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Behavioral pattern in Texel x Corriedale terminal crossbreeding: Maternal behavior score at birth, lambs' feeding behaviors, and behavioral responses of lambs to abrupt weaning



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ABSTRACT

Texel x Corriedale (TxC) crossbred lambs grow faster than purebred Corriedale lambs (CxC). Thus, they should develop different feeding strategies, depending less on their mother, which should influence their behavioral response at weaning. The objective of this study was to compare the maternal behavior score at early postpartum, the feeding behaviors of TxC and CxC lambs before and after weaning, and the behavioral responses at weaning. Furthermore, we determined whether the sex of the lamb had any influence on those responses in pure or crossbred lambs. Crossbreeding had no effect on maternal behavior score, milk yield, or ewe body weight postpartum. Crossbred lambs were heavier than CxC lambs ($P < 0.004$) postpartum. During the lactation period, TxC lambs ruminated more frequently than CxC lambs ($P = 0.002$). There was no difference between groups in the frequency in which lambs grazed or in the number of suckling events. Crossbred lambs ruminated more frequently than CxC lambs ($P = 0.0009$) on the day of weaning. Although TxC lambs were never observed pacing, CxC lambs were observed pacing one day after weaning ($0.2 \pm 0.2\%$). In conclusion, crossbred lambs were more advanced in nutritional independence from their mothers, ruminating more than CxC lambs during the lactation period. This resulted in TxC lambs growing faster than CxC lambs, allowing them to cope better with a late artificial weaning.

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Introduction

In several countries of South America, including Uruguay, the use of terminal crossbreeding of consolidated breeds, such as Corriedale, with rams from breeds used for meat production has gained great importance as an alternative in sheep production during the last two decades. Texel is one of the breeds more frequently used for terminal crossbreeding, as Texel X Corriedale (TxC) crossbred lambs are heavier at birth and have good postnatal growth, achieving a heavier carcass yield than purebred Corriedale (CxC) (Barbato et al., 2011).

Heavier lambs are more liable to show malpresentation and need assistance at delivery, which may also negatively affect the neonatal attachment behaviors (Dwyer, 2003; Dwyer and Bünger, 2012). Moreover, as TxC lambs are heavier at birth than CxC lambs, during gestation, TxC lambs' mothers should mobilize more fat reserves to respond to the higher demand. As a consequence, standing up and suckling for the first time are delayed in lambs (Dwyer, 2003). Moreover, as TxC lambs have a bigger energetic coast for their mothers, mothers should invest more energy to protect offspring from a challenging situation, such as predators' presence or human handling of the neonate. Furthermore, as TxC lambs grow faster than CxC lambs, the former also require more energy to grow; therefore, these lambs should modify their feeding strategy advancing the process of nutritional independence from their mothers.

In meat and wool production systems, lambs are commonly abruptly weaned between 60 and 150 days of age (Freitas-de-Melo and Ungerfeld, 2016). Weaning is a highly stressful event for lambs, as

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the mother-lamb relationship ends, triggering an emotional stress response. Weaning also involves changes in the physical and social environment, the end of suckling, and the complete replacement of milk by solid food (Freitas-de-Melo and Ungerfeld, 2016). Lambs are less stressed if after weaning they remain in close contact with a human who handled them gently or if they stayed in contact with two adult ewes (Pascual-Alonso et al., 2015). After abrupt separation, lambs vocalize frequently (Orgeur et al., 1998) and increase the time spent standing, walking, and pacing (Damián et al., 2013; Freitas-de-Melo et al., 2017a). Consequently, there is a reduction in the time they spend lying and ruminating (Cockram et al., 1993). Lambs weaned at 147 days of age were less agitated and vocalize less compared with lambs that were weaned at 42 and 91 days of age (Schichowski et al., 2010). In this context, as the strength of the ewe-lamb attachment (Nowak and Boivin, 2015) and the nutritional independence from the mother (Freitas-de-Melo and Ungerfeld, 2016) affect the response to separation in lambs, we expected that TxC lambs cope better with weaning than CxC lambs.

Therefore, our hypothesis was that TxC lambs increase the consumption of pastures earlier and, as a consequence, are less stressed at weaning than CxC lambs. Thus, the objective of this study was to compare the maternal behavior score at early postpartum, the feeding behaviors of TxC and CxC lambs before and after weaning, and the behavioral responses at weaning. Furthermore, as males usually grow faster than females (Yilmaz et al., 2007), our hypothesis was that males would gain nutritional independence earlier than females, thus responding less to weaning. Therefore, we determined if the sex of the lamb has any influence on those responses in pure or crossbreed lambs.

