ECOSISTEMAS Y RECURSOS AGROPECUARIOS

EFFECTS OF NON-GENETIC FACTORS ON PRE-WEANING GROWTH TRAITS IN DORPER SHEEP MANAGED INTENSIVELY IN CENTRAL MEXICO

Efectos no genéticos sobre características del crecimiento predestete de corderos Dorper manejados intensivamente en el centro de México

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ABSTRACT. The objective of this study was to determine the non-genetic factors which affect growth traits in Dorper lambs under intensive conditions. Nine hundred and ninety birth weight records and 851 weaning weight data from a commercial sheep farm were used. A model containing the effects of year of birth, season of birth, litter size, dams' age and gender was used for identification of factors affecting growth traits. Birth weight was highest ($p < 0.05$) in summer and lowest in winter and spring. Male lambs excelled females in birth weight, weaning weight, and average daily gain. Young dams produced offspring with a lower ($p < 0.05$) birth weight and weaning weight than older ewes As a conclusion, important influences of environmental factors on growth traits were identified for Dorper lambs.
Key words: Birth weight, weaning weight, pre-weaning, weight gain, growth traits, Dorper lambs

RESUMEN. Para determinar los factores no genéticos que influyen en las características de crecimiento de corderos Dorper en condiciones intensivas se registraron 990 pesos al nacimiento (PN) y 851 pesos al destete de una unidad de producción de ovejas entre 2006 y 2010. Se analizó el efecto del año, estación de nacimiento, tamaño de camada, edad de la madre y sexo de los corderos. El año de nacimiento afectó ($p < 0.05$) el peso al nacer pues fue más elevado en verano y más reducido en invierno y primavera. Los machos fueron más pesados ($p < 0.05$) al nacimiento y al destete y las tasas de crecimiento pre-destete fueron mayores que en las hembras ($p < 0.05$). Las ovejas primíparas produjeron crías más livianas ($p < 0.05$) al nacimiento y destete que las ovejas pluríparas. Se concluyó que diversos factores ambientales tuvieron un importante efecto en las características de crecimiento de corderos Dorper.
Palabras clave: Peso al nacimiento, peso al destete, pre-destete, ganancia de peso, características de crecimiento, corderos Dorper.

INTRODUCTION

The importance of sheep production as a source of meat in Mexico has been increasing during recent years, particularly in tropical areas and the central temperate zone of the country (Montaldo *et al.* 2011, Osorio-Avalos *et al.* 2012). This production of mutton has experienced changes regarding the use of introduced meat breeds, in order to increase the growth rate of lambs (Pérez-Hernández *et al.* 2011, Ríos-Utrera *et al.* 2014). During the last decade, the production of crossbred lambs has increased, using native Pelibuey and Criollo as maternal breeds and the Dorper and Katahdin as sires (Hinojosa-Cuéllar and Oliva-Hernández 2009, Hinojosa-Cuéllar *et al.* 2013). Dorper rams have

proved to work well as terminal meat sires because they produce lambs which pre-weaning growth rate, post-weaning average daily gain (ADG), feeding efficiency, and carcass characteristics are similar to those of Suffolk crossbred lambs and purebred Columbia lambs but with a slight improvement in tenderness (Snowder and Duckett 2003).

Thus, there is a great demand for Dorper sheep to improve the growth performance of lambs, which is an important trait that determines the overall productivity of the flock. Also, Dorper sheeps as purebred have increased in the past few years due to its superior conformation, high survival of lambs to weaning, high mother ability (Kosgey *et al*. 2008), the ability to breed out of season (Burke 2005), and superior rates of gain and carcass characteristics relative to some wool (Schoeman 2000) and hair (Wildeus 1997). Under intensive conditions, Dorper breeders focus on conformation, fertility, masculinity, and femininity to ensure that Dorper can be the basis for a productive and economical lamb industry. Studies on non-genetic factors influencing growth traits of Dorper sheep are scarce for sheep reared under intensive conditions and bred in all seasons of the year in Mexico (Hinojosa-Cuéllar *et al*. 2009). Birth weight as an early measurable trait is of great interest because of its positive genetic correlation with further live weights. On the other hand, weaning weight is the most important economic trait determining economic returns from commercial sheep flocks (Mousa *et al*. 2013, Shiotsuki *et al*. 2014). A number of non-genetic factors affect growth of lambs and interfere with the objective evaluation of the growth genetic potential of lambs. Due to the increasing interest in fast growing, excellent meat yields and fat distribution, easy to handle and fertile sheep breeds in Mexico, such as Dorper, a clearer understanding of the influence of diverse non-genetic factor affecting weight traits of this breed of sheep is required, particularly for intensive production systems. Therefore, the objective of this study was to evaluate non-genetic factors affecting the growth traits of purebred Dorper sheep under intensive conditions in central Mexico.

