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Lactation Curve, Milk Production of Pelibuey Ewes and Preweaning Growth Rate of the Lambs

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ABSTRACT

Objective: To estimate the lactation curve and milk production of Pelibuey ewes and their relationship with preweaning growth rate of the lambs.

Design/Methodology/Approach: Forty-five Pelibuey ewes were milked during 70 days in Montecillo, Mexico, in 2018, to estimate the daily and total milk production. The lactation curve was fitted with the incomplete gamma function. In addition, the effects of type of birth and ewe weight at milking on milk production were analyzed, and correlations were calculated between ewe milk production and growth rate of the lambs, per week and for the entire lactation.

Results: A "typical" lactation curve was found, average ewe milk production for the whole lactation, weighted for the number of lambs suckling, was 131±8 L, with 444±24 g d^{-1}. Ewe weight at milking had an effect ($p<0.01$) on milk production. Positive correlations were found ($p<0.05$) between ewe milk production and preweaning growth rate of the lambs.

Study Limitations/Implications: There is a strong dependency of the lambs on the milk production of the Pelibuey ewe, a factor of great relevance so that lambs can gain body weight and survive during lactation.

Findings/Conclusions: Pelibuey ewes produce less milk than dairy ewes. Therefore, lambs should be weaned at a maximum of 10 weeks of lactation.

Keywords: maternal ability, live weight, lamb survival.

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INTRODUCTION

Sheep production in Mexico is an activity that has attained great advances in the productive and commercial aspect because mutton represents an important option for the diet, product that is consumed primarily as a traditional dish known as "barbacoa". The predominant hair breeds in Mexico are Pelibuey and Blackbelly (Hinojosa-Cuéllar *et al.*, 2012). Of these, the most frequently used in Mexico in grazing and mixed systems is Pelibuey, primarily due to its adaptation to various agro-climate environments, which currently is a factor of great consideration because of the climate changes affecting the animals (Núñez-Domínguez *et al.*, 2016; Tsartsianidou *et al.*, 2021), and also due to its characteristics of prolificacy and rusticity (Ramón-Ugalde and Sanginés-García, 2002) and resistance to gastrointestinal nematodes (Zaragoza-Vera *et al.*, 2019). In sheep production systems for meat in grazing without dietary supplementation, the production and quality of the ewe milk is vital for the lambs during the first weeks of life (Peniche *et al*., 2015), so a strong relationship has been found between the growth rate and the survival of the lambs with milk production (MP) of the ewe during lactation (Afolayan *et al*., 2009; Naik *et al*., 2016).

In hair sheep, information about MP and associated characteristics is very limited, for example knowledge about the lactation curve (Adewumi and Olorunnisomo, 2009; Güngör and Atasoy, 2020), as well as the relationship between the ewe's MP and the lambs' daily weight gain (LWG) during the lactation. Understanding the lactation curve is important because it allows the sheep producer to make decisions about animal management, such as monitoring the diet, the health state, discarding animal, which are factors that impact the economy of milk production (Takma *et al*., 2009; Tekel *et al*., 2019). In Mexico there are studies carried out in hair sheep (Peniche *et al*., 2015; Chay-Canul *et al*., 2019) where the MP was evaluated; however, in these studies the relationship between MP and the lamb's growth rate (LGR) was not determined, and in hair lamb production systems for supply it is important to understand the milk production of the ewes. Therefore, the objectives of this study were: 1) to fit the lactation curve of Pelibuey ewes, 2) to estimate the total and daily milk production of the ewes, 3) to evaluate the effects of the number of lambs suckling and the ewe weight at milking on the MP, and 4) to calculate the correlations between the MP and the LGR, per week and total.

MATERIALS AND METHODS

Location, animals and management

This study was performed in the Sheep and Goat Reproduction Laboratory belonging to Colegio de Postgraduados, Campus Montecillo, located in Montecillo-Texcoco, Estado de México. This place is located in coordinates 19° 29' Latitude North and 98° 53' Longitude West, at 2250 masl. The climate is classified as temperate sub-humid with summer rains (García, 2004).