Material and methods

Location, animals, and general management

The experiment was performed at the Estación Experimental Bernardo Rosengurt, Facultad de Agronomía, Universidad de la República (Cerro Largo, Uruguay; 32° S, subtropical region; year 2013; early spring; humid subtropical weather, Cfa) with multiparous Corriedale ewes that were inseminated with semen of Corriedale or Texel rams. Seventeen days before conception ewes weighed 50.5 ± 1.0 kg (mean \pm sem) and had a body condition score (BCS) of 2.8 ± 0.1 (scale 1–5; Russel et al., 1969). Ewes received two doses of a PGF $_{2\alpha}$ analogue (10 mg, dinoprost tromethamine, Lutalyse, Pfizer, Kalamazoo, MI, USA) at 10-day intervals, and estrus was recorded twice daily with vasectomized rams fitted with markers (ram:ewe ratio, 1:10). Twelve hours after being detected with estrus (day 0), ewes were randomly inseminated with fresh semen from one of two Corriedale rams (group CxC) or one of two Texel rams (group TxC). Pregnancy was diagnosed by transrectal ultrasound on day 30, and ewes carrying a single fetus were used in the experiment. From these, 12 ewes were TxC (six ewes carrying a male and six a female fetuses) and 11 ewes were CxC (five ewes carrying a male and six a female fetus).

During gestation, ewes from each group were allocated on three independent paddocks of approximately 11 ha each; thus, each treatment had three replications, where they grazed native pasture. Pasture allowance was adjusted every month based on the measurements of pasture mass and body weight (BW) of all the ewes. Pasture allowance varied from 10 to 12 kg of dry matter/100 kg of BW per day from 40 days before conception until day 105 (Freitas-de-Melo et al., 2015).

All ewes were shorn during winter on days 106 and 107 of gestation; from day 99 until parturition, ewes received rice bran (200 g/animal/day) and 50 mL of crude glycerin/animal/day (77% of glycerol). The chemical composition of rice bran was 88% dry

matter, 14% crude protein, 9% acid detergent fibre, and 24% neutral detergent fibre, and crude glycerin composition was 3% water, 6% ashes, 77% glycerol, 13% fat, and 1% methanol. After shearing, ewes grazed on *Festuca arundinacea* (14 kg of dry matter/100 kg of BW per day, the chemical composition of which was 12.55% crude protein, 48.59% neutral detergent fibre, 22.56% acid detergent fibre, and 10.82% ash). From day 145, ewes were kept in two paddocks of approximately 1 ha grazing on native pastures with no restriction (12–15 kg of dry matter/100 kg BW per day) during daylight (06.00–18.00 hours). During dark hours (18.30–05.30 hours), ewes were moved to a 40 \times 20 m pen, close to their former paddock, with artificial dim light to allow observations. The date of birth and the sex of the lamb were recorded. Lambing assistance was given if the second stage of parturition (from appearance of fetal front or rear legs to complete lamb expulsion) took more than 2 hours.

Body weight, body condition score of ewes, and body weight of lambs

The BW and BCS of all ewes were recorded in the morning on days 17, 41, 79, 105, and 145. The BW of ewes and lambs were recorded 32, 63, 95, and 140 days after parturition, and lambs' BW was also recorded on 145 days after lambing.

Maternal behavior score

The MBS of each ewe was determined 12–24 hours after lambing, systematically by the same observer, while the lamb was weighed. An observer recorded the behavior and the distance that the ewe kept from her lamb while it was handled. Thereafter, each ewe received a score based on O'Connor et al., (1985). Ewes were categorized on a 1 to 5 points score, where 1 = minimum (ewe fled when the observer approached, showing no interest in the lamb and did not return) and 5 = maximum (ewe remained within 1 m from the lamb, even with physical contact with her lamb; ewe also vocalized, walked around her lamb, and/or kicked the ground). The MBS was determined in a paddock of approximately 1 ha, adjacent to the pen where the ewes lambed.

Recordings during postpartum

Milk yield

During the morning, all ewes were manually milked 32, 63, 95, and 140 days after lambing. Milk production was estimated using an oxytocin milking technique (Freitas-de-Melo et al., 2013, 2017b). In brief, lambs were shifted to another paddock where they have access to native pastures and water, and all ewes were injected intramuscularly with 5 IU of oxytocin (Hipofamina, LaboratoriosDispert, Montevideo, Uruguay) and were milked completely. Four hours later, ewes were milked again with the same protocol, and then reunited again with their lambs. Daily milk production was calculated according to Doney et al., (1979) by extrapolating the total quantity of milk obtained after the 4-hour period to a 24-hour period.

Feeding behaviors of lambs

From 7 days after birth until the end of the experiment, ewes and their lambs grazed on native pastures with no restricted availability in a paddock of approximately 2 ha. During the observations, this paddock was divided with electric fences into two smaller paddocks of 0.2 ha separated by 20 m. All lambs were marked with different colors around the body to allow recording their activity from outside the paddock. Trained observers recorded three different behaviors (grazing, ruminating, and suckling; see description in Table 1) of the lambs of each group 23, 24, 53, 54, 76, and 77 days after lambing. In

Table 1
Lambs' recorded behaviors

Behavior	Description
Standing	Maintaining an upright position on extended legs
Lying	Lying down in any resting position
Ruminating	Chewing regurgitated boluses of feed
Grazing	Consuming pasture with the head down
Walking	All four legs are moved with the head raised or down
Pacing	Moving parallel to the fence line, within 1-2m
Suckling	The lamb suckles the udder for at least 5 seg
Vocalization	Bleating with the open or closed mouth

those days, data were recorded during two observation periods: from 07.30-12.30 hours and 13.30-18.30 hours. Grazing and ruminating were recorded using 15-minute scan sampling, totalizing 42 recordings, day 1. Suckling events were recorded continuously during the same period of the day.

