Mellado, Miguel; Macías, Ulises; Avendaño, Leonel; Mellado, Jesús; García, José Eduardo

Growth and pre-weaning mortality of Katahdin lamb crosses

Revista Colombiana de Ciencias Pecuarias, vol. 29, núm. 4, octubre-diciembre, 2016, pp. 288-295

Universidad de Antioquia

Medellín, Colombia

Available in: http://www.redalyc.org/articulo.oa?id=295047693007
Short Communication

Growth and pre-weaning mortality of Katahdin lamb crosses

Crecimiento y mortalidad pre-destete de corderos híbridos Katahdin

Miguel Mellado¹, Zoot, PhD; Ulises Macías², Zoot, PhD; Leonel Avendaño², Zoot, PhD; Jesús Mellado¹, Zoot, PhD; José Eduardo García*, Zoot, PhD.

¹Universidad Autónoma Agraria Antonio Narro, Departamento de Nutrición Animal, Saltillo 25315, México.
²Instituto de Ciencias Agrícolas, Universidad Autónoma de Baja California, Valle de Mexicali, México.

(Received: October 09, 2015; accepted: July 29, 2016)

doi: 10.17533/udea.rccp.v29n4a06

Summary

Background: Katahdin breed sheep is highly disseminated in Mexico. This breed and its crosses have recently gained attention among sheep producers. However, research with crosses between Katahdin and other meat breeds is limited.

Objective: to evaluate the genetic and non-genetic factors affecting growth and mortality rate of crossbred lambs from Katahdin ewes fecundated with breeds specialized for meat production.

Methods: crossbred lambs (n = 152) from Katahdin ewes sired with Hampshire (KH; n = 43), Texel (KT; n = 53) or Charolais (KCH; n = 56) were evaluated under intensive management conditions. The effects of genotype and non-genetic factors on birth weight, weaning weight, pre-weaning daily weight gain, and mortality rate were determined.

Results: breed differences were not detected for birth weight (4 ± 1.1, 4.3 ± 0.9 and 4 ± 1.1 Kg for KCH, KH, KT, respectively), nor for the 60-d weaning weight (20.2 ± 4.3, 20.9 ± 4.3, 18.2 ± 4.2 Kg for KCH, KH, KT, respectively). Weight of lambs did not differ significantly between sexes, but it decreased (p<0.05) with increased litter size (weaning weight at 60 days for single, twins and triplets was 24.5 ± 2.6, 19.2 ± 3.5, and 14.3 ± 3.8 Kg, respectively). Pre-weaning mortality of KH lambs was 13.3% and it was significantly lower than that of the other genotypes (24.5 and 39.3% for KT and KCH, respectively).

Conclusion: inclusion of Charolais, Hampshire or Texel rams in Katahdin flocks results in similar lamb weaning weight, but Hampshire-sired progeny excels regarding pre-weaning survival.

Keywords: birthweight, Charolais, Hampshire, Texel, weaning weight.
Resumen
Antecedentes: la raza de ovejas Katahdin se ha difundido ampliamente en México. Esta raza y sus cruces han ganado recientemente la atención de los productores de ovinos; sin embargo, la investigación con cruces entre Katahdin y otras razas productoras de carne es limitada. Objetivo: evaluar factores genéticos y no genéticos que afectan las tasas de crecimiento y mortalidad de corderos hijos de ovejas Katahdin fecundadas con razas de carne. Métodos: corderos híbridos (n = 152) derivados de ovejas Katahdin fecundadas con machos Hampshire (KH; n = 43), Texel (KT; n = 53) y Charolais (KCH; n = 56) se evaluaron bajo condiciones intensivas de manejo. Se determinó el efecto del genotipo y factores no genéticos en el peso al nacer, peso al destete, ganancia de peso pre-destete, tasa de ganancia de peso pos-destete y mortalidad de los corderos. Resultados: no se detectaron diferencias entre grupos raciales para el peso al nacer (4 ± 1,1, 4,3 ± 0,9 y 4 ± 1,1 Kg para KCH, KH, KT, respectivamente) ni para el peso al destete realizado a los 60 días (20,2 ± 4,3, 20,9 ± 4,3, 18,2 ± 4,2 Kg para KCH, KH, KT, respectivamente). Los pesos de los corderos no difirieron significativamente entre sexos, pero disminuyeron (p<0,05) con el aumento del tamaño de la camada (el peso al destete a los 60 días para los corderos individuales, gemelos y trillizos fue 24,5 ± 2,6, 19,2 ± 3,5 y 14,3 ± 3,8 Kg, respectivamente). La tasa de mortalidad pre-destete de los corderos KH fue de 13,3% y fue significativamente más baja que la de los otros genotipos (24,5 y 39,3% para KT y KCH, respectivamente). Conclusión: el uso de sementales Charolais, Hampshire o Texel en rebaños de ovejas Katahdin genera resultados similares para peso de los corderos a los 60 días, pero la progenie de los moruecos Hampshire tiene mayor sobrevivencia hasta el destete.
Palabras clave: Charolais, Hampshire, peso al destete, peso al nacimiento, Texel.

