Ewe and lamb pre-weaning performance of Pelibuey and Katahdin hair sheep breeds under humid tropical conditions

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Introduction

Animal production efficiency and profitability are determined by the genetic merit of animals for efficiency of nutrient utilisation and growth (Boval et al. 2015; Chaokaur et al. 2015). Pre-weaning is a very important stage in all domestic production systems focussed on meat production. Since milk of the ewe is the only food during the first months of life of the lamb (Godfrey et al. 1997; Van der Linden et al. 2010), in this stage, maternal ability has a key role in lamb development and productivity. Some factors such as nutrition, health, environment, parity, lambing type (litter size), sex of lamb and breed or genotype may influence milk production of ewes (Miguel et al. 2011; Hamad and El-Moghazy 2015).

Few studies have investigated the effect of breed and litter size on ewe milk production and lamb weaning weight in sheep. Danso et al. (2016) found that the Katahdin ewes produced more milk than Pelibuey ewes, yet ewes from both breeds had similar litter weaning weight. In this study, maternal ability has a key role in lamb development and productivity. Some factors such as nutrition, health, environment, parity, lambing type (litter size), sex of lamb and breed or genotype may influence milk production of ewes (Miguel et al. 2011; Hamad and El-Moghazy 2015).

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that live weight, body condition and mating season of the sheep have minimal effects on milk production and weaning growth of twin lambs. Snowden and Glimp (1991) reported a positive correlation between ewe milk production and lamb growth from birth to 56 days.

Pelibuey and Katahdin, are two of the main hair sheep breeds currently used in different agro-ecological regions of Mexico. Pelibuey, is the most predominantly hair sheep breed in Mexico because its adaptability to a broad range of environmental factors (Macías-Cruz et al. 2012; Chay-Canul et al. 2016). Rusticity, non-seasonality of reproduction, prolificacy and parasite tolerance are some of the referred favourable traits associated to this breed (Macías-Cruz et al. 2012; Magana-Monforte et al. 2013; Chay-Canul et al. 2016). On the other hand, Katahdin was introduced from the United States during the 2000’s (Sánchez-Dávila et al. 2015). More recent reports suggest their introduction for crossbred purposes (Macías-Cruz et al. 2012).

Breed selection for increased lamb performance at weaning under tropical conditions requires knowledge on ewe milk production, litter size at birth and lamb survival and growth for each of the breeds potentially available for utilisation. Milk production and composition have been evaluated in Pelibuey ewes (Castellanos and Valencia 1982; Espinoza-Hernández et al. 2013) and crossbred Pelibuey × Katahdin ewes (Peniche et al. 2015). Other few studies have evaluated weights of lambs at birth and weaning of purebred and crossbred hair sheep (Godfrey et al. 1997; Macías-Cruz et al. 2012; Nasrat et al. 2016; Godfrey and Weis 2016). Litter size at birth and weaning and lamb survival at day 30 and weaning were evaluated in the study of Macías-Cruz et al. (2012). Nonetheless, limited documentation on comparative performance of hair sheep breeds under humid tropical conditions is available in the literature.

The objective of this study was to evaluate the performance of ewes for milk yield and live weight change and lamb pre-weaning performance of Pelibuey and Katahdin breeds under humid tropical conditions.

Materials and methods

Animal care

The animals were treated in accordance with guidelines and regulations for animal experimentation of the División Académica de Ciencias Agropecuarias, Universidad Juárez Autónoma de Tabasco.

Experimental design

The present study was carried out in the “El Rodeo” ranch, located at 17° 84’ N latitude and 92° 81’ W longitude, Tabasco State, Mexico, with a mean of 28°C of temperature and 63 mm of pluvial precipitation during the experiment months, with extremes of relative humidity between 54% and 95% (CONAGUA 2016). Data from 49 clinically healthy Pelibuey (N = 28) and Katahdin (N = 21) ewes recently lambed (3–5 days) were collected. Ewes were 2 to 3 years old with mean body weight and body condition score (BCS) of 47.50 ± 2.128 kg and 2.56 ± 0.12 points for Pelibuey, and 43.87 ± 1.53 kg and 1.73 ± 0.14 points for Katahdin, respectively. BCS of ewes was evaluated by two technicians using the assessment of Russel et al. (1969). Data from 39 Pelibuey and 28 Katahdin lambs included litter size at birth (LS: single or double), sex (male or female) and weekly body weights from birth to 56 days. Null mortality was observed during the test period.