Behavioral response to weaning

Weaning was performed in spring, 143 days after lambing, at 06.30 hours. The lambs from each group were placed in a different paddock (20 × 20 m), where they remained grazing native pastures. Those paddocks were approximately 5000 m away from the paddock where their mothers remained, so they did not have visual, olfactory, or auditory communication between them. Trained

observers recorded seven different behaviors (Table 1; standing, lying down, walking, and pacing are mutually exclusive, grazing and ruminating, which are also mutually excluding behaviors) of lambs in each treatment 141, 142, 143, 144, 145, and 151 days after lambing according to Freitas-de-Melo et al., (2017a). Behaviors were recorded using 15-minute scan sampling, totalizing 42 recordings, day 1. Vocalizations were recorded for a 30-second period every 15 minutes using 0/1 sampling (Lehner, 1996). Data were daily recorded from 08.00-11.00 hours and 15.30-18.30 hours.

Statistical analysis

All the variables were tested for normal distribution with the Shapiro-Wilk test, and data were analyzed as a completely randomized design. The percentage of recordings at which each animal was observed displaying each behavior was calculated and used for the analysis. The BW of ewes and lambs, the milk yield, the number of suckling events, and the frequency of other behaviors recorded during postpartum were compared between groups with the mixed procedure of SAS (SAS Institute, Cary, NC, USA), including the autoregressive, order 1 covariance structure. The model included the group, the time as a repeated measure, the sex of lambs, as well as the interaction between group and time, and group and sex as fixed effects. The ewe or the lamb, and the ram into each group, as well as the repetition were included as random effects. Differences between groups and time were performed using the Tukey-Kramer test. The MBS was compared with the Mann-Whitney test. Results were considered significantly different when $P \leq 0.05$ and a tendency when $0.05 < P \leq 0.1$. Data are presented as LSmeans ± sem.

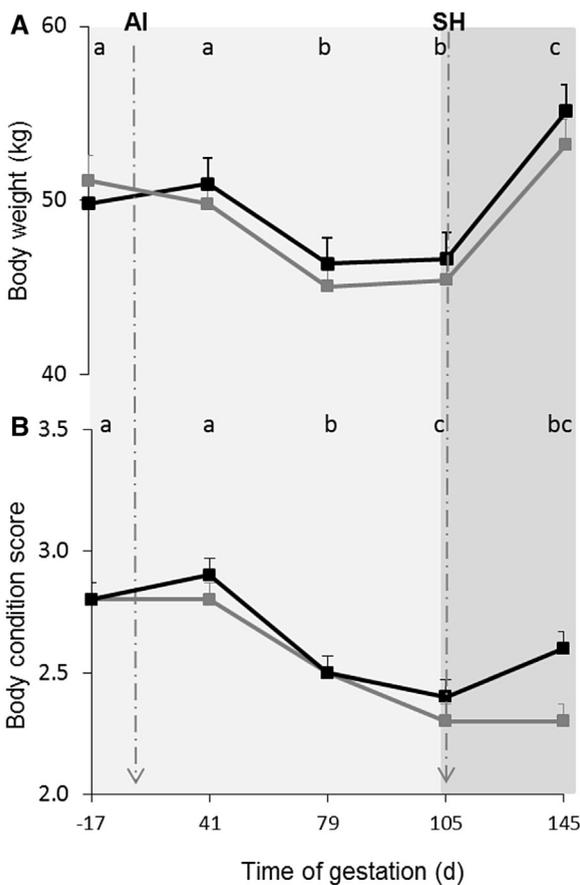


Figure 1. Body weight (A) and body condition score (B) from 17 days before insemination until 145 days of gestation of ewes carrying Texel x Corriedale (—■—) or Corriedale x Corriedale (- -■-) fetuses. Different letters indicate significant differences between days ($P < 0.0001$). The gray arrow indicates the moment of artificial insemination (AI; day = 0), and the black arrow shows the day of shearing (SH). The light gray area shows the period when ewes grazed on native pasture, and the dark gray area shows the period when all ewes grazed on *Festuca arundinacea*.