Resumo
Antecedentes: Katahdin é uma raça de ovelhas altamente disseminada no México. Esta raça e seus cruzamentos têm recentemente ganhado atenção entre os produtores de ovinos. No entanto, a pesquisa com cordeiros híbridos entre Katahdin e outras raças de carne é ainda limitada. Objetivo: avaliar fatores genéticos e não-genéticos que afetam a taxa de crescimento e a taxa de mortalidade de cordeiros híbridos de ovelhas Katahdin fecundadas com raças de carne. Métodos: cordeiros híbridos (n = 152) derivados de ovelhas Katahdin fecundadas com carneiro Hampshire (KH; n = 43), Texel (KT; n = 53) e Charolais (KCH; n = 56) foram usadas neste estudo sob condições intensivas. Foi determinado o efeito do genótipo e dos fatores não-genéticos sobre o peso ao nascimento, peso ao desmame, peso pré-desmame e percentagem de sobrevivência. Resultados: não foram detectadas diferenças raciais por peso ao nascimento (4 ± 1,1, 4,3 ± 0,9 e 4 ± 1,1 Kg para KCH, KH, KT, respectivamente), e peso ao desmame aos 60 dias (20,2 ± 4,3, 20,9 ± 4,3, 18,2 ± 4,2 Kg para KCH, KH, KT, respectivamente). Os pesos dos cordeiros não diferiram significativamente entre os sexos, mas o peso diminuiu (p<0,05) com o aumento do tamanho da leitegada (o peso ao desmame aos 60 dias de cordeiros individuais, gemelos e trilhizos foi de 24,5 ± 2,6, 19,2 ± 3,5 e 14,3 ± 3,8 Kg, respectivamente). A taxa de mortalidade pré-desmame dos cordeiros KH foi de 13,3% e foi significativamente mais baixa que a de os outros genotipos (24,5 e 39,3% para KT e KCH, respectivamente). Conclusão: o uso de sementais Charolais, Hampshire ou Texel em rebanhos de ovelhas Katahdin gera resultados semelhantes para peso de cordeiros aos 60 dias, mas a descendência Hampshire destacou-se por sua maior sobrevivência até o desmame.
Palavras chave: Charolais, Hampshire, peso ao desmame, peso ao nascimento, Texel.

Introduction
As sheep operations intensify in Mexico, it becomes important to enhance the efficiency of meat production. Crossbreeding can be used to improve lamb production efficiency, but the Mexican sheep industry has yet to determine the optimum production system and which specific crosses will result in the highest profitability under intensive management conditions.

The introduction of a number of sheep breeds in Mexico during the last decades has contributed to improve the productivity of indigenous breeds (Bores-Quintero et al., 2002; Cuéllar, 2007). Katahdin, one of these introduced breeds, has been widely disseminated in Mexico because of its easy care, lamb production, tolerance to internal parasites (Burke and Miller, 2004), resistance to harsh environments (Marai et al., 2007), good fertility and capacity to reproduce in spring (González-Godínez et al., 2014; Burke, 2005).
and good efficiency of forage utilization (Wildeus et al., 2005, 2007; Brown et al., 2012). However, Katahdin, as most hair sheep, are generally smaller and have lower growth rates than traditional wool sheep (Wildeus et al., 2007).

