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ORIGINAL ARTICLE

Finishing lambs using an integral feed under a restricted-feeding program in an intensive production system in Northern Mexico

Karla Rodríguez-Hernández[a], Jorge A. Maldonado-Jáquez[a], Lorenzo D. Granados-Rivera[b*], Juan I. Sánchez-Duarte[a], Pablo A. Domínguez-Martínez[c], Glafiro Torres-Hernández[d], Emanuel A. Argüelles-Verdugo[e]

ABSTRACT. The objective of this study was to compare the productive performance of finishing lambs using an integral diet under a restricted-feeding program. Ten Dorper lambs were assigned to two homogenous groups according to live weight and age under a complete randomised block design. Group 1 was fed a traditional diet commonly used by the producer and group 2 was fed an integral feed restricted to 75% of dry matter requirement of lambs. The evaluated variables were: dry matter intake, initial and final live weight, daily weight gain, feed efficiency and body growth expressed in height, body length, thoracic diameter, cane length and cane width. A partial cost analysis was carried out to evaluate the economic viability. Lambs fed with the integral feed had better feed efficiency, higher dry matter intake, daily weight gain, height, body length and thoracic diameter when compared with the lambs fed the traditional diet. The use of an integral feed under a restricted-feeding program reduced the cost of finishing lambs by 2.46 dollars per head and finishing length by 120 days. Overall, providing an integral feed under a restricted-feeding program is a viable alternative for improving finishing lambs under intensive conditions in the Northern Mexico.

Key words: restricted-feeding, economic profitability, Dorper lambs.

INTRODUCTION

It is important that animals show adequate development to achieve a successful lamb fattening (Bernes *et al* 2012). In intensive production systems, this is accomplished by using total mixed rations (TMR) that meet the protein and energy requirements of the lambs (Atwood *et al* 2006). The use of TMR ensures a uniform ruminal fermentation because a constant level of concentrate is maintained, which together with an appropriate fiber content, stimulates chewing and saliva production, minimising losses by fermentation and ensuring a better utilisation of ammonia (Varga and Kolver 1997, Van Ackeren *et al* 2009). However, TMR require time and specialised equipment (mixer wagon, tractor, among others), which makes the adoption of this technology difficult for small producers (Bretschneider *et al* 2015). Therefore, an option that includes the benefits of the TMR is the preparation of an integral feed equivalent to a TMR but using dry ingredients, which can be stored in sacks to be used at the time required without the need of major equipment (Maldonado-Jáquez *et al* 2017).

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[a]Campo Experimental La Laguna, Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Coahuila, México.

[b]Campo Experimental General Terán, Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Nuevo León, México.

[c]Campo Experimental Valle del Guadiana, Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Durango, México.

[d]Programa de Ganadería, Colegio de Postgraduados, Montecillo, México.

[e]Departamento de Postgrado, Facultad de Agronomía y Zootecnia, Universidad Juárez del Estado de Durango, Durango, México.

*Corresponding author: LD Granados-Rivera; General Terán, Nuevo León, C.P. 67400, México; granados.danilo@inifap.gob.mx

Additionally, in the intensive production systems, feed is one of the factors which increases costs when considering the combination of high feed consumption and the price of the feedstuffs (dos Reis *et al* 2001, Bosa *et al* 2012). In order to reduce production costs, it is possible to resort to restricted-feeding programs, which consist of offering high-energy diets in restricted amounts of dry matter (Loerch 1990). This type of feeding program was originally designed for the beef industry; however, it also has been used for feeding replacement dairy heifers (Rodríguez-Hernández 2018). In dairy cattle, the restriction of dry matter is based on a percentage of live weight and can be as low as 1.5% or as high as 2.65% (Zanton and Heinrichs 2008, Lawrence *et al* 2016, Manthey and Anderson 2018).