MATERIAL AND METHODS

Data were obtained on purebred Dorper sheep raised on a large commercial farm in central Mexico (19º 32' N, 1240 m of altitude, mean annual temperature 21.5 °C and mean annual precipitation 623 mm). Birth (n= 990) and weaning (n= 851) weights were registered in Dorper lambs born from 2006 to 2010, inclusive. Mating and parturition occurred throughout the year.

All lambs were raised as either singles or multiples and had a pelleted, commercial, creep feed available ad libitum. Diets for the lambs consisted of a pelleted feed (2.99 Mcal ME kg^{-1} DM with 20 % CP, Lamb Tech, Purina®, Salamanca, Mexico). Young lambs were allowed to suckle freely through the day and they remained with their mothers for 24 hours up to weaning. Lambs were weaned at an average of 88 $\pm$ 2.6 days of age and weights were recorded. The individual weaning lamb weight was corrected to 90 days of age by using the following equation:

$$Corrected\ weght\ = \frac{(actual\ weight - birth\ weight)}{actual\ age\ in\ days} 90 + birth\ weight$$

Ewes were maintained as one group in an orchard grass (*Dactylis glomerata*) pasture throughout gestation. Ewes were supplemented with 300 g d^{-1} concentrate (Ovina 14, *Purina*®) and alfalfa hay *ad libitum* from the third month of gestation until the end of lactation. Traits studied were birth weight, weaning, and average preweaning weight (ADG). Fixed environmental factors investigated were year and season of birth, litter size, dams' age, and gender.

Birth and weaning weights as well as ADG were analyzed by univariate general linear model (GLM procedure of SAS) with explanatory variables as fixed effects. The model for traits measured on lambs fit effects of year of birth (four years), season of birth (four seasons), dams' age (three categories) gender, litter size (three categories; litters with three and four lambs were combined into a single category) and two-way interactions between variables; the non-significant interactions were removed from the final model. Birth weight was fitted

as a covariate for ADG analysis. Means of variables analyzed were compared using the probability of a statistical difference (PDIFF option of SAS). Statistical differences were considered significant at $p < 0.05$.

RESULTS AND DISCUSSION

Birth weight

The birth weight of Dorper lambs in the present study (3.8 ± 0.8 kg) is close to that found by other researchers (3.3 - 3.9 kg) under pasture conditions (Neser *et al*. 2001, Hinojosa-Cuéllar *et al*. 2013). Year of birth had a significant effect on birth weight, producing shifts in this trait of up to 0.5 kg (Table 1). These effects occurred despite no obvious difference in flock management, nutrition, and health practices. The mean birth weight of lambs was lower in 2010 (3.4 ± 0.8 kg) than in the other years, whereas the higher mean birthweight was observed in 2009 (4.0 ± 0.7 kg). It is well established that year of birth causes variations on weight and performance of lambs due to climatic variations (rate of rainfall, humidity, and temperature). It is presumed that the environment during pregnancy may have influenced overall birth weight. Likewise, occurrence of diseases in different years (Gardner *et al*. 2007) as well as sample size may explain the influence of year of parturition on lamb birth weight. The significant influence of year on birth weight of lambs obtained matches the results from previous studies in other countries in different breeds of sheep (Dixit *et al*. 2001, Gardner *et al*. 2007). There was also a significant interaction between the year and season of birth ($p < 0.01$), between year of birth and gender of lambs ($p < 0.01$), between year of birth and dams' age and between year of birth and litter size ($p < 0.01$). Means for year-season interactions ranged from 3.1 ± 0.7 kg in summer of 2007 to 4.1 ± 0.6 kg in summer of 2006.