Thus, crossbreeding between hair-sheep and meat-type sheep with superior growth to increase lamb production seems to be a feasible alternative to increasing sheep productivity, as has been demonstrated by a limited number of studies in Mexico (Partida de la Peña et al., 2009; Vázquez-Soria et al., 2011). The number of lambs marketed per ewe favorably impacts profitability (Braga Lôbo et al., 2011), but liveweight of lambs also constitutes a major factor determining the total Kg of lamb weaned or marketed from a sheep flock. Therefore, improving total weight of lamb weaned is important for Katahdin producers because sale of meat is the primary source of income. This aspect is becoming more important as intensive sheep operations are rapidly increasing in Mexico. Poorly executed crossbreeding programs may bring disappointing results. This research was undertaken to evaluate genetic and non-genetic factors influencing growth traits and mortality rates of crossed lambs from Katahdin females with Charolais, Hampshire, and Texel meat breeds.

Material and methods

Ethical considerations

This experiment was conducted in conformity with the “Guiding principles for research involving animals and human beings” approved by the Council of the American Physiological Society (Published 1 August 2002 Vol. 283 no. 2, R281-R283 DOI: 10.1152/ajpregu.00279.2002). Ethical considerations did not arise during the course of the study.

Animals

The study was conducted in a commercial sheep farm in central Mexico (20°N, 550 mm rainfall, 1940 m above sea level; 16°C annual median temperature) between September and November 2013. One hundred and twenty-eight multiparous Katahdin (K) ewes were separated into 3 groups. Estrus of all ewes was synchronized with intravaginal sponges containing 20 mg fluorogestone acetate (Chronogest®, Intervet, Mexico) for 12 days. Ewes in estrus were detected with intact rams wearing an apron to prevent copulation. Ewes in estrus were inseminated in the uterus 12 hours after the beginning of estrus with non-frozen semen (laparoscopy) from Texel (n = 6), Hampshire (n = 6) or Charolais (n = 5) rams. Ninety-two ewes lambed and 152 crossbred lambs were born (53 Texel, 43 Hampshire and 56 Charolais).

Sheep were kept in shaded open-sided pens with dirt floor. Feed bunks were located at the front of each pen. Late pregnant ewes were kept in individual lambing pens with no bedding for better care during lambing. Lambs were kept together with their dams in these pens. All lambs were weighed within 12 h after birth using a platform scale weighing from 0 to 20 Kg and reading to 0.1 Kg. Lambs were again weighed individually at 30 and 60 days of age. Average daily gains (ADG) from birth to 60 days were registered. Lambs were ear tagged at birth and birth date, type of birth and gender were recorded. Lamb mortality was recorded as number of lambs born dead or alive dying within 60 days post-lambing.

All lambs were offered a total-mixed diet ad libitum. The diet met the NRC (2007) recommendations for maximum growth rate (2.90 Mcal metabolizable energy (ME)/Kg dry matter (DM) with 20% crude protein (CP) (Lamb Tech, Purina®, Salamanca, Mexico) from approximately 14 d of age and until weaning at 60 days of age. Lamb survival was defined in this paper as the number of lambs weaned per 100 lambs born (dead and alive). The lamb survival trait was coded as follows: 0 = dead if any lamb recorded at birth subsequently had no live weight recorded at 60 days, and 1 = alive, if it survived at 60 days so that a binomial analysis of this trait could be used.

Statistical analysis

Growth data were analyzed with the MIXED procedure of SAS (SAS version 9.4, 2013, SAS Inst., Inc., Cary, NC, USA). The model measured fit effects on lambs of breed, gender, litter size and three two-way interactions between variables. The non-significant interactions were removed from the final model. Means were compared using the probability
of a statistical difference (PDIF option of SAS). The effect of genotype group, gender, litter size (one to three offspring) and birth weight of lambs (three categories: <3.5, 3.5-4.5, and >4.5 Kg) and their interaction with mortality (yes/no) until weaning was assessed with a logistic model (Proc Genmod of SAS). Comparison of means was carried out using the Least Square/DIFF procedure of SAS. Statistical differences were considered significant at p<0.05.