For the specific case of lambs, information regarding the use of restricted feeding schemes is limited, particularly in intensive production systems of arid and semi-arid regions of northern Mexico, where information on nutrition and feeding of sheep is minimal (Meda-Alducin *et al* 2011). Therefore, the use of an integral feed in combination with a restricted-feeding program could be an economically viable option for lamb finishing particularly in the arid and semi-arid regions. The aim of this study was to evaluate the productive behaviour of finishing Dorper lambs using an integral feed offered in a restricted manner, under intensive conditions in the Comarca Lagunera of Northern Mexico.

MATERIAL AND METHODS

The management of the animals used in this study was strictly adhered to the accepted guidelines for the ethical use, care and welfare of animals used for international research

according to the Federation of Animal Science Societies[1] and the National Academy of Medicine (NAM 2002).

The study was conducted in a production unit of the communal farm (ejido) La Goma, Lerdo, Dgo., Mexico, located in the Comarca Lagunera (24°22' and 26°23' N Latitude, 102°22' and 104°47' W Longitude, 1100 m.a.s.l.). This region has a desert climate corresponding to BWhw of Köppen classification (García 1988), characterised for being very dry or arid, semi-warm with cool winter, average annual precipitation of 240 mm, and an average annual temperature of 25 °C, with ranges of –1 °C in winter to 44 °C in summer.

Ten Dorper lambs were blocked by initial body weight (BW) and age, and then randomly assigned to one of two experimental diets under a complete randomised block design. Experimental diets consisted of 1) traditional diet (n = 5; BW of 18.9 ± 1.8 kg and 95 ± 6.8 days of age), which was used daily by the producer and was composed for 75% of corn silage and 25% of mixed forages hay and 2) integral feed (n = 5; BW of 18.7 ± 5.7 kg and 97 ± 3.8 days of age) that consisted of a TMR that was prepared in a unique occasion in the facilities of the Experimental Station La Laguna of the INIFAP, located in Matamoros, Coahuila, Mexico. To elaborate TMR of integral feed, alfalfa hay and corn stover were chopped in a hammer mill grinder with a sieve of 1 cm of diameter, which was modified by adding along the sieve two central lines of 7 holes each with 5 cm of diameter. Subsequently, to prepare 800 kg of integral feed all the ingredients were weighed individually (forages and concentrates). All the ingredients were mixed using a spinning top type concrete mixer of 120 liters. The grain mix was prepared by first adding the ingredients in the following order: 2 parts of corn grain, 2 parts of sorghum grain, 1 part of soybean meal, 2 parts of bran, urea, minerals, and molasses which were mixed for 5 minutes at a speed between 28 to 32 rpm. The operation was repeated until all the concentrated ingredients were mixed. Subsequently, the forages were mixed with the grain mix by adding 2 parts of forages and 1 part of grain mix repeatedly until the mixer content was near three quarters full and allowed to mix for 3 more minutes, then the mixer was emptied and the operation was repeated until all the forages were mixed with the grain mix. Subsequently, the integral feed was placed in sacks with a capacity of 500 kg and transported to the production unit where the study was conducted.

The lambs were kept in individual 2x3 m pens, with shading, feeding troughs, and drinking water *ad libitum*. The initial amount of traditional diet was established according to the producer's feeding system, which theoretically should cover 100% of the dry matter requirements of the lambs. The integral feed contained 40% forages (alfalfa hay and corn stover) and 60% grain mix (Maldonado-Jáquez *et al* 2017). The initial quantity of integral feed offered was restricted to 75% of the dry matter intake recommendations of the National Research Council (NRC 1985) for early weaned lambs of 20 kg BW, which is 5% of BW then we multiplied it for 75% which expressed in percentage of BW is equivalent to 3.7%. The amount of ration offered was increased by 20% for both diets when rejection was less than 10% of total offered. The feed intake was calculated daily by the difference between the amount of feed offered and the rejected feed.

The nutritional composition of corn silage and the forages mixture in the traditional diet is shown in table 1.

The components and nutritional quality of the traditional diet and the integral feed are shown in table 2. Feed was delivered daily at 7:00, 13:00 and 18:00 h for both groups. Fifty percent of the ration was offered on the first feeding time, and 25% in each of the subsequent feeding times. All the lambs had *ad libitum* access to fresh and clean water.