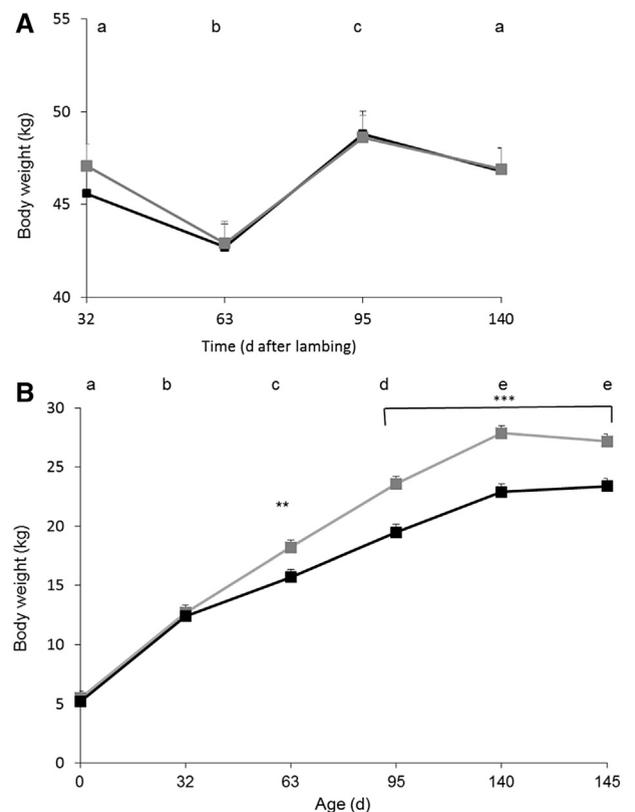


Figure 2. Body weight of ewes (A) and their lambs (B) during postpartum period. Ewes carried a Texel x Corriedale (—■—) or a Corriedale x Corriedale (- -■-) lamb. Artificial weaning was performed at 140 days of age. Different letters indicate significant differences between days ($P < 0.0001$). Asterisks indicate differences between groups** = $P < 0.008$; *** = $P < 0.001$.

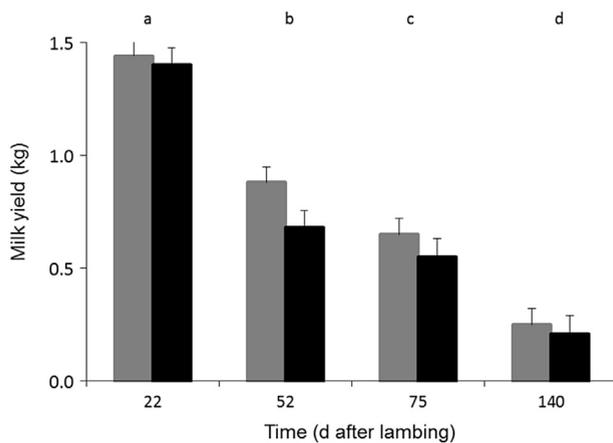


Figure 3. Milk yield of Corriedale ewes that gave birth to Texel x Corriedale (—■—) or Corriedale x Corriedale (—■—) lamb. Milk yield was measured from day 22 to day 140 postpartum. Different letters indicate significant differences between days ($P < 0.0001$).

Results

Ewe's BW and BCs during gestation and MBS at parturition crossbreeding did not affect the ewes' BW and BCS (BW: 48.9 ± 1.4 kg vs. 49.8 ± 1.4 kg; BCS: 2.5 ± 0.04 vs. 2.6 ± 0.04 , respectively; Figure 1A and B). Both ewes' BW and BCS changed over time ($P < 0.0001$), and both decreased from day 41 to day 79 in both groups ($P < 0.0001$ for both variables). Although BW increased from day 105 to day 145 ($P < 0.0001$), BCS did not change. There was no interaction between group and time in BCS; however, there was a tendency for an interaction between group and time in BW ($P = 0.06$).

Crossbreeding had no effect on MBS (4.7 ± 0.4 vs. 4.8 ± 0.1 for TxC and CxC groups, respectively). No ewe had malpresentation, and birth assistance was provided to four ewes, two from each group.

Ewes' and lambs' BW during the postpartum period

Crossbreeding did not affect the ewes' BW (LSmeans during the studied period: 46.4 ± 1.1 kg vs. 46.0 ± 1.1 kg for TxC and CxC groups, respectively). On the other hand, the BW of ewes changed over time ($P < 0.0001$), it decreased from day 32 to day 63 ($P < 0.0001$) and increased from day 63 to day 95 ($P < 0.0001$), returning to initial values 140 days after parturition (Figure 2A).

The TxC lambs were heavier than CxC lambs (LSmean from birth until 145 days of age: 19.2 ± 0.5 kg vs. 16.5 ± 0.6 kg, $P < 0.004$). However, lambs' birth BW did not differ between groups (5.5 ± 0.1 kg vs. 5.2 ± 0.6 kg for TxC and CxC groups, respectively). There was a significant interaction between group and time in lambs' BW ($P < 0.0001$); TxC lambs were heavier than CxC lambs from 63 days old until the end of the experiment (Figure 2B).

Milk yield

Milk yield/day was similar in both groups of ewes (LSmean during the studied period: 0.8 ± 0.06 kg vs. 0.7 ± 0.05 kg for ewes from TxC and CxC groups, respectively). Milk yield decreased with time ($P < 0.0001$), without interaction between group and time (Figure 3).