Results

No interactions were statistically significant for any trait. Therefore, only main effects are described. Breed of sire was not significant for birth weight (Table 1). Likewise, weaning weights were similar (p>0.10) among breed types, but KH and KCH lambs had higher (p<0.05) weight gain from birth to weaning than KT lambs (Table 1). Contrary to expectation, lamb gender was not a significant source of variation for birth and weaning weight, as well as pre-weaning daily gain. Lambs coming from higher litter sizes had lower (p<0.05) birth weights than single-born lambs across all breed groups (Table 1). Breed by type of birth interaction was not significant; therefore, the reduction in birth weight of triple-born lambs compared to single-born lambs was 2.1 Kg for all breeds.

Overall, 27.6% of the lambs (42/152) died before 60 days of age. Mortality rate was significantly lower for KH lambs compared to KCH and KT lambs (Table 2). There was no significant difference in lamb mortality attributable to litter size and gender (p>0.05). Heavy lambs at parturition exhibited lower (p<0.05) mortality rates than lighter lambs. On the other hand, light-born lambs experienced the highest rate of mortality (p<0.05).

Table 1. Growth performance of progeny sired by Charolais (CH), Hampshire (KH), and Texel (T) breeds on Katahdin ewes in central Mexico.

| Item          | Birth weight, Kg | 30-d weight, Kg | 60-d weight, Kg | Average daily weight gain 0-30 d, g | Average daily weight gain 0-60 d, g |
|---------------|------------------|-----------------|-----------------|-----------------------------------|-----------------------------------|
| **Breed**     |                  |                 |                 |                                   |                                   |
| KCH           | 4.0 ± 1.1        | 11.3 ± 2.4      | 20.2 ± 4.3      | 243 ± 63                          | 270 ± 64                          |
| KH            | 4.3 ± 0.9        | 11.5 ± 2.4      | 20.9 ± 4.3      | 241 ± 68                          | 277 ± 59                          |
| KT            | 4.0 ± 1.1        | 10.7 ± 2.6      | 18.2 ± 4.2      | 224 ± 67                          | 237 ± 61                          |
| **Gender**    |                  |                 |                 |                                   |                                   |
| Female        | 3.9 ± 1.0        | 11.0 ± 2.2      | 19.4 ± 3.9      | 236 ± 61                          | 258 ± 71                          |
| Male          | 4.2 ± 1.0        | 11.3 ± 2.7      | 20.1 ± 4.8      | 237 ± 72                          | 265 ± 72                          |
| **Litter size** |               |                 |                 |                                   |                                   |
| 1             | 4.8 ± 0.9        | 13.9 ± 1.9      | 24.5 ± 2.6      | 303 ± 53                          | 328 ± 56                          |
| 2             | 4.1 ± 0.8        | 10.8 ± 1.9      | 19.2 ± 3.5      | 223 ± 56                          | 252 ± 60                          |
| 3             | 2.7 ± 0.7        | 8.2 ± 1.3       | 14.3 ± 3.8      | 183 ± 45                          | 193 ± 83                          |

Values are means ± SD. Means within the same column with different superscripts letters (a, b, c) indicate significant difference (p<0.05).

Table 2. Pre-weaning lamb mortality in an intensive system in central Mexico, as a function of genotype, litter size, birth weight, and gender.

| Item          | Number | Mortality rate (%) |
|---------------|--------|--------------------|
| **Genotype group** |        |                    |
| Katahdin x Charolais | 22/56  | 39.3\(^{a}\)      |
| Katahdin x Hampshire | 7/43   | 16.3\(^{b}\)      |
| Katahdin x Texel    | 13/53  | 24.5\(^{a}\)      |
| **Litter size**     |        |                    |
| 1                | 9/31   | 29.0               |
| 2                | 27/104 | 26.0               |
| 3                | 6/17   | 35.3               |
| **Birth weight (Kg)** |    |                    |
| <3.5             | 21/39  | 53.9\(^{a}\)      |
| 3.5-4.5          | 16/56  | 28.6\(^{b}\)      |
| >4.5             | 5/57   | 8.8\(^{c}\)       |
| **Gender**        |        |                    |
| Males            | 19/75  | 25.3               |
| Females          | 23/77  | 27.6               |

Within items, means with different superscript letters (\(^{a, b, c}\)) indicate significant difference (p<0.05).
Discussion