The variables analysed in this study were: dry matter intake (DMI), Initial BW, final BW, average daily weight gain (ADG), and feed efficiency. In addition, the growth of the animals was evaluated through body measurements of height, body length, thoracic diameter, cane length and width. Data collection was performed weekly during 9 weeks. The lambs were weighed using a hook-type electronic commercial scale with a capacity of 45 kg ± 5 g (Metrology, Nuevo Leon, Mexico). A soft tape (Selanusa, Mexico City, Mexico) was used to determine body measurements, and a mechanical vernier (PRETUL, Mexico City, Mexico) was used to measure the cane width. The ADG was calculated by subtracting the initial BW from the final BW and dividing it between the test days. Feed efficiency was calculated dividing total weight gain between total feed consumption.

The information was analysed using the PROC MIXED of SAS version 9.4 (SAS Institute, 2013). The initial BW was used as a covariate for BW and ADG. To determine

Table 1. Nutritional composition of diet components used in the traditional diet for finishing Dorper lambs.

Nutrient(1)	Corn silage	Forages mix hay
DM, % of silage and mix	30.70	93.14
CP	10.47	14.13
NDF	52.77	55.44
ADF	32.99	36.77
TDN	59.59	60.78
NE_m, MJ kg^{-1} DM	5.61	5.90
NE_g, MJ kg^{-1} DM	3.22	3.43

(1)Expressed as percentage of the dry matter (DM) unless otherwise is indicated; CP=crude protein; NDF=neutral detergent fiber; FDA=acid detergent fiber; TDN=total digestible nutrients; NE_m=net energy for maintenance; NE_g=net energy for gain.

[1] FASS, Federation of Animal Science Societies. 2010. Guide for de care and use of agricultural animal an agricultural research and leaching. Available at: http://www.fass.org/docs/agguide3rd/Ag_Guide_3rd_ed.pdf (Accessed 15.08.2017).

the most appropriate covariance structure for each variable the Schwartz's Bayesian and Akaike criterions were used. When appropriate, the comparison of least squares means was made through the adjusted Tukey test. The general structure of the model was: $Y_{ijkl}=\mu + T_i + R_{j(i)} + S_k + (S_k \times T_j) + \beta(X_{ijkl} - X\ldots) + E_{ijkl}$; where: Y_{ijkl} = dependent variable; μ = constant that characterises the population, T_i = fixed effect of the i-th block (treatment) (j=1, 2), $R_{j(i)}$ = random effect of the i-th repetition (animal) nested in the j-th treatment (i=1, 2, 3, 4, 5), S_k = random effect of the k-th week of treatment, $S_k \times T_i$ = effect of the treatment × time interaction; X = effect of the covariate (initial weight), β = regression coefficient associated with the covariate, E_{ijkl} = random residual error. All random components were assumed to be normally distributed with zero mean and common variance. Dry matter intake and food efficiency data were analysed using the PROC GLM (SAS Institute 2013). The determination of relationships between body measurements with BW and ADG was made through the Pearson correlation analysis using the InfoStat v.2008 program (Balzarini *et al* 2008). Additionally, a partial cost analysis was performed to verify the feasibility of using the restricted-fed of the integral feed for finishing lambs. All the cost values were converted to US dollars.

Table 2. Ingredients and nutritional composition of diets used for feeding finishing Dorper lambs.

Item[(1)]	Traditional diet	Integral feed
Ingredient		
Corn silage	75.0	–
Alfalfa hay	15.0	32.0
Oat hay	7.0	–
Triticale hay	3.0	–
Corn stover	–	8.0
Corn grain	–	17.1
Sorghum grain	–	17.1
Wheat bran	–	9.0
Soybean meal	–	9.0
Urea	–	1.2
Molasses	–	4.8
Mineral pre-mix[(2)]	–	1.8
Nutrient		
DM, % of diet and feed	61.92	93.34
CP	14.13	20.18
FDN	55.44	32.77
FDA	36.77	19.28
TDN	60.78	76.30
NE_m, MJ kg^{-1} DM	5.90	8.12
NE_g, MJ kg^{-1} DM	3.43	5.40

[(1)]Expressed as a percentage of the dry matter (DM) unless otherwise is indicated; CP=crude protein; NDF=neutral detergent fiber; FDA=acid detergent fiber; TDN=total digestible nutrients; NE_m=net energy for maintenance; NE_g=net energy for gain. [(2)]Mineral premix Ovi3ways group BIOTECAP.