Mean birth weight was highest ($p < 0.05$) in summer and lowest in winter and spring. The seasonal differences in birth weight in the present study may have been partly due to alterations in ambient temperature and maternal pre-natal effects during gestation. The lower body weights of winter and spring-born lambs emphasizes the need of providing supplementary food and adequate management for ewes at the end of fall in order to increase the growth rate of fetuses. Multiple studies have shown the strong influence of season on birth weight of lambs of all breeds (Dixit *et al*. 2001, Yilmaz *et al*. 2007, Rosov and Gootwine 2013).

As expected, males were, on average, 200 g heavier at birth than female lambs ($p < 0.01$). A great number of authors have documented this result in sheeps (Afolayan *et al*. 2006), which is due to the fact that males grow faster than respective females in-utero (Loos *et al*. 2001), because of the testosterone secretion. Acute prenatal androgen treatment increases birth weight of lambs (Gill and Hosking 1995). Means for the interaction ($p < 0.01$) between year of birth and gender of lambs ranged from 3.4 ± 0.7 kg (females born in 2010) to 4.2 ± 0.6 kg (males born in 2006). Other significant interactions detected were gender x litter size and gender x age of dams. The proportional decrease in birthweight relative to litter size was greater in females. On the other hand, to illustrate gender x age of dam interactions on birth weight, the percentage increase in birth weight relative to maternal age was greater in males than in females.

Litter size was the most important factor affecting birth weight of lambs. Lambs born as singles were 0.6 kg heavier ($p < 0.05$) than twins, 1.6 kg heavier than triplets and 1.9 kg heavier than quadruplets. The maternal uterine space has a finite capacity to gestate offspring, and as litter size increases, individual birth weights decline (Gluckman and Hanson 2004). The standard deviation for birth weight decreased with increasing litter size, indicating that the compact uterine space limits variance in birth weight. Means for the interaction ($p < 0.01$) between season of birth and litter size ranged from 2.3 ± 0.6 kg (quadruplets born in fall) to 4.4 ± 0.7 kg (singles born in summer).

Young ewes (< 20 months of age) produce lambs that were 300 g lighter ($p < 0.05$; Table 1) at birth than ewes > 20 months of age. primi-

Table 1. Least squares means and standard errors for birth weight, 90 d weaning weight and daily weight gain from birth to weaning for well-fed Dorper sheep in central Mexico.

	Birth weight, kg			Weaning weight, kg*			Daily gain, g		
	No	Mean	SD	No	Mean	SD	No	Mean	SD
Item	990	3.8	0.8	851	32.3	5.8	854	319	62
Year									
2007	305	3.8^{c}	0.9	288	30.4^{c}	6.4	288	298^{c}	63
2008	271	$3.8b^{c}$	0.7	259	32.7^{b}	6.2	262	322^{b}	68
2009	235	3.9^{ab}	0.7	191	34.7^{a}	4.3	191	343^{a}	46
2010	179	3.5^{d}	0.8	113	32.6^{b}	3.7	113	322^{b}	52
Season									
Winter	282	3.7^{b}	0.8	224	31.2^{c}	6.0	224	306^{c}	66
Spring	253	3.7^{b}	0.8	224	33.5^{a}	4.3	224	334^{b}	52
Summer	220	4.0^{a}	0.7	216	32.5^{ab}	5.2	216	317^{a}	54
Fall	235	3.8^{b}	0.9	187	32.0^{bc}	7.2	190	318^{a}	71
Gender									
Male	496	3.9^{a}	0.7	434	33.4^{a}	5.8	437	328^{a}	63
Female	494	3.7^{b}	0.8	411	31.3^{b}	5.4	416	309^{b}	57
Litter size									
1	227	4.3^{a}	0.8	203	35.1^{a}	5.3	203	354^{a}	53
2	634	3.7^{b}	0.7	538	32.2^{b}	5.4	538	315^{b}	57
3	149	3.0^{c}	0.7	110	28.2^{c}	5.8	110	276^{c}	60
Age dam (months)									
< 20	317	3.6^{a}	0.8	266	30.9^{a}	5.8	266	307^{a}	59
20-60	295	3.9^{b}	0.8	272	32.3^{b}	5.9	272	316^{a}	63
>60	378	3.8^{b}	0.7	313	33.6^{c}	5.4	313	331^{b}	60