Different to other studies with hair sheep (Freking and Leymaster, 2004; Osorio-Avalos et al., 2012) sire breed did not alter birth weight of lambs. Values for this trait, regardless of genetic group, were higher than the 3.3-3.9 Kg reported for purebred Katahdin lambs (Burke et al., 2003; Hinojosa-Cuellar et al., 2009; López-Carlos et al., 2010) or hair x meat sheep crossbred lambs (Cardoso et al., 2013) from well-fed mothers. On the other hand, birth weight of purebred, 2013) from well-fed et al crossbred lambs (Cardoso 2009; López-Carlos. et al lambs (Burke 2003) than the 3.3-3.9 Kg reported for purebred Katahdin this trait, regardless of genetic group, were higher breed did not alter birth weight of lambs. Values for this trait, regardless of genetic group, were higher than the 3.3-3.9 Kg reported for purebred Katahdin lambs (Burke et al., 2003; Hinojosa-Cuellar et al., 2009; López-Carlos et al., 2010) or hair x meat sheep crossbred lambs (Cardoso et al., 2013) from well-fed mothers. On the other hand, birth weight of purebred Texel and Charolais lambs observed in other studies (Christley et al., 2003; Yaqoob et al., 2004) is higher than weight found in the present study for Texel and Charolais-sired lambs. Thus, it seems that the use of meat-type sires on Katahdin ewes resulted in an intermediate birth weight of these hybrid lambs, as it has been observed in other studies (do Prado Paim et al., 2013; Ríos-Utrera et al., 2014). In addition, clearly there was not a genetic component accounting for some of the variation in birth weight of these lambs.

Lamb gender did not affect birth or weaning weight, nor pre-weaning daily gain, which is not in accordance with various reports indicating that ram hair lambs grow faster than withers (Cloete et al., 2007; Ríos-Utrera et al., 2014). But a number of reports indicate no differences in weight and daily gain between male and female hair lambs (Hinojosa-Cuellar et al., 2012; Cardoso et al., 2013).

Breed group did not affect weaning weight, which is in agreement with observations by Hinojosa-Cuellar et al. (2011) on crossbreed Pelibuey x Blacbelly and Katahdin x hair sheep. Likewise, Malhado et al. (2009) found similar weaning weight between Dorper x Morada Nova and Dorper x Rabo Largo sheep. This trait is strongly affected by maternal environment and it seems that the good mother ability of Katahdin ewes caused the similar weaning weight observed among genotypes.

ADG from birth to weaning was higher in KH and KCH lambs. This trait is a common measurement of growth and is an economically important characteristic in the breeding of mutton sheep. In addition, this trait has a high genetic and phenotypic correlation with feed efficiency (Cammack et al., 2005). Pre-weaning ADG was higher than the weight gains reported by Vázquez-Soria et al. (2011), Macías-Cruz et al. (2012) and Moreno-Cañez et al. (2013) for pure or crossbred Katahdin lambs in intensive systems in central and northern Mexico.

Similar to findings in multiple previous studies, lambs from higher litter sizes had reduced birth weights compared to single-born lambs across breed groups. Lamb characteristics at birth were in agreement with Godfrey et al. (1997), Osorio-Avalos et al. (2012) and Ríos-Utrera et al. (2014), who reported that single born lambs are heavier at birth and grow faster than twins and triplets.

Mortality of lambs in the present study is much higher than that observed with other well-fed hair lambs (Macías-Cruz et al., 2012; Knights et al., 2012) but close to the findings by Cloete et al. (2007) with Dorper ewes crossbred to meat sheep. The extent of pre-weaning mortality is a complex issue. It is influenced by the lamb capability for survival, the ewe’s maternal ability, and to management practices at lambing and during the rearing period (Nowak and Poindron, 2006; Sawalha et al., 2007). The fact that birth weight of lambs was similar among genotypes suggests that factors other than birth weight were involved in the deaths of lambs.

In the present study, a many deaths were due to dystocic parturition. This condition is associated with increased risk of lamb loss (Hinch and Brien, 2014; Holmøy et al., 2014). The marked difference in lamb mortality between genotype groups remains unexplained. Heritability for lamb survival is extremely low (Brien et al., 2010; Hatcher et al., 2010), hence the interactions between rearing ability of the mother, lamb viability, and climatic conditions around lambing possibly accounted for the difference in the incidence of lamb losses among genotype groups.