Management of animals

Each ewe and its respective offspring were managed in a feedlot system using individual pens during 56 days, with access to food and water. However, the offspring did not have direct access to the ewe’s feeders. Ewes were dewormed with Cydectin NF® (Pfizer, Brazil) at a dosage of 0.2 mg/kg of body weight. The food supplied consisted of star grass hay (Cynodon nlemfuensis), ground corn, soybean meal, sugarcane molasses and minerals, with an estimated metabolizable energy of 12 MJ/kg DM and 15% crude protein (AFRC 1993). The amount of feed offered to each ewe was adjusted weekly according to BW. The diet was formulated for the requirement of ewes with a mean BW of 45 kg with a milk yield of 1.74 kg d⁻¹ and CP and fat content of 4.5 and 7.0% respectively, according the AFRC (1993) equations; trying to maintain their BW and BCS through the experimental period.

Lamb milk consumption (MC) was determined by the weigh-suckle-weight method (WSW) as described by Peniche et al. (2015) and lamb live weights (LLW, kg) were measured since the first week of the experiment until day 49 (7 weeks). The WSW method involved once a week the separation of lamb from the dam at 3:00 a.m., for three hours, posteriorly were allowed to suckle for 10 min at 6:00 a.m. Then, lambs were separated again after a suckling period (9:00, 12:00, 15:00 and 18:00 h) but located in pens allowing sight and smell contact with their dams and avoiding suckling. The difference between pre and post-suckling weights was defined as MC. Daily milk production
(DMY, kg) of ewes was calculated by the total of the estimations recorded during the 12 h period and multiplying by two. Total milk production (TMY) was calculated by the integration under the curve making interpolations every week.

The data collected also included initial (IBW, kg) and final (FBW, kg) body weight of the ewe. Calculated traits included daily pre-weaning weight gain of lambs (ADG, kg), change in ewe body weight per day during lactation (BWC, kg) which was estimated as the difference between FBW and IBW divided by 56 days, litter weaning weight (LWW, kg) obtained as the sum of weight of weaned lambs by ewe. Ewe weaning efficiency (EE) was calculated as LWW/FBW × 100 (Godfrey et al. 1997).

Statistical analysis

All statistical analyses were performed using the Statistical Analysis System software (SAS, 2002). Ewe performance traits (TMY, DMY, BWC, LWW and EE) were analysed using the GLM procedure with a linear model that included the fixed effect of breed (Pelibuey or Katahdin), litter size (single or double) and breed × litter size interaction. Lamb performance traits (BW, WW and ADG) were analysed using the GLM procedure with a linear model that included the fixed effect of breed (Pelibuey or Katahdin), litter size (single or double), breed × litter size interaction and sex of lamb.

Repeated measures of ewe milk production were analysed using the MIXED procedure with a mixed linear model that included the fixed effect of sampling day, breed, litter size, two-way interaction of breed × sampling day, three-way interaction of breed × litter size × sampling day, and the random effect of animal. Similarly, repeated measures of lamb weights were analysed using the MIXED procedure with the same mixed linear model used to analyse ewe milk production plus, but the sex of lamb was included as fixed effect. Repeated measures on the same animal were modelled assuming a compound symmetry (CS) covariance structure.

Least squares means and standard errors for fixed effects were obtained and used for multiple comparisons using the LSD test with the Tukey-Kramer adjustment.

Results

Ewe and lamb performance for the two breeds is presented in Table 1. Compared to Pelibuey ewes, Katahdin ewes produced 24% more TMY (19.4 kg) and DMY (0.35 kg) (p < .001). Katahdin ewes maintained body weight during the experimental period, whereas Pelibuey ewes experienced a significant negative body weight change (p = .025). Ewes from both breeds had similar LWW and EE. Katahdin lambs were heavier than Pelibuey lambs (p < .001) at birth but differences between the two breeds for WW and ADG were not significant. Effects of lamb sex and breed × litter size interaction were not significant for any studied trait.