*Weight adjusted at 90 days of age ^{a,b,c}Means within a column followed by different superscripts differ ($p < 0.01$).

parous ewes are growing during gestation and complement their growth in addition to fetus growth, which increases metabolic strain, and that affects lamb weight. Additionally, as ewes grow older, their uterus gets larger which allows allocating more nutrients to the nourishment of lambs in the uterus than immature ewes. Other researchers (Gardner *et al.* 2007, Petrovic *et al.* 2011) have widely documented the same results. Additionally, Corner *et al.* (2013) have previously shown that ewe lambs have the potential to partition available resources towards themselves rather than the growing fetus.

Weaning weight adjusted to 90 d

Year of birth affected greatly ($p < 0.01$) the weaning weight of lambs (Table 1). In addition, significant interactions existed between year and season of birth ($p < 0.01$), between year of birth and sex ($p < 0.01$), and between year of birth and age of dam at birth ($p < 0.05$). The significant influence of year of birth in the present study agrees with results of previous studies at various locations in different breeds of sheep (Assan and Makuza 2005, Bermejo *et al.* 2010). Differences in lamb performance between years reflect environmental variations (variation of quantity and quality of herbage available), which cannot be controlled.

Season of the year affected ($p < 0.01$) weaning weight with the lowest weights being for lambs born in winter. Thus, external environment or climate during early growth may have influenced overall pre-weaning growth rate, as it has been observed in a variety of sheep breeds (Yilmaz *et al.* 2007). Gender of lambs was an important ($p < 0.01$) factor affecting weaning weight, with males being 2.1 kg heavier than females. Significant effects of lamb sex on weaning weight traits have been reported in various sheep breeds (Fogarty *et al.* 2005, Hopkins *et al.* 2005).

It is well documented that single lambs are

heavier at weaning than twins (Yilmaz *et al*. 2007, Mohammadi *et al*. 2010). In the present study single born lambs weighed 6.9 kg more than triplets. This result shows that heavier weight of single over multiple lambs is partly due to the birth weight advantage of single-born lambs. Average weaning weight increased linearly with increased age of dams, which is in line with other researchers' findings (Momany-Shaker *et al*. 2002). It is well known that mothering ability (milk yield) increases with parity, and older ewes are usually larger in body size and produce more milk, which explains the greater weaning weights of lambs from older dams.

Pre-weaning daily weight gain

The average pre-weaning ADG of 319 $\pm$ 62 g for Dorper lambs in this study is higher than the 240-280 g published values by Schoeman (2000) and Neser *et al* (2001) for Dorper flocks from widely different production systems. This indicates that sheep in the present study had very favorable conditions in nutrition and management compared to other studies where suboptimal conditions prevailed. Both year and season of birth had marked effects on pre-weaning ADG (Table 1). Lambs born in spring grow faster than those born in winter. Numerous studies have documented the important influence of year and season for pre-weaning daily weight gain in lambs (Hassen *et al*. 2004).

The only significant interaction observed for this trait was year x season of birth, which may indicate variation in quantity and quality of feed across seasons and years, which can be directly connected to the amount of precipitation and its distribution. Moreover, changes in the occurrence of disease and management have a marked influence on lambs' growth performance. Birth type represented the greatest barrier on pre-weaning growth of any of the environmental factors studied. The comparative growth rates of lambs born as singles and as multiples are presented in Table 1. The differences between singles and twins, twins and triplets, and triplets and quadruplets were significant, which matches a number of studies in different breeds and management systems (Rios-Utrera *et al*. 2014, Teklebrhan *et al*. 2014). This is explained in part by competition for suckling between multiple birth lambs from birth to weaning period.

Lambs out of young ewes (< 20 months) grew slower ($p < 0.001$) than ewes > 20 months of age. This is explained by the fact that young ewes that had not reached adult size continue to grow and thus muscle synthesis compete with milk synthesis for available nutrients, and thus less milk is available for suckling lambs. It is well known that mothering ability (milk yield) increases with parity, and older ewes are usually larger in body size and produce more milk. This response has been amply documented with other sheep breeds in different environments (Momany-Shaker *et al*. 2002, Mohammadi *et al*. 2010, Rashidi *et al*. 2008).