In the present study, male and female lambs had similar chances of surviving to weaning. This is in agreement with results of Matos et al. (1993), who found that males and females have similar survival rates, but it does not agree with previous studies both in wool (Sawalha et al., 2007; Hatcher et al., 2009; Everett-Hincks et al., 2014) and hair sheep (Holmøy et al., 2012; Hinch and Brien, 2014), where male lambs had higher mortality than females. Contrary
to the above-mentioned studies, Atashi et al. (2013) found that Iranian male lambs showed higher survival rate than females. It could be that Katahdin dams are not drastically affected by the greater size and weight at birth of male lambs, which leads to longer labor, compared to females (Dwyer, 2003) and eventually tend to have higher mortality than females.

In this study, either no consistent superiority was observed of singles or twins compared with triplet-born lambs in terms of survival to weaning. This result does not agree with previous reports (Gama et al., 1991; Matos et al., 1993) where increased litter size lead to decreased lamb survival. On the other hand, other researchers observed that lamb survival was higher for lambs born as twins compared to singles (Everett-Hincks et al., 2005). The hybrid nature of all lambs in the present study could have reduced the risk of hypothermia or starvation, which is characteristic of smaller lambs from large litters (Kerslake et al., 2010). This study suggests that Katahdin ewes did apparently not display the result and competition between lambs for milk supply was not strong.

Regardless of birth type, higher weaning weights were associated with lower mortality risk, whereas the risk of mortality at weaning was greater for lambs with low weaning weight. These results agree with those by several authors (Sawalha et al., 2007; Hatcher et al., 2009; Boujenane et al., 2013). This study suggests that selection programs for increased birth weight in crossbred animals would reduce lamb mortality.

The present study indicates that under intensive management conditions, farmers with flocks of Katahdin ewes would expect similar weaning weight of lambs from crossbreeding these ewes with either Charolais, Texel or Hampshire sires. However, higher survival to weaning can be expected for Hampshire-sired litters compared to Texel and Charolais-sired lambs.

**Conflicts of interest**

The authors declare they have no conflicts of interest with regard to the work presented in this report.

**References**

Atashi H, Izadifard J, Zamiri MJ, Akhlaghi A. Investigation in early growth traits, litter size, and lamb survival in two Iranian fat-tailed sheep breeds. Trop Anim Health Prod 2013; 45:1051-1054.

Bores-Quintero RF, Velazquez-Medrano PA, Heredia-Aguilar M. Evaluation of terminal breed in commercial breeding schemes with F1 hair sheep. Tec Pec Mex 2002; 49:71-79.

Boujenane I, Chikhi A, Lakcher O, Ibenlachyr M. Genetic and environmental factors affecting perinatal and preweaning survival of D’man lambs. Trop Anim Health Prod 2013; 45:1391-1397.

Braga Lobo RN, Costa Pereira ID, Facó O, McManus CM. Economic values for production traits of Morada Nova meat sheep in a pasture based production system in semi-arid Brazil. Small Rumin Res 2011; 96:93-100.

Brien FD, Hebart ML, Smith DH, Hocking-Edwards JE, Greeff JC, Hart KW, Refshauge G, Bird-Gardiner TL, Gaunt G, Behrendt R, Robertson MW, Hinch GN, Geenty KG, van der Werf JHJ. Opportunities for genetic improvement of lamb survival. Anim Prod Sci 2010; 50:1017-1025.

Brown MA, Starks PJ, Gao FQ, Wang XZ, Wu JP. Bermudagrass intake and efficiency of utilization in Katahdin, Suffolk, and reciprocal-cross lambs. Profess Anim Scient 2012; 28:358-363.

Burke JM. Lamb Production of Dorper, Katahdin, and St. Croix Bred in Summer, Winter, or Spring in the Southeastern United States. Sheep Goat Res J 2005; 20:51-59.

Burke JM, Miller JE. Relative resistance to gastrointestinal nematode parasites in Dorper, Katahdin, and ST. Croix lambs under conditions encountered in the southern regions of the United States. Small Rumin Res 2004; 54:43-51.