Feeding behavior before weaning

Lambs from TxC group ruminated more frequently than CxC lambs ($19.0 \pm 0.8\%$ vs. $15.0 \pm 0.8\%$, respectively; $P = 0.002$,

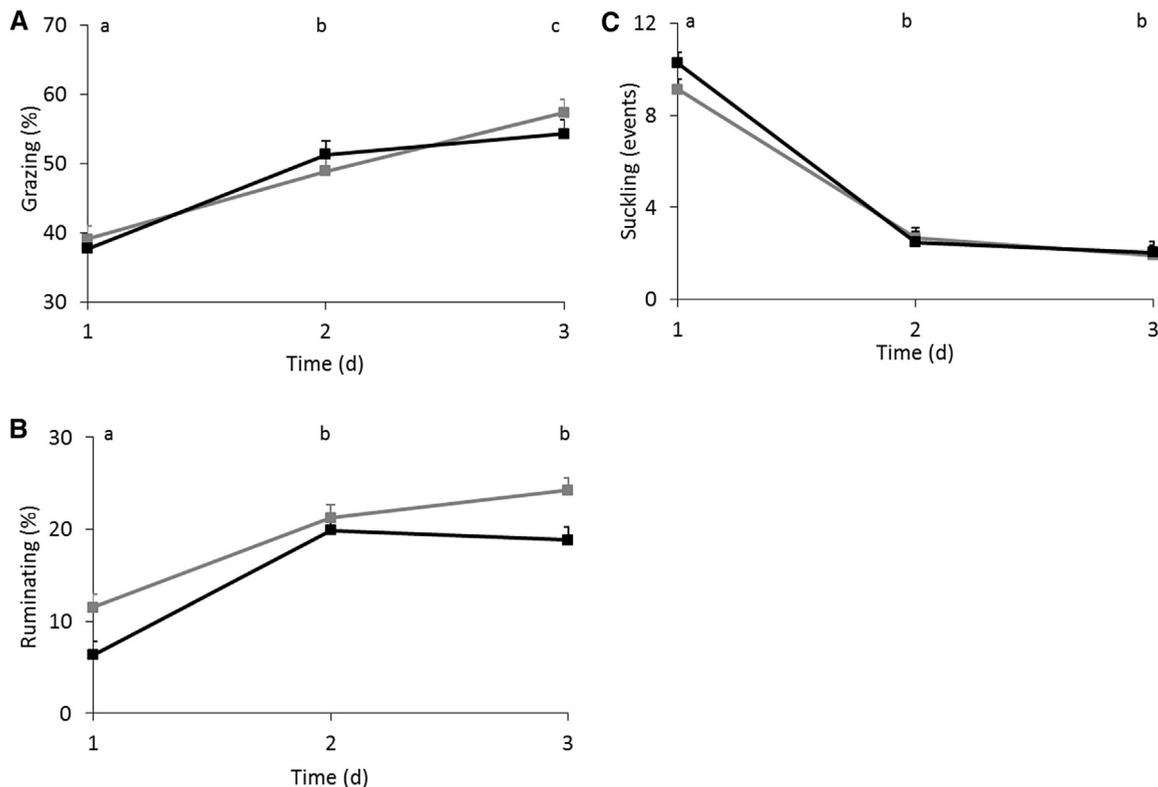


Figure 4. Percentage (mean \pm SEM) of observations in which Texel x Corriedale lambs (—■—) or Corriedale x Corriedale lambs (—■—) were observed (A) ruminating, (B) grazing, and (C) suckling during the lactation period. The times 1, 2, 3, and 4 represent the mean values in days 23/24, 53/54, 76/77 after lambing. Different letters indicate significant differences between days ($P < 0.0001$).