RESULTS

Table 3 shows the effect of using the integral feed on the production and growth performance of lambs. Lambs fed the integral feed consumed 270 g d^{-1} of dry matter (DM) more than lambs receiving the traditional diet ($P<0.05$). The initial BW was similar between treatments ($P>0.05$), but the final BW was higher ($P<0.05$) in lambs receiving integral feed than in the lambs fed the traditional diet. Therefore, the ADG of lambs fed the integral feed was 200 g d^{-1} more than the lambs fed the traditional diet. Considering ADG and DMI, a higher feeding efficiency ($P<0.05$) was observed in lambs fed the integral feed compared with traditional diet fed lambs. Likewise, the lambs of the integral feed had better growth performance in terms of height, length and thoracic diameter. The average DMI expressed as a percentage of BW was 2.3% in lambs fed the traditional diet and 3.0% in lambs fed integral feed.

Table 3. Effect of feeding a traditional diet or an integral restricted-fed feed (mean ± standard deviation) on the productive performance and growth of finishing Dorper lambs.

Item[(1)]	Traditional diet	Integral feed	EE[(2)]	Effect
DMI, g d^{-1}	540 ± 84.74	811 ± 62.15	0.05	***
Inicial BW, kg	18.99 ± 1.82	18.78 ± 5.73	1.92	NS
Final BW, kg	26.74 ± 4.11	38.30 ± 9.47	0.70	***
ADG, g d^{-1}	120 ±32.67	320 ± 74.13	0.02	***
Feed efficiency	0.180 ± 0.03	0.400 ± 0.09	0.03	***
Height, cm	50.74 ± 16.48	53.99 ± 14.49	0.39	***
Length, cm	51.48 ± 7.49	53.25 ±8.37	0.51	*
Thoracic diameter, cm	60.55 ± 20.37	65.14 ± 21.22	0.53	***
Cane length, cm	12.46 ± 4.31	12.87 ± 3.87	0.45	NS
Cane width, cm	3.85 ± 0.46	3.88 ± 0.51	0.34	NS

[(1)]DMI = dry matter intake; BW = body weight; ADG = average daily weight gain; [(2)]EE= mean standard error; NS = non-significant. *=$P<0.05$; ***=$P<0.0001$; Feed efficiency= total weight gain/total feed consumption.

Treatment × time interaction was observed for BW, ADG and some growth performance variables. Lambs fed the integral feed had higher BW from week 6 until the end of the experiment, and had higher ADG in weeks 2 and 3, and from week 6 to 9 (figure 1, $P<0.05$).

On the other hand, the height of lambs fed the integral feed was higher from week 5 compared to the lambs fed the traditional diet. Body length and thorax diameter were higher in lambs fed the integral feed in weeks 8 and 6, respectively (figure 2, $P<0.05$). No differences were observed for cane length and width between treatments during the experimental period ($P>0.05$).

The correlation analysis between the growth performance variables indicated that most of the body measurements in lambs were positively correlated (table 4). Body weight was highly correlated ($P<0.0001$) with ADG, height, body