Forty-five second birth Pelibuey ewes were used with an initial average weight of 49.1±13.6 kg, of which 27 were of single birth and 18 of double birth. The ewes began lambing on May 17, 2018. Since lambing, the ewes were fed with a commercial diet (Table 1) that had 14% raw protein and 2.96 Mcal kg^{-1} digestible energy.

Likewise, they always had access to clean and fresh water. The daily serving was divided into equal parts in the morning and the afternoon, while alfalfa was offered only in the mornings. The health program of the ewes included elimination of gastrointestinal nematodes at the beginning of the study, and sodium Levamisol (Prolevan®) was used in a dose of 1 mL for every 20 kg of live weight; for vaccination against pneumonic pasteurellosis, symptomatic carbon, malign edema, and enterotoxemia, the Vaccine:bobac 8 was used in the last third of gestation in a dose of 2.5 mL per ewe; in addition, 2 mL of the ADE vitamin complex per ewe were used. The ewes started to be milked manually in the mornings (08:00 h) on day five post-lambing to allow the consumption of colostrum by the lambs, and since then every seven days for 10 weeks, with a total of 70 days in lactation. Therefore, the first record of MP was since day 5 post-lambing. In this study three milking sessions were carried out every week at intervals of 2 h each (08:00 to 14:00 h). To measure the MP the double weighting method (DWM) of the lamb was used (Benson *et al.*, 1999), which consists in weighing the lambs before and after suckling to have an estimation of milk produced by the ewe in every session, and later removing through manual milking the residual milk contained in the udder. This measurement was carried out in each session of 6 h and repeated every week during the 10 total weeks of the trial. In the day prior to the first measurement, the lambs were put away in a pen at 18.00 h to separate them from their mothers, although between mothers and lambs sight and smell were possible, but not suckling. The ewes were put away in a separate pen, without considering the type of birth. On the next day, start of the first session, the lambs were allowed to exit their pen to seek their mothers and once they located the ewe their live weight was taken, after which they were allowed to suckle until emptying the udder. Once the lamb was no longer suckling it was weighed again, to therefore have an estimator of the ewe's milk production. This procedure was repeated in the next two sessions and throughout the lactation. The MP of the three sessions was added and the amount of residual milk that corresponded was added to this, thus obtaining an estimator of the MP produced in 6 h. The resulting value was multiplied by four, to have an estimator of the MP produced in 24 h, under the assumption that the amount of milk produced was constant during the day (Cardellino and Benson, 2002). The assumption was also made that this MP measured every week represents the average daily milk production for the week that it was measured (Al Jassim *et al.*, 1999). Milk production of the ewe per week was recorded, and for the whole lactation period.

Statistical procedure

To fit the lactation curve, the incomplete gamma function or Wood's model (Wood, 1967) was used, because its three parameters are linked to the biology of the lactation curve (Portolano *et al.*, 1996), and because it has had good results in milk production studies in ewes (Ángeles Hernández *et al.*, 2014; Nava-García *et al.*, 2019). Fitting the lactation curve was done based on the average of the individual lactation curves, both for the group of ewes with one lamb and with those that had two lambs. The model is: $y_t = at^b\ e^{-ct}$, where: y_t is the milk production in day t, e is the base of the natural logarithm, a, b and c are parameters of the curve, where a represents the milk production at the beginning of the lactation, while b and c represent the limit decline of the curve before and after the peak of lactation, respectively. With the purpose of analyzing the model linearly, a logarithmic transformation was carried out, and the model resulted as follows: $\log y_t = \log a + b\ log\ t - cn$, after which the parameters a, b, and c were estimated through multiple linear regression. After obtaining parameters a, b, c, according to Nezamidoust *et al.* (2013) and taking the average of all the ewes, the following were obtained: the peak of lactation (PLA) as: $Y_{max} = a(b/c)be - b$, the time until the peak of lactation (TPLA) as: b/c, and the persistence as: $(S) = -(b+1)\ln$ c. Only the value of Y_{max} was obtained with the NLIN procedure of the statistical package SAS (2004).