Trends in daily lamb weight and ewe milk production during the pre-weaning period are presented in Figures 1 and 2. Lamb growth curves for the two breeds were similar. Lactation curves for daily milk yield for the two breed were similar; in both breeds milk production increased as the days in milk progressed without a significant peak during the lactation, but Katahdin ewes consistently producing more milk than Pelibuey ewes (p < .05).

Effects of litter size were significant on all ewe and lamb pre-weaning performance traits (p < .05), except for BWC (Table 2). Twin-bearing ewes produced more TMY and DMY than single-bearing ewes (p < .05) in both breeds (Figure 2). The two-way interaction of breed × litter size was significant resulting in Katahdin ewes rearing twin lambs with the highest DMY and TMY. The interaction of breed × litter size was not significant for LWW and EE. Katahdin twin-bearing ewes had similar performance to Pelibuey twin-bearing ewes, and Katahdin single-bearing ewes had similar performance to Pelibuey single-bearing ewes for LWW and EE, but regardless of breed twin-bearing ewes had better performance than single-bearing ewes for these two traits (p < .01).

Pelibuey lambs born as twins were lighter at birth than Katahdin twin lambs but there were no significant differences between breeds for single-born lambs. There were no significant differences between single-born and twin-born lambs within breed. Single-born lambs were lighter at birth than Katahdin twin lambs but there were no significant differences between breeds for single-born lambs. There were no significant differences between single-born and twin-born lambs within breed. Single-

### Table 1. Pre-weaning ewe and lamb performance traits (least squares mean ± SE) in Pelibuey and Katahdin breeds.

| Breed | Traits | Pelibuey | Katahdin | p-value |
|-------|--------|---------|----------|---------|
|       | TMY (kg) | 79.90 ± 2.97 | 99.26 ± 3.48 | < .001 |
|       | DMY (kg) | 1.43 ± 0.05 | 1.77 ± 0.06 | < .001 |
|       | IBW (kg) | 47.78 ± 1.29 | 43.87 ± 1.51 | .055 |
|       | FBW (kg) | 44.71 ± 1.44 | 46.64 ± 1.69 | .975 |
|       | BWC (kg/d) | −0.06 ± 0.02 | 0.01 ± 0.03 | .025 |
|       | LWW (kg) | 15.49 ± 0.62 | 16.05 ± 0.73 | .561 |
|       | EE (%) | 33.78 ± 1.67 | 36.57 ± 1.96 | .284 |
|       | BW (kg) | 3.27 ± 0.12 | 3.95 ± 0.14 | .001 |
|       | WW (kg) | 10.72 ± 0.35 | 11.28 ± 0.41 | .310 |
|       | ADG (kg/d) | 0.13 ± 0.01 | 0.13 ± 0.01 | .840 |

*TMY: Total milk production; DMY: Daily milk production; IBW: Initial body weight; FBW: Final body weight; BWC: Change in ewe body weight per day during lactation; LWW: Litter weaning weight; EE: Ewe efficiency calculated as LWW/FBW × 100; BW: Birth weight; WW: Weaning weight at 56 days; ADG: Daily pre-weaning weight gain of lambs

*A significant difference is indicated by p < .05.
born lambs had greater ADG and were more than 2.7 kg heavier at weaning than twin-born lambs regardless of breed (Figure 2(a,b)). The interaction of breed × litter size was significant for BW (p = .04), and highly significant for WW and ADG (p < .001). Twin-born Pelibuey lambs were significantly lighter (p < .05) than twin-born Katahdin lambs, but there were significant differences between breeds for single-born lambs. Single-born lambs had significantly (p < .001) higher WW and ADG than twin-born lambs, in both breeds (Table 2).

Discussion

Ewe pre-weaning performance

The literature is scarce of studies reporting milk production in meat sheep breeds (Van der Linden et al. 2010), such as the hair sheep breeds. The relevance of
these traits is directly related to the lamb performance during the pre-weaning period (Van der Linden et al. 2010). In the present study, milk productions per day of both breeds were higher than daily yields (1.11 kg/day) reported for Pelibuey Katahdin crossbred ewes (Peniche et al. 2015), but similar to the productions levels for Pelibuey ewes (Espinoza-Hernández et al. 2013) rearing two lambs and fed medium and high levels of metabolisable energy producing 1.66 kg and 1.74 kg milk per day, respectively. Comparatively, Katahdin ewes had higher milking performance compared with Pelibuey ewes. Although, information on milking ability of Katahdin ewes is scarce, perhaps its composite origin and inherent genetic background may be related to higher and sustained DMY and TMY, although, suckling behaviour of growing lambs may explain partially these results as well.