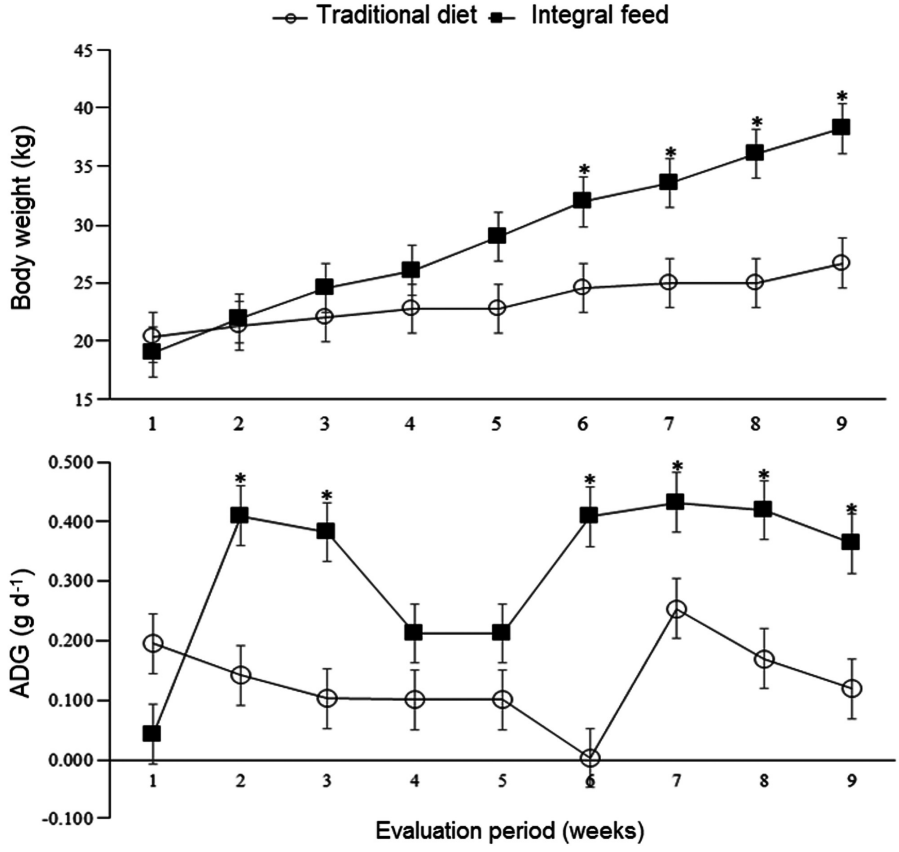

Figure 1. Treatment × time interaction effect on body weight and average daily gain of finishing Dorper lambs. *=$P<0.05$.

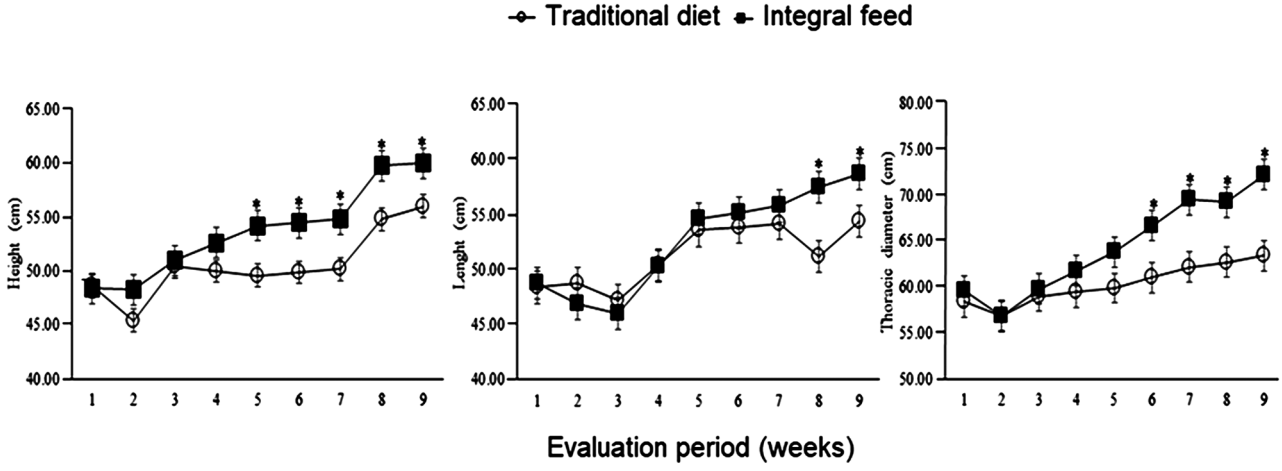

Figure 2. Treatment × time interaction effect on body growth of finishing Dorper lambs. *=$P<0.05$.