Then, an analysis of variance was performed using the GLM procedure of SAS (2004) to evaluate the effects that the independent variables can have, such as type of birth of the offspring (single and double) and ewe weight at milking (as covariable) on the dependent variable total MP. Finally, the correlations between MP of the ewe and LGR were calculated, per week and total. It should be clarified that the LGR was used because the weight of the lambs before and after suckling represented an estimator of the ewe's milk production, which was an objective of the study, not the weight gains of the lambs, so they were not weighed for this purpose.

RESULTS AND DISCUSSION

The lactation curves of ewes with one and two lambs are shown in Figure 1. The lactation peaks (maximum milk production) in ewes with one and two lambs were found in the second and third week of lactation, respectively.

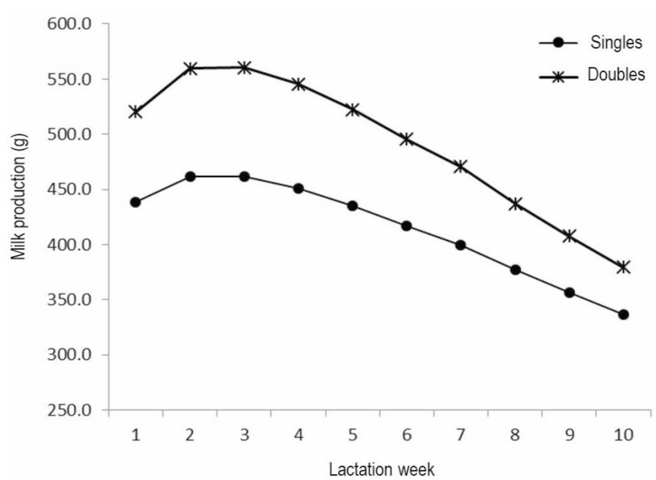

Figure 1. Milk production lactation curve of Pelibuey ewes according to number of lambs suckling.

Table 2 presents the estimated total milk productions for ewes with one and two lambs.

Table 2. Total milk production of Pelibuey ewes (mean ± s.e.), nursing one (n=27) or two (n=18) lambs, total lactation milk production, and daily mean production.

	One lamb	Two lambs
Total milk production (liters)	122±1.8a	144±2.2a
Total milk production/ewe (liters)*	131±8	
Mean daily milk production/ewe (g)**	444±24	

*: weighted mean for the number of lambs suckling during the entire lactation (70 days).
**: average for the entire lactation. a: no significant differences (p>0.05).

Table 3 shows the estimators (a, b, c) of the parameters obtained from the lactation curve for ewes with one and two lambs.

Table 3. Parameters (± standard error) of the milk production lactation curve obtained from the Wood model, according to lamb birth type (BT).

Parameter	a	b	c
BT:			
Single	0.44±0.072	0.186±0.021	0.010±0.001
Double	0.53±0.070	0.210±0.022	0.015±0.001

a: milk production at the beginning of lactation, b: limit decline of the curve before the peak of lactation, c: limit decline of the curve after the peak of lactation.

For the entire lactation, the average production per ewe, weighed by the number of lambs suckling, was 131±8 L with an average of 444±24 g d^{-1} (Table 2).

For the whole lactation period, it was found that the ewes that were suckling two lambs produced a similar amount of milk than that produced by ewes that suckled only one lamb ($p>0.05$, Table 2).

Table 4 shows the PLA values according to the type of birth of the lamb (single, double), of the TPLA, and those of persistence; these did not show significant differences between one another ($p>0.05$).