The lactation curves of the breeds evaluated in this study had a positive trend to increase as the days in lactation; LWW: Litter weaning weight; EE: Ewe efficiency calculated as LWW/FBW × 100; BW: Birth weight; WW: Weaning weight at 56 days; ADG: Daily pre-weaning weight gain of lambs.

| Traits b | Single | Double | Single | Double | p-value |
|----------|--------|--------|--------|--------|---------|
| TMY (kg) | 65.91 ± 3.55 c | 93.89 ± 4.76 b | 79.45 ± 4.02 b,c | 119.06 ± 5.69 a | <.001 |
| DMY (kg) | 1.17 ± 0.06 c | 1.67 ± 0.08 b | 1.41 ± 0.07 b,c | 2.12 ± 0.10 a | <.001 |
| IBW (kg) | 45.45 ± 1.53 | 50.10 ± 2.06 | 42.93 ± 1.74 | 44.81 ± 2.46 | .172 |
| FBW (kg) | 42.65 ± 1.72 | 46.77 ± 2.31 | 46.77 ± 1.95 | 42.50 ± 2.76 | .175 |
| DWC (kg/d) | −0.05 ± 0.02 | −0.06 ± 0.03 | 0.07 ± 0.02 | 0.04 ± 0.04 | .059 |
| LWW (kg) | 12.66 ± 0.75 b | 18.31 ± 1.00 a | 12.91 ± 0.84 b | 19.19 ± 1.19 a | <.001 |
| EE (%) | 28.80 ± 1.99 b | 38.76 ± 2.67 a | 29.25 ± 2.26 b | 43.89 ± 3.20 a | <.001 |
| BW (kg) | 3.53 ± 0.17 a,b | 3.01 ± 0.15 b | 4.13 ± 0.19 a | 3.77 ± 0.19 a | .044 |
| WW (kg) | 12.07 ± 0.53 a | 9.37 ± 0.46 b | 12.94 ± 0.58 b | 9.61 ± 0.58 a | <.001 |
| AG (kg/d) | 0.15 ± 0.01 a | 0.11 ± 0.01 b | 0.16 ± 0.01 a | 0.10 ± 0.01 b | <.001 |

*LSM ± SE: Least square mean ± standard error.

*Means in same trait with different letters are statistically different (p < .05).

Influenced by litter size; ewes bearing multiple lambs had higher milk secretion rates than ewes bearing singleton lambs.

Pelibuey ewes had a significant body weight losses during lactation suggesting that body reserves were mobilised and used to meet energy requirements for milk production. The mobilisation of body reserves in early lactation is generated, as nutrient demand at this stage is high, and usually exceeds the ability of animals for food consumption (AFRC 1993). Commonly, this physiological response in early lactation, depending on the body condition at lambing, is related to a lost in average weight between 0.100 and 0.150 kg per day, which is considered as acceptable (AFRC 1993). In meat sheep breeds a significant decrease of body weight has been reported to occur in the first month of lactation (Abu Ishmais et al. 2004; Benchohra et al. 2014) in agreement with the results observed for the Pelibuey ewes of this study.

Pelibuey and Katahdin ewes had similar preweaning overall performances for LWW and EE as a result of the combination of ewe milk production and body weight, litter size and lamb growth. However, in this study lamb mortality during the experimental period was null and ewe prolificacy was not evaluated, therefore, overall ewe productivity needs to be interpreted with caution. Pelibuey ewes have been reported to have lower prolificacy rate than Blackbelly sheep under tropical conditions of South Mexico (Carrillo and Segura 1993) and Katahdin ewes have been reported to have similar prolificacy to Dorper and St. Croix breeds under tropical conditions of South eastern of the United States (Burke 2005).