Cardoso MTM, Landim AV, Louvandini H, McManus, C. Performance and carcass quality in three genetic groups of sheep in Brazil. R Bras Zootec 2013; 42:734-742.

Cammack KM, Leymaster KA, Jenkins TG, Nielsen MK. Estimates of genetic parameters for feed intake, feeding behavior, and daily gain in composite ram lambs. J Anim Sci 2005; 83:777-785.

Christley RM, Morgan KL, Parkin TDH, French NP. Factors related to the risk of neonatal mortality, birth-weight and serum immunoglobulin concentration in lambs in the UK. Prev Vet Med 2003; 57:209-226.

Cloete JJE, Cloete SWP, Olivier JJ, Hoffman LC. Terminal crossbreeding of Dorper ewes to Ile de France, Merino Landsheep and SA Mutton Merino sires: Ewe production and lamb performance. Small Rumin Res 2007; 69:28-35.

Cuellar A. Perspectivas de la produccion ovina en México para el año 2010. Rev Borrego 2007; 47:14-18.
Dwyer CM. Behavioural development in the neonatal lamb: effect of maternal and birth-related factors. Theriogenology 2003; 59:1027-1050.

Everett-Hincks JM, Lopez-Villalobos N, Blai, HT, Stafford KJ. The effect of ewe maternal behaviour score on lamb and litter survival. Livest Prod Sci 2005; 93:51-61.

Everett-Hincks JM, Mathias-Davis H C, Greer GJ, Auvray BA, Dodds KG. Genetic parameters for lamb birth weight, survival and death risk traits. J Anim Sci 2014; 92:2885-2895.

Freking BA, Leymaster KA. Evaluation of Dorset, Finnsheep, Romanov, Texel, and Montadale breeds of sheep: IV. Survival, growth, and carcass traits of F1 lambs. J Anim. Sci. 2004; 82:3144-3153.

Gama LT, Dickerson GE, Young LD, Leymaster KA. Genetic and phenotypic variation in sources of preweaning lamb mortality. J Anim Sci 1991; 69:2744-2753.

Godfrey RW, Gray ML, Collins JR. 1997. Lamb growth and milk production of hair and wool sheep in a semi-arid tropical environment. Small Rumin Res 1997; 24:77-83.

González-Godínez A, Urrutia-Morales J, Gámez-Vázquez HG. Reproductive performance of Dorper and Katahdin ewes bred in spring season in the northern Mexico. Trop Subtrop Agroecosyst 2014; 17:123-127.

Hatcher S, Atkins KD, Safari E. Lamb survival in Australian Merino sheep: a genetic analysis. J Anim Sci 2010; 88:3198–3205.

Hinch GN, Brien F. Lamb survival in Australian flocks: a review. Anim Prod Sci 2014; 54:656-666.

Hinojosa-Cuellar JA, Regalado-Arrazola FM, Oliva-Hernandez J. Crecimiento prenatal y predestete en corderos Pelibuey, Dorper, Katahdin y sus cruces en el sureste de México. Rev Cient FCV-LUZ 2009; 19:522-532.

Hinojosa-Cuellar JA, Torres-Hernández G, Oliva-Hernández J, Aranda-Ibáñez E, Segura-Correa JC, González-Camacho JM. Pre-weaning performance of lambs from purebred and crossbred hair ewes under humid tropical conditions of Tabasco, Mexico. J Anim Vet Adv 2011; 10:3149-3154.

Holmøy IH, Kielland C, Stubsjøen SM, Hektoen, Waage S. Housing conditions and management practices associated with neonatal lamb mortality in sheep flocks in Norway. Prev Vet Med 2012; 107:231-241.

Holmøy IH, Waage S, Gröhn YT. Ewe characteristics associated with neonatal loss in Norwegian sheep. Prev Vet Med 2014; 114:267-275.

Kerslake JL, Kenyon PR, Stafford KJ, Morris ST, Morel PCH. Do lambs within a twin and triplet-born litter produce different amounts of heat during a cold stress event? Proc NZ Soc Anim Prod 2010; 70:171-174.

Knights M, Siew N, Ramgattie R, Singh-Knights D, Bourne G. Effect of time of weaning on the reproductive performance of Barbados Blackbelly ewes and lamb growth reared in the tropics. Small Rumin Res 2012; 103:205-210.