Several researchers (Bermejo *et al*. 2010, Mohammadi *et al*. 2010) have shown that male lambs grow faster than female lambs before weaning. The present study confirms these findings and indicates that part of the advantage of male lambs in pre-weaning weight gains results from the larger birth weights of males. Thus, heavier lambs at birth indicate rapid growth rates which are expressed prenatally and which result in faster growth rates. The present paper shows that the single greatest effect on birth and weaning weight as well as pre-weaning weight gain of Dorper lambs was litter size. Further, significant effects on birth weight were found to be year of birth, age of dam, and sex of the lamb. These results have practical implications not only for the husbandry of the sheep as an economical commodity, but also for the increased knowledge of factors that significantly influence variation in growth traits in Dorper sheep in central Mexico.

LITERATURE CITED

Afolayan RA, Adeyinka IA, Lakpini, CAM (2006) The estimation of live weight from body measurements in Yankasa sheep. Czech Journal of Animal Science 51: 343-348.

Assan N, Makuza SM (2005) The effect of non genetic factors on birth weight and weaning weight in three sheep breeds of Zimbabwe. Asian Australasian Journal of Animal Science 18: 151-157.

Bermejo LA, Mellado M, Camacho A, Mata J, Arévalo JR, de Nascimento L (2010) Factors influencing birth and weaning weight in Canarian hair lambs. Journal of Applied Animal Research 37: 273-275.

Burke JM (2005) Lamb production of Dorper, Katahdin, and St Croix bred in summer, winter or spring in the southeastern United States. Sheep and Goat Research Journal 20: 51-59.

Corner RA, Mulvaney FJ, Morris ST, West DM, Morela PCH, Kenyon PR (2013) A comparison of the reproductive performance of ewe lambs and mature ewes. Small Ruminant Research 114: 126-133.

Dixit SP, Dhillon JS, Singh G (2001) Genetic and non-genetic parameter estimates for growth traits of Bharat Merino lambs. Small Ruminant Research 43: 101-104.

Fogarty NM, Ingham VM, Gilmour AR, Cummins LJ, Gaunt GM, Stafford J, *et al.* (2005) Genetic evaluation of crossbred lamb production 1 Breed and fixed effects for birth and weaning weight of first-cross lambs, gestation length, and reproduction of base ewes. Australian Journal of Agricultural Research 56: 443-453.

Gardner DS, Buttery PJ, Daniel Z, Symonds ME (2007) Factors affecting birth weight in sheep: maternal environment. Reproduction 133: 297-307.

Gill JW, Hosking BJ (1995) Acute prenatal androgen treatment increases birth weights and growth rates in lambs. Journal of Animal Science 73: 2600-2608.

Gluckman PD, Hanson MA (2004) Maternal constraint of fetal growth and its consequences. Seminars in Fetal and Neonatal Medicine 9: 419-425.

Hassen Y, Sölkner J, Fuerst-Waltl B (2004) Body weight of Awassi and indigenous Ethiopian sheep and their crosses. Small Ruminant Research 55: 51-56.

Hinojosa-Cuéllar JA, Oliva-Hernández J (2009) Distribución de partos por estación en ovejas de razas de pelo y cruces en un ambiente tropical húmedo. Revista Científica, FCV-LUZ 19: 288-294.

Hinojosa-Cuéllar JA, Oliva-Hernández J, Torres-Hernández G, Segura-Correa JC (2013) Productive performance of F_1 Pelibuey x Blackbelly lambs and crosses with Dorper and Katahdin in a production system in the humid tropic of Tabasco, México. Archivos de Medicina Veterinaria 45: 135-143.

Hopkins DL, Stanley DF, Martin LC, Gilmour AR (2005) Genotype and age effects on sheep meat production 1 Production and growth. Animal Production Science 47: 1119-1127.

Kosgey IS, Rowlands GJ, Van Arendonk, JAM, Baker RL (2008) Small ruminant production in small holder and pastoral/extensive farming systems in Kenya. Small Ruminant Research 77: 11-24.