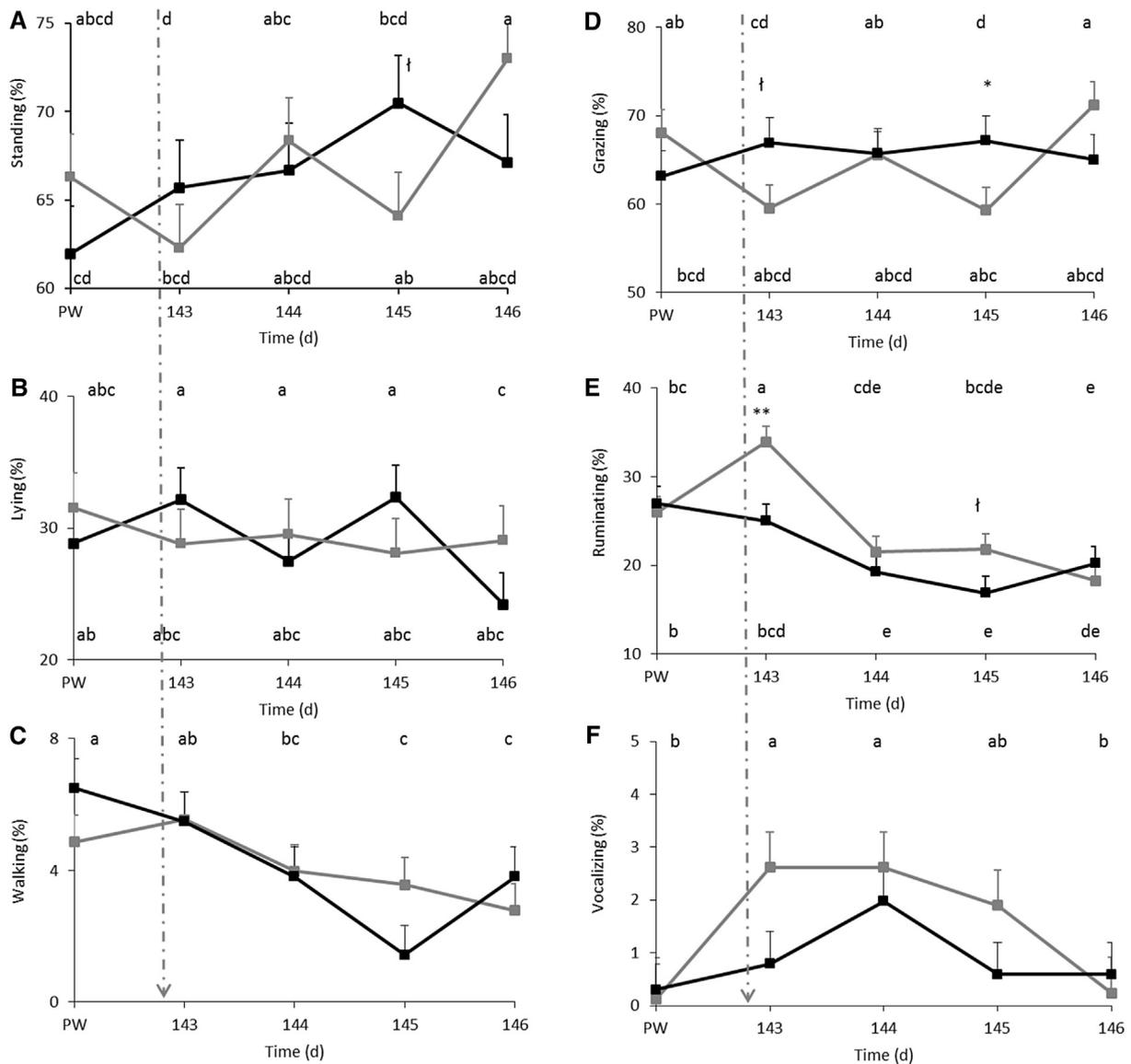


Figure 5. Percentage (mean \pm SEM) of observations in which Texel x Corriedale lambs (—■—) or Corriedale x Corriedale lambs (—●—) were observed (A) standing, (B) lying down, (C) walking, (D) grazing, (E) ruminating, and (F) vocalizing before and after weaning. These data correspond to the mean value of the three last days before weaning (days 140, 141, and 142 after lambing). Weaning was performed when lambs were 143 days old, which is shown by an arrow. Different letters indicate significant differences between days ($P < 0.0001$). Asterisks indicate differences between treatments on the same day: * = $P < 0.05$; ** = $P < 0.01$; † indicate that treatments tended to be different on that day ($P > 0.05$). PW = preweaning period.

Figure 4B). Sex affected the frequency of observations in which lambs were ruminating; regardless of whether they were pure or crossbreed, males tended to ruminate more than females ($18.0 \pm 0.8\%$ vs. $16.0 \pm 0.8\%$, respectively; $P = 0.08$). There was also an interaction between group and sex; TxC male lambs ruminated more frequently than other lambs (TxC males: $21.3 \pm 1.1\%$; TxC females: $16.7 \pm 1.1\%$; CxC males: $14.7 \pm 1.2\%$; CxC females: $15.4 \pm 1.1\%$; $P = 0.02$). There were no effects on the frequency at which lambs grazed or on the number of suckling events (Figure 5B and C). There was a non-significant tendency for an interaction between group and sex for grazing ($P = 0.09$). Males suckled more times than females during lactation (5.1 ± 0.2 vs. 4.4 ± 0.2 , respectively; $P = 0.05$), without differences between groups. Grazing and ruminating increased with age ($P < 0.0001$), and the number of suckling events decreased ($P < 0.0001$). There was no interaction between group and time for any of the feeding behaviors.

Behavioral recordings at weaning

There was an interaction between group and time in the frequency in which lambs were observed standing, lying down, grazing, and ruminating ($P < 0.02$ for the four behaviors). The frequency of observations in which lambs were standing increased from the day of weaning to the following day in TxC group ($P = 0.03$; Figure 5A), whereas there was no change in CxC lambs. The second day after weaning, CxC lambs may have tended to be observed more times standing than TxC lambs ($P = 0.08$). Although TxC lambs decreased the frequency lying down from weaning to the following day ($P = 0.05$), there was no change in CxC.

The frequency of observations in which lambs were grazing decreased in TxC lambs the day of weaning ($P = 0.001$; Figure 5D), but there was no change in CxC lambs. That day, the frequency in which animals were observed grazing tended to be lower in TxC than in CxC lambs ($P = 0.06$). On the other hand, two days after

weaning, TxC lambs grazed less frequently than CxC lambs ($P = 0.04$).

Ruminating frequency increased in TxC lambs on the day of weaning ($P = 0.0001$), without change in CxC lambs; thereafter, TxC lambs ruminated more frequently than CxC lambs ($P = 0.0009$).

Although TxC lambs were never observed pacing, CxC lambs were observed pacing one day after weaning ($0.2\% \pm 0.2$). On the day of weaning, all the lambs increased their frequency vocalizing ($P = 0.04$), returning to initial values 3 days after weaning without differences between group.