López-Carlos MA, Ramírez RG, Aguilera-Soto JI, Aréchiga CF, Rodríguez H. (). Size and shape analyses in hair sheep ram lambs and its relationships with growth performance. Livest Sci 2010; 131:203-211.

Macías-Cruz U, Álvarez-Valenzuela FD, Olguín-Arredondo HA, Molina-Ramírez L, Avendaño-Reyes. Pelibuey ewes synchronized with progestagens and mated with rams from Dorper and Katahdin breeds under feedlot conditions: ewe production and lamb growth during the pre-weaning period. Arch Vet Med 2012; 44:29-37.

Malhado CHM, Carneiro PLS, Affonso PRAM, Souza AAO, Sarmiento JLR. (). Growth curves in Dorper sheep crossed with the local Brazilian breeds, Morada Nova, Rabo Largo, and Santa Inês. Small Rumin Res 2009; 84:16-21.

Marai IFM, EI-Darawany AA, Fadiel A, Abdel HMAM. Physiological traits as affected by heat stress in sheep. A review. Small Rumin Res 2007; 71:1-12.

Matos CA, Ritter C, Gianola D, Thomas DL. Bayesian analysis of lamb survival using Monte Carlo numerical integration with importance sampling. J Anim Sci 1993; 71:2047-2054.

Moreno-Cañez E, Ortega-García C, Cáñez-Carrasco MG, Peñahúiri-Molina F. Evaluation of post-weaning behavior in feedlot of upcoming stud rams breeds Pelibuey and Katahdin in Sonora. Tecoc Sonora 2013; 7:7-16.

Nowak R, Poindron P. From birth to colostrum: early steps leading to lamb survival. Reprod Nutr Dev 2006; 46:431-46.

NRC (National Research Council) Nutrient requirements of small ruminants. Natl Acad Press, Washington DC; 2007.

Osorio-Avalos J, Montaldo HH, Valencia-Posadas M, Castillo-Juárez H, Ulloa-Arvizu R. Breed and breed × environment interaction effects for growth traits and survival rate from birth to weaning in crossbred lambs. J Anim Sci 2012; 90:4239-4247.

Partida de la Peña JA, Braña-Varela D, Martínez-Rojas L. Productive performance and carcass characteristics in Pelibuey sheep and crossbreeds (Pelibuey x Suffolk–Dorset). Téc Pec Méx 2009; 47:313-322.

Prado do Paim T., Ferreira da Silva A, Saraiva Martins RF, Oliveira Borges B, de Mello Tavares Lima P, Cardoso CC, Ferreira a Esteses GI, Louvandini H, McManus C. Performance, survivability and carcass traits of crossbred lambs from five paternal breeds with local hair breed Santa Ines ewes. Small Rumin Res 2013; 112:28-34.

Ríos-Utrera A, Calderón-Robles R, Lagunes-Lagunes J, Oliva-Hernández J. Preweaning weight gain in Pelibuey lambs and its relationships with growth performance. Theriogenology 2003; 71:1-12.

Rebollar JI, Kenyon PR, Stafford KJ, Morris ST, Morel PCH. Genetic and phenotypic variation in sources of preweaning lamb mortality. J Anim Sci 1991; 69:2744-2753.

Sarmento JLR. (). Growth curves in Dorper sheep crossed with the local Brazilian breeds, Morada Nova, Rabo Largo, and Santa Inês. Small Rumin Res 2009; 84:16-21.
Vázquez-Soria ET, Partida de la Peña JA, Rubio-Lozano MS, Méndez-Medina D. Productive performance and carcass characteristics in lambs from crosses between Katahdin ewes and rams from four specialized meat breeds. Rev Mex Cien Pec 2011; 2:247-258.

Wildeus S, Turner KE, Collins JR. Growth performance of Barbados Blackbelly, Katahdin and St. Croix hair sheep lambs fed pasture- or hay-based diets. Sheep Goat Res J 2005; 20:37-41.

Yaqoob M, Merrell BG, Sultan JI. Comparison of three terminal sire breeds for birth weight of lambs kept under upland grassland conditions in the northeast of England. Pakistan Vet J 2004; 24:196-198.