Table 4. Correlation matrix for body growth in finishing Dorper lambs.

	BW	ADG	Height	Body length	Thoracic diameter	Cane width	Cane length
BW	1.00	***	***	***	***	***	NS
ADG	0.41	1.00	***	*	***	NS	NS
Height	0.79	0.35	1.00	***	***	***	***
Body length	0.78	0.22	0.66	1.00	***	***	NS
Thoracic diameter	0.94	0.39	0.81	0.79	1.00	***	NS
Cane width	0.35	0.06	0.47	0.34	0.36	1.00	***
Cane length	–0.12	0.005	–0.32	–0.17	–0.13	–0.92	1.00

NS = Non-significant; BW = body weight; ADG = average daily weight gain; *=P<0.05; ***=P<0.0001.

Table 5. Partial cost analysis of traditional diet and integral feed used for feeding finishing Dorper lambs.

Ingredients	Traditional diet		Integral feed	
	g kg^{-1}	Dollars kg^{-1}	g kg^{-1}	Dollars kg^{-1}
Corn silage	750	0.06	–	–
Alfalfa hay	150	0.06	320	0.04
Oat hay	70	0.03	–	–
Triticale hay	30	0.01	–	–
Corn stover	–	–	80	0.003
Corn grain	–	–	171	0.04
Sorghum grain	–	–	171	0.04
Wheat bran	–	–	90	0.02
Soybean meal	–	–	90	0.04
Urea	–	–	12	0.004
Molasses	–	–	48	0.007
Mineral Premix	–	–	18	0.02
Total cost	–	0.16	–	0.20

Rate exchange price of 1 US dollar per 20.33 MXN (December 10, 2018).

length, thoracic diameter, and cane width. Similarly, ADG was correlated (P<0.0001) with body height, thoracic diameter and body length. There was a correlation between height, body length and thoracic diameter (P<0.0001). Cane width was only correlated with cane length (P<0.0001).

DMI and ADG were considered for the analysis partial costs. Starting from the costs of each ingredient used, the cost per kg of diet used was determined (table 5). The cost per kg of integral feed was $0.20 and for the traditional diet it was $0.16. The feeding cost per day for lambs receiving integral feed was $0.19. When considering ADG and the period of 70 days needed to obtain a final sale BW of 38.30 kg for lambs fed the integral feed therefore the total cost of fattening was $13.02 per lamb. The feeding cost per lamb fed the traditional diet was $0.08 per day; however, considering the ADG in this group, a fattening period of 190 days would be required to achieve a final sale BW similar to the lambs fed the integral feed. Therefore, the total cost of fattening lambs fed the traditional diet would be $15.55.

DISCUSSION

The observed DMI expressed as a percentage of BW of the lambs fed the traditional diet was lower than that reported by other authors when a diet based on corn silage was used (2.8% of BW, Nouel-Borges *et al* 2013), and the NRC (1985) recommendation for growing lambs is 5% of BW. Therefore, the 75% inclusion rate of corn silage on the traditional diet could limit the DMI of the lambs and subsequently affect feed efficiency (dos Reis *et al* 2001).

Additionally, there are reports indicating that the use of corn silage in lamb rations produces meat with a high proportion of fatty acids beneficial to human health (Sulliman *et al* 2016, Bernes *et al* 2012), as it is a feedstuff that provides high energy (Golmahi *et al* 2006). However, corn silage has low CP content, therefore nutritional requirements for optimum growth are difficult to meet even if this silage has a high nutritional quality, consequently observing an inadequate productive performance during fattening (da Silva-Dos Reis *et al* 2017, Grabowicz *et al*

2013, Bernes *et al* 2012). Moreover, keep animals with high starch content diets increases the incidence of fat accumulation reducing consumer acceptability