Discussion

In general, TxC lambs presented a faster body growth and an earlier process of nutritional independence from their mother during the advanced postpartum than CxC lambs. Although birth BW was not greater in crossbreed lambs, BW during postpartum and weight gain was higher in TxC than in CxC lambs. It is interesting that lambs' birth BW was higher than those typically reported in our country for CxC and TxC lambs (Ciappesoni et al., 2014; Suarez et al., 2000). It is possible that owing to the nutrient supply offered to ewes during late gestation led the fetuses to achieve a maximum growth increase. We did not record differences between groups in lambs' BW during the first 30 days of age, which may be explained by the main dependence of growth on milk rather than solid food (Williams et al., 1976). Thus, as milk yield and suckling frequency were similar in both groups, probably the greater potential growth of TxC than CxC lambs was limited while the main income was milk. However, from 60 days of age on, TxC lambs were heavier than CxC lambs, coinciding with the greater frequency in which TxC lambs were observed ruminating, demonstrating an earlier digestive maturation. The higher frequency of ruminating in TxC lambs is mainly explained by TxC male lambs ruminating more than all the other lambs. In this way, probably TxC male lambs presented the most precocious ruminal development, taking more advantage of the nutritional contributions of the pasture. In addition to these results, we found that male lambs presented a greater number of suckling events than female lambs during postpartum, possibly explained by the greater nutritional requirements of males than females (Hai Tao et al., 2015).

During early postpartum, ewes that lambed TxC or CxC lambs displayed similar responses to the manipulation of their lambs, as we recorded similar MBS. Moreover, as the frequency of birth assistance, lambs' birth BW and ewes' BW during gestation did not differ between groups, probably ewes and lambs established a similar bond since birth (Dwyer, 2003; Dwyer and Bünge, 2012). Although during the early postpartum period ewes had a similar reaction to handling of TxC lambs and CxC lambs, the response of lambs differed at weaning, indicating that the bond with their mothers evolved differently. At weaning, TxC lambs ruminated more than before weaning and also more than CxC lambs, probably as a response to the loss of milk. As the adaptation to solid food is one of the main components of the stress response to weaning (Freitas-de-Melo and Ungerfeld, 2016), TxC lambs probably coped better with weaning than CxC lambs. Moreover, vocalizations and pacing, which are the main behavioral changes related to the stress response at weaning (Damián et al., 2013; Freitas-de-Melo et al., 2017a), were not observed or observed very infrequently in TxC lambs even the day in which they were weaned. Although the frequency recorded was very low, while CxC lambs paced the day of weaning, TxC lambs never did it. The behavioral response after weaning was probably stronger in less developed lambs, as happens with Rhoensheep lambs compared to German Merino (Schichowski et al., 2008) or with younger lambs (Schichowski et al., 2010). Similarly, the decrease in grazing in TxC lambs but

not in CxC lambs indicated that pasture input was of greater importance in TxC lambs the day of weaning. All these considered together suggest that the greater growth of TxC lambs is explained more by an earlier nutritional independence from the mother rather than by differences in the relationship with their mothers. Moreover, as emotional reactivity is influenced by genetic differences (Boissy et al., 2005), we cannot definitively say that crossbreed lambs are less reactive to the stress of being separated from their mother. These results are of great interest for grazing productive systems, as TxC lambs besides of growing more also suffer less from artificial weaning than CxC lambs, an important event for welfare considerations (Freitas-de-Melo and Ungerfeld, 2016). Furthermore, it is interesting that we found differences between groups in some variables even considering the low number of animals used in the experiment.

In conclusion, TxC crossbreed lambs were more advanced in the nutritional independence from their mothers, ruminating more than CxC lambs during the lactation period. This resulted in TxC lambs growing faster than CxC lambs, allowing them to cope better with artificial late weaning. Moreover, male lambs suckled more frequently than female lambs during lactation; however, the sex of lambs did not affect lamb' growth. Thus, considering that weaning in farm animals is one of the most stressful management practices for the lambs, it is interesting that TxC lambs not only grow faster but also their welfare is less affected by weaning.

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Ethical consideration

All the procedures were performed according to the Comisión Honoraria de Experimentación Animal (Universidad de la República, Uruguay).

Conflict of interest

The authors declare no conflicts of interest.

References

- Barbato, G., Kremer, R., Rosés, L., Rista, L., 2011. Producción de ovejas Corriedale y cruzas F1 con Milchschaef y Texel en condiciones de pastoreo. *Veterinaria (Uruguay)* 47, 9–13.
- Boissy, A., Bouix, J., Orgeur, P., Poindron, P., Bibé, B., Le Neindre, P., 2005. Genetic analysis of emotional reactivity in sheep: effects of the genotypes of the lambs and of their dams. *Genet. Sel. Evol.* 37, 381–401.
- Ciappesoni, G., Vázquez, A., Bancharo, G., 2014. Diallel Cross Between Texel and Corriedale: Lamb Growth and Survival. *Proceedings, 10th World Congress of Genetics Applied to Livestock Production*.
- Cockram, M.S., Imlah, P., Goddard, P.J., Harkiss, G.D., Waran, N.K., 1993. The behavioural, endocrine and leucocyte response of ewes to repeated removal of lambs before the age of natural weaning. *Appl. Anim. Behav. Sci.* 38, 127–142.
- Damián, J.P., Hötzel, M.J., Bancharo, G., Ungerfeld, R., 2013. Behavioural response of grazing lambs to changes associated with feeding and separation from their mothers at weaning. *Res. Vet. Sci.* 95, 913–918.
- Doney, J.M., Peart, J.N., Smith, W.F., Louda, F., 1979. A consideration of the technique for estimation of milk yield by suckled sheep and a comparison of estimates obtained by two methods in relation to the effect of breed, level of production and stage of lactation. *J. Agric. Sci.* 92, 123–132.
- Dwyer, C.M., Bünge, L., 2012. Factors affecting dystocia and offspring vigour in different sheep genotypes. *Prev. Vet. Med.* 103, 257–264.
- Dwyer, C.M., 2003. Behavioural development in the neonatal lamb: effect of maternal and birth-related factors. *Theriogenology* 59, 1027–1050.