The LWW of 15.5 kg and 16.1 kg for Pelibuey and Katahdin ewes estimated in this study were lower than the values for these breeds (21.2 kg and 22.4 kg,
respectively) reported by Nasrat et al. (2016). The values of EE for both breeds considered in this study were lower than those reported by Godfrey and Weis (2016) using St. Croix White and Dorper × St. Croix, meaning that Pelibuey and Katahdin breeds had less overall productivity than the crossbred ewes used in the Godfrey and Weis (2016) study. Similarly, the values of EE are lower than values reported by Godfrey et al. (1997) who reported EE ranging from 42.3 to 47.3 for Barbados Blackbelly and St. Croix White hair ewes; furthermore, consistently with the present results, the authors found that the twin-bearing ewes were more efficient to than those single-bearing ewes (37.2 vs 49.1).

**Lamb pre-weaning performance**

Katahdin lambs had higher BW than Pelibuey, which agreed with results reported by Ríos et al. (2014) comparing Katahdin × Pelibuey crossbred lambs under tropical conditions of Central Mexico. However, the BW estimated in this study, 4.0 kg and 3.3 kg for Katahdin and Pelibuey lambs were much higher that the BW values reported by Ríos et al. (2014) of 2.9 kg and 2.6 kg for Katahdin × Pelibuey and Pelibuey lambs, respectively. Another study by López-Carlos et al. (2010) reported similar BW in both breeds in the arid upland region of Mexico and for Katahdin, Mellado et al. (2016) reported similar BW in purebred and crossbred animals maintained in uplands of central Mexico. The inconsistency between studies reflects the diversity of management systems and environmental conditions.

The effect of litter size at birth and rearing on lamb performance is well documented in the literature about sheep production (Kenyon 2008). In specialised meat sheep breeds, singleton lambs are heavier at birth and weaning than twin lambs which are in turn heavier than triplet-born lambs. In this study singleton lambs were heavier at birth than twin lambs in the Pelibuey breed, this this difference was not observed in the Katahdin lambs.

Singleton lambs had significantly higher ADG than twin lambs resulting in heavier lambs at weaning. This could be explained because single lambs have access to all the milk of the ewe, whereas twin lambs are competing for the milk produced by the ewe, which in most of the cases is not enough to satisfy the daily nutrient requirements for optimal growth (Hinojosa et al. 2013).

**Implications**

Maternal effects during the pre-weaning period could be more important in sheep than in other domestic species because of the greater relative variation in litter size and because lambs are highly dependent on their mother’s milk supply until the time of weaning (Bradford 1972). Results from this study made a contribution to the knowledge on ewe and lamb performance of two meat hair sheep breeds under tropical conditions.

Currently, Pelibuey and Katahdin are two of the main hair sheep breeds used in Mexico for meat production. Pelibuey sheep represents the genetic basis of most of the traditional sheep production systems of humid and sub humid tropics of Mexico; nonetheless, in the last decades a sizeable introduction of composite breeds (e.g. Katahdin) has taken place in order to improve the market demands of meat with both, purebred and crossbred strategies. In the tropics of Mexico, the production levels of Pelibuey sheep are low compared with those used in temperate improved systems, due to poor management practices (Nasrat et al. 2016) and selection programmes (Magaña-Monforte et al. 2013; Chay-Canul et al. 2016).

Under the conditions of the present study, Pelibuey animals showed similar performance with Katahdin animals. Since prolificacy of ewes was not fully accounted for, the main difference in pre-weaning performance was perhaps related to the milk composition. This factor lead lambs to a better pre-weaning growth as a conditional of ewe’s efficiency even when Katahdin lambs had higher levels of milk consumption. Espinoza-Hernández et al. (2013) indicated that the milk from Pelibuey ewes had an approximate content of 6% in fat and 5% in protein. These levels are comparative to those from some milk sheep breeds (Bencini and Pulina 1997). An experimental assessment of milk composition between these breeds is required to evaluate if differences in milk composition of Pelibuey and Katahdin ewes can explain similar overall ewe productivity in spite that Pelibuey ewes produced less milk than Katahdin ewes. This can assist to choose the best maternal breed for a systematic crossbreeding system under tropical conditions.

**Conclusions**

In conclusion, Pelibuey and Katahdin ewes showed differences in total milk yield but similar overall pre-weaning performance and efficiency. Katahdin lambs are heavier at birth but have similar pre-weaning growth and live weight at weaning to Pelibuey lambs.
Litter size is an important factor conditioning pre-weaning performance in ewes and lambs of Pelibuey and Katahdin breeds.

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