Table 4. Lactation peak (LP), time at lactation peak (TLP) and persistency (S), according to ewes of single (n=27) and double (n=18) birth type.

Variable	LP	TLP	S
Birth type:			
Single	409.5a	14.2a	−5.09a
Double	463.4a	16.9a	−5.35a

a: no significant differences ($p>0.05$).

The weight of the ewe at milking (as covariable) had a significant influence ($p<0.01$) on the MP; a regression coefficient of $b_{y/x}$=0.026 kg was found, value that indicates that for each kg of live weight gain of the ewe at the time of milking, the MP increased in 26 g.

Finally, Table 5 shows the correlation coefficients between MP and LGR, per week and total.

It can be observed that the correlations were significant, except in the cases of the single birth (week 3), double birth (week 6), and in both types of birth (week 10), this being the last week that corresponds to the date when the ewes were close to drying up. It can also be seen that the magnitude of the correlations shows a tendency to decrease with time, this being more evident in the ewes rearing two lambs.

The average and adjusted lactation curves, both for ewes with one lamb and with those with two lambs, correspond to a "typical" curve, which is characterized by having a gradual increase at the beginning of the lactation until reaching the peak of lactation, followed by a gradual decline until the end of the lactation that corresponds to the type of curve that has been found in other groups of sheep, as in Cuban Pelibuey (Pérez Corría *et al.*, 2017) and East Friesian (Ángeles Hernández *et al.*, 2018). The time until the peak of lactation in this study agrees with the results obtained by Benson *et al*. (1999) in Suffolk ewes using also the DWM, and with those by Cardellino and Benson (2002) in ewes milked through mechanical milking. However, it differs from the results by Peniche *et al*. (2015), Allah *et al*. (2011), and Peralta-Lailson *et al*. (2005) in terms of the dates of time until the peak of lactation, since in these studies the dates were weeks seven, five and one, respectively. These differences regarding the of type of lactation and date of the time until the peak of lactation is attributed mainly to the effects of the genotype of the ewe and management practices, as found by Aboul-Naga *et al*. (1981) when comparing three sub-tropical non-dairy sheep breeds. Peralta-Lailson *et al*. (2005) in Mexico's Chiapas sheep of the black, white, and brown varieties, concluded that another factor that can influence the lactation curve is the selection effect.

Table 5. Phenotypic correlations between ewe milk production and growth rate of lambs (per week and total), according to lamb birth type (BT).

	BT	
Week	**Single**	**Double**
1	0.68**	0.73**
2	0.53**	0.61**
3	0.32^{ns}	0.58**
4	0.67**	0.62**
5	0.58**	0.47**
6	0.50**	0.31^{ns}
7	0.47**	0.52**
8	0.54**	0.58**
9	0.43**	0.48**
10	0.32^{ns}	0.28^{ns}
Total	0.68**	0.75**

*: p<0.05, **: p<0.01), ^{ns}: non-significant (p>0.05).

Afolayan *et al*. (2002) also found that the parameters *a, b,* and *c* were higher in ewes with two lambs, which suggests that the number of lambs suckled by the ewe has an important influence on the MP, which has been found before in other sheep breeds (Snowder and Glimp, 1991). On the other hand, Afolayan *et al*. (2002) mentioned that the parameters *b* and *c* are the ones responsible for shaping the lactation curve. In Mexico's Chiapas sheep, Peralta-Lailson *et al*. (2005) used Wood's model, and they found that Creole Chiapas ewes of the white and brown varieties had atypical lactation curves, which is attributed to the values of parameters *b* and *c*. Some estimators of the parameters of Wood's model that have been estimated in dairy ewes are a=0.979, b=0.071, c=0.009 (Ángeles-Hernández *et al*., 2013), a=1,333, b=0.3, c=0.092 (Miguel *et al*., 2016); in these studies, the magnitude of parameter a standout, which represents milk production at the beginning of the lactation, indicating specialized breeds in milk production.

