24 ± 0.09 kg and 24.14 kg, respectively. In the current study, TLWW per ewes was considerably influenced by the parity of the ewes (P < 0.01). Higher TLWW was obtained at parity four (25.64 kg) and parity five (24.98 kg). This result is consistent with the report of Yavarifard et al. (2015). However, TLBW was not affected (P > 0.05) by the parity of ewes. Highest (P < 0.01) values of litter weight at birth (7.38 kg) and at weaning (32.07 kg) were found for quadruplet birth types followed by a triple, twin, and single birth types in that order. The values for the single birth type LSB and LSW was 3.22 kg and 16.29 kg, respectively. In the study of Mehmet et al. (2017), productivities of multiple-born ewes were higher than those of single-born ewes for Turkey Karayaka ewes. The TLBW and TLWW were also affected by breeder cooperatives (P < 0.01). The highest TLBW values were recorded from Murasa (5.79 kg), Hawora (5.69 kg), and Serera (5.71 kg) breeder cooperatives. This difference might be due to variations in litter size traits from the ongoing Bonga and Horro sheep CBBP. Others have also reported the impact of lambing year on LSW (Yavarifard et al. (2015) for Mehraban sheep, Tesema et al. (2020) for Dorper x Tumele sheep breeds, and Deribe et al. (2021) for Dorper crossbred lambs. The impact of lambing year on LSW has also been found by Boujenane et al. (2013) for D’man ewes. The litter size of Sumatra thin-tailed sheep averaged 1.52 ± 0.04 lambs at birth (Dolok-saribu et al., 2000) which have relatively comparable with the current study. The present results were higher than the resuresultsorted by Taye et al. (2010) and Abegezi (2002) for Washara (1.19) and Horro (1.3) sheep breeds respectively.
3.3. Lamb pre-weaning survival

Overall out of 4530 lambs born, 214 (4.72%) lambs died during the pre-weaning period. The influence of different factors on lamb mortality during the pre-weaning period is presented in Table 3. Sex of lambs significantly (P<0.01) influenced the survival outcome for the lambs till weaning age (90 days) where female lambs showed 36% of pre-weaning lamb mortality. The higher survival rate of male lambs might be attributed to the preferential management of male lambs in terms of feed supplementation and medications to guarantee the superiority of rams compared to females. The higher mortality in female lambs compared to male lambs has also been reported by Turkson and Sualisu (2005). On the contrary, Gowane et al. (2020) documented that male animals have a greater risk of death as compared to females. Obviously, the sample size we used for male lambs was larger (2693) than for females (1835) which may affect the significance level between male and female lambs. This needs further investigation on the relationship between the sex of lamb and pre-weaning lamb mortality by balanced data.

Preweaning lamb mortality was affected by CBBP breeder cooperatives at P<0.01. Higher estimates of percent preweaning lamb mortality were observed from Lesmisuticho, Murasa, Gomora, and Ancha breeder cooperatives which were 90, 80, 78, and 65% respectively as compared to Women breeder cooperative. The low survival rate of lambs in those breeder cooperatives might be attributed to the low feed supply for pregnant ewes, lactating ewes, and lambs. Among the breeder cooperatives, Hawora had low lamb mortality which was 12% compared to women breeder cooperative. Cooperative to cooperative variation could be due to management differences that existed among breeder cooperatives kept in different locations. The better lamb survival reported by women breeder cooperatives implies that appreciable genetic improvement could be achieved through legally organized women CBBP.
This might be due to better top ram usage, better housing, better sanitation, and proper animal feeding by women participant farmers. Women have a greater role in animal genetic improvement activities and caring for animals (Wamatu et al., 2021; Aldosari, 2018).

The effect of birth type was significant on lamb pre-weaning mortality. The odds of single and twin-born lambs were observed to be 2.95 (95% CI, 1.63–5.22) and 2.70(95% CI, 1.64–4.45) times better respectively compared with quadruplet-born lambs. The possible reason for the low lamb survival for quadruplet birth lambs could be lamb competition with its litter mate for colostrum and milk (Hatcher et al., 2010; Southey et al., 2003) and Abegaz, 2002). This suggests that including litter size as a selection objective trait increases the number of lambs born over time while decreasing their chances of survival rates. Thus, improvement of management interventions for multiple-born lambs should be paid greater attention.

Birth weight of lamb was a significant source of variation (P < 0.05) for preweaning lamb mortality. There was higher pre-weaning lamb mortality was observed for lambs born with less than 2 kg weight (58%) compared with lambs in the fourth birth weight category (>4 kg). Preweaning lamb mortality declined in percent of birth weight of lamb increased in weight (Table 3). Lambs with birth weights of 2.1–2.9 kg and 3–3.9 kg had a higher survival rate compared with lambs with birth weights greater than 4 kg. The current results indicated that critical care of the lambs born with low birth weight is essential to reduce lamb losses in the first three months emphasizing colostrum feeding, suckling of milk, and proper housing for prevention from the cold climate and direct wind strikes. Tesema et al. (2020) and Gowane et al. (2020), document similar results.

Year of birth exerted a significant influence on pre-weaning lamb mortality significantly (P < 0.01). The year 2013 showed the incidence of lamb mortality on pre-weaning lamb mortality by 80%.

However, odds of survival for the years 2017, 2018, and 2019 were observed at 1.92, 2.14, and 1.59 times better compared with the year 2020 respectively. The year-to-year variation could be due to uneven rainfall variation that affects feed availability and hence the variation in milk production of lactating ewes. The current preweaning lamb survival rate was excellent compared to the already available reports by several authors for various sheep breeds, viz, about 20% of pre-weaning lamb mortalities were reported for Horro sheep by Abegaz (2002). In the study of Getachew et al. (2015), the pre-weaning lamb survival rates of indigenous Menz and Wollo sheep breeds were 87.8% under the farmer management system.

4. Conclusions

The current study concludes the reproductive performance and survivability of Doyogena sheep managed under community-based breeding program. The offspring yield capacity of Doyogena sheep was higher than other breeds reported in the country. The sum of multiple-born lamb weights was higher than those of single-born ewe. In this regard, multiple-born lambs require proper management. In accordance with the present study, lamb sex, breeder cooperatives, lamb birth type, and year of birth were the most important influencing factor for preweaning lamb mortality. Apart from year-to-year variation, special care for the lambs born with low weight and born as triplets and quadruplets is required to reduce the lamb losses. From the macro and microclimatic perspectives, management strategies should be employed to improve the performance of lambs with unfavorable non-genetic components. From the genetic perspective, analysis of genetic parameters for the traits is necessary for appropriate genetic evaluation.

Ethical approval

The studied animals are generally managed and owned by CBBP participant farmers and data were collected with their permission. No animals were injured during performance data collection.

Declarations

Author contribution statement

Ayana Haile & Tesfaye Getachew: Conceived and designed the study, Analyzed and interpreted the data; Contributed analysis tools or data; Wrote the paper.

Kebede Habtegiorgis: Conceived and designed the study, Analyzed and interpreted the data; Wrote the paper; Contributed analysis tools or data

Deribe Gemiyo & Adisu Jimma: Contributed reagents, materials, analysis tools or data.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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