Loos RJ, Derom C, Eeckels R, Derom R, Vlietinck R (2001) Length of gestation and birth weight in dizygotic twins. Lancet 358: 560-561.

Mohammadi K, Beygi-Nassiri MT, Fayazi J, Roshanfekr M (2010) Investigation of environmental factors influence on pre-weaning growth traits in Zandi lambs. Journal of Animal and Veterinary Advances 9: 1011-1014.

Momany-Shaker M, Abdullah AY, Kridli RT, Sada I, Sovjak R Muwalla MM (2002) Effect of crossing indigenous Awassi sheep breed with mutton and prolific sire breeds on the growth performance of lambs in a subtropical region. Czech Journal of Animal Science 47: 239-246.

Montaldo HH, Flores-Serrano C, Sulaiman Y, Osorio-Avalos J, Ortiz-Hernández A, Angulo-Mejorada RB (2011) Growth and reproductive performance of Poll Dorset and Suffolk sheep under intensive conditions. Revista Mexicana de Ciencias Pecuarias 2: 359-369.

Mousa E, Monzaly H, Shaat I, Ashmawy A (2013) Factors affecting birth and weaning weights of native Farafra lambs in upper Egypt. Egyptian Journal of Sheep and Goat Sciences 8: 1-10.

Neser FWC, Erasmus GJ, van Wyk JB (2001) Genetic parameter estimates for pre-weaning weight traits in

Dorper sheep. Small Ruminant Research 40: 197-202.

Osorio-Avalos J, Montaldo HH, Valencia-Posadas M, Castillo-Juárez H, Ulloa-Arvizu R (2012) Breed and breed x environment interaction effects for growth traits and survival rate from birth to weaning in crossbred lambs. Journal of Animal Science 90: 4239-4247.

Pérez-Hernández P, Vilaboa-Arroniz J, Chalate-Molina H, Candelaria-Martínez B, Díaz-Rivera P, López-Ortiz S (2011) Descriptive analysis of sheep production systems in the state of Veracruz, Mexico. Revista Científica FCV-LUZ 21: 327-334.

Petrovic MP, Ruzic-Muslic D, Caro-Petrovic V, Maksimovic N (2011) Influence of environmental factors on birth weight variability of indigenous Serbian breeds of sheep. African Journal of Biotechnology 10: 4673-4676.

Rashidi A, Mokhtari MS, Safi-Jahanshahi A, Mohammad-Abadi MR (2008) Genetic parameter estimates of pre-weaning growth traits in Kermani sheep. Small Ruminant Research 74: 165-171.

Ríos-Utrera A, Calderón-Robles R, Lagunes-Lagunes J, Oliva-Hernández J (2014) Ganancia de peso predestete en corderos Pelibuey y sus cruces con Blackbelly, Dorper y Katahdin. Nova Scientia 12: 271-286.

Rosov A, Gootwine E (2013) Birth weight and pre- and postweaning growth rates of lambs belonging to the Afec-Assaf strain and its crosses with the American Suffolk. Small Ruminant Research 113: 58-61.

Shiotsuki, L, Pernambuco de Oliveira D, Braga Lôbo RN, Facó O (2014) Genetic parameters for growth and reproductive traits of Morada Nova sheep kept by smallholder in semi-arid Brazil. Small Ruminant Research 120: 2004-2008.

Schoeman SJ (2000) A comparative assessment of Dorper sheep in different production environments and systems. Small Ruminant Research 36: 137-146.

Snowder GD, Duckett SK (2003) Evaluation of the South African Dorper as a terminal sire breed for growth, carcass, and palatability characteristics. Journal of Animal Science 81: 368-375.

Teklebrhan T, Urge M, Mekasha Y, Baissa, M (2014) Pre-weaning growth performance of crossbred lambs (Dorper x indigenous sheep breeds) under semi-intensive management in eastern Ethiopia. Tropical Animal Health and Production 46: 455-460.

Yilmaz O, Denk H, Bayram D (2007) Effects of lambing season, sex and birth type on growth performance in Norduz lambs. Small Ruminant Research 68: 336-339.

Wildeus S (1997) Hair sheep genetic resources and their contribution to diversified small ruminant production in the United States. Journal of Animal Science 75: 630-640.