Estimators of daily averages of MP that have been obtained in hair ewes are: 131 g in Mexico Pelibuey ewes (Castellanos Ruelas and Valencia-Zarazúa, 1982); 1.43 and 1.77 kg in Mexico Pelibuey and Katahdin ewes, respectively (Chay-Canul *et al.*, 2019); 123 and 173 g in Blackbelly and St. Croix ewes, respectively (Godfrey *et al.*, 1997); 1,200 g in Martinik ewes (Ortega-Jiménez *et al.*, 2005); 1,400 g in Santa Inés ewes (Araujo *et al.*, 2008). According to Godfrey *et al.* (1997) and Robles-Jiménez *et al.* (2020), the differences in daily milk production can be attributed mainly to the genotype of the ewe and management practices, although Aboul-Naga *et al.* (1981) and Peralta-Lailson *et al.* (2005) also include the selection effect.

Most studies indicate that ewes with two lambs produce more milk than those with only one (Cardellino and Benson, 2002; Morgan *et al.*, 2006), and it has been mentioned that the ewes that carry more than one offspring have a higher concentration of serum progesterone and a high volume of the placenta, producing an increase in placental lactogen, thus stimulating the development of the mammary gland during gestation and before lambing, which in turn provokes an increase in MP (Ochoa-Cordero *et al.*, 2007; Adegoke *et al.*, 2015). Other factors, such as the histo-morphological characteristics of the udder can also affect the MP in ewes (Murawski *et al.*, 2019). The lack of differences in MP between ewes with one lamb and ewes with two lambs could be attributed to the size of the sample used in this study.

Heavier ewes generally produce more milk than those of lower body weight (van der Linden *et al.*, 2009) and an influence has been found ($p<0.01$) of the ewe weight at the time of birth on the MP (Ángeles Hernández *et al.*, 2018), and in genetic improvement programs the body weight of the ewe is used as a selection criterion to increase milk production (Mavrogenis and Papachristoforou, 2000). In the literature, no studies were found where the effect of the ewe weight at the time of milking on the MP has been analyzed. In this study it was decided to measure the ewe weight at milking during the 10 weeks due precisely to its proximity to the moment of milking; however, an inconvenience of this procedure could be the stress and management to which ewes are subjected, whose effect was not quantified in this study.

Godfrey *et al.* (1997) found a correlation of $r=0.37$ ($p<0.0001$) in St. Croix ewes between pre-weaning LWG of the lambs and MP of the ewe measured by the oxytocin method; however, in Blackbelly ewes from the same study the correlation ($r=0.17$) was not significant ($p>0.10$). Using the lamb's DWM to measure MP in wool ewes, Snowder and Glimp (1991) and Benson *et al.* (1999) mention positive correlations ($p<0.05$) between MP of the mother and pre-weaning LWG of the lambs. In the study by Benson *et al.* (1999), the correlation between pre-weaning LWG of the lambs and MP of the mother throughout the lactation (63 days) was $r=0.60$ ($p<0.03$), indicating in this study the strong dependence of the lambs on the mother's milk to gain weight and survive, since the lambs did not have access to solid food during the entire lactation. Snowder and Glimp (1991) mentioned in their study that the decreasing value of the correlations as the lactation advanced indicates that in lambs the dependency on milk for their growth decreases.

CONCLUSIONS

Pelibuey ewes show a typical lactation curve, characterized by a gradual increase in milk production until reaching a peak, followed by a gradual decrease until the end of the lactation. Milk production during the entire lactation was 131±8 L, with a daily average of 444±24 g. There were no differences ($p>0.05$) in milk production between ewes suckling one or two lambs in the whole lactation. The weight of the ewe at milking (as covariable) had an effect ($p<0.01$) on milk production; for every kg of the ewe's weight increase at milking, the milk production increased in 26 g. For the entire lactation, positive correlations were obtained ($p<0.01$) between total milk production and growth rate of the lambs.

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