- Freitas-de-Melo, A., Banchemo, G., Hötzel, M.J., Damián, J.P., Ungerfeld, R., 2013. Progesterone administration reduces the behavioural and physiological responses of ewes to abrupt weaning of lambs. *Animal* 8, 1367–1373.
- Freitas-de-Melo, A., Ungerfeld, R., 2016. Destete artificial en ovinos: respuesta de estrés y bienestar animal (Artificial weaning in sheep: stress response and animal welfare). *Rev. Mex. Cienc. Pecu.* 7, 361–375.
- Freitas-de-Melo, A., Ungerfeld, R., Hötzel, M.J., Abud, M.J., Alvarez-Oxiley, A., Orihuela, A., Damián, J.P., Pérez-Clariget, R., 2015. Mother–young behaviours at lambing in grazing ewes: effects of lamb sex and food restriction in pregnancy. *Appl. Anim. Behav. Sci.* 168, 31–36.
- Freitas-de-Melo, A., Ungerfeld, R., Hötzel, M.J., Orihuela, A., Pérez-Clariget, R., 2017a. Low pasture allowance until late gestation in ewes: behavioural and physiological changes in ewes and lambs from lambing to weaning. *Animal* 11, 285–294.
- Freitas-de-Melo, A., Ungerfeld, R., Orihuela, A., Hötzel, M.J., Pérez-Clariget, R., 2017b. Early mother–young relationship and feeding behaviour of lambs are unaffected by low pasture allowance until the beginning of the last third of gestation in single-bearing ewes. *Anim. Prod. Sci.* 58, 930–936.
- Hai Tao, N., Zhang, H., Hao You, J., Wang, F., 2015. Determination of energy and protein requirement for maintenance and growth and evaluation for the effects of gender upon nutrient requirement in Dorper X Hu Crossbred Lambs. *Trop. Anim. Health. Prod.* 47, 841–853.
- Lehner, P.N., 1996. *Handbook of Ethological Methods*. Cambridge University Press, Cambridge.
- Nowak, R., Boivin, X., 2015. Filial attachment in sheep: similarities and differences between ewe-lamb and human-lamb relationships. *Appl. Anim. Behav. Sci.* 164, 12–28.
- O'Connor, C.E., Jay, N.P., Nicol, A.M., Beatson, P.R., 1985. Ewe maternal behaviour score and lamb survival. *Proc. N.Z. Soc. Anim.* 45, 159–162.
- Orgeur, P., Mavric, N., Yvone, P., Bernard, S., Nowak, R., Schaal, B., Levy, F., 1998. Artificial weaning in sheep: consequences on behavioural, hormonal and immuno-pathological indicators of welfare. *Appl. Anim. Behav. Sci.* 58, 87–103.
- Pascual-Alonso, M., Miranda-de la Lama, G.C., Aguayo-Ulloa, L., Ezquerro, L., Villarroel, M., Marin, R.H., Maria, G.A., 2015. Effect of postweaning handling strategies on welfare and productive traits in lambs. *J. Appl. Anim. Welf. Sci.* 18, 42–56.
- Russel, A.J.F., Doney, J.M., Gunn, R.G., 1969. Subjective assessment of body fat in live sheep. *J. Agric. Sci.* 72, 451–454.
- Schichowski, C., Moors, E., Gauly, M., 2008. Effects of weaning lambs in two stages or by abrupt separation on their behavior and growth rate. *J. Anim. Sci.* 86, 220–225.
- Schichowski, C., Moors, E., Gauly, M., 2010. Influence of weaning age and an experimental *Haemonchus contortus* infection on behaviour and growth rates of lambs. *Appl. Anim. Behav. Sci.* 125, 103–108.
- Suarez, V.H., Buseti, M.R., Garriz, C.A., Gallinger, M.M., Babinec, F.J., 2000. Pre-weaning growth, carcass traits and sensory evaluation of Corriedale, Corriedale X Pampinta and Pampinta lambs. *Small Rumin. Res.* 36, 85–89.
- Yilmaz, O., Denk, H., Bayrama, D., 2007. Effects of lambing season, sex and birth type on growth performance in Norduz lambs. *Small Rumin. Res.* 68, 336–339.
- Williams, C.M.J., Geytenbeck, P.E., Allden, W.G., 1976. Relationships between pasture availability, milk supply, lamb intake and growth. *Proc. Aust. Soc. Anim. Prod.* 11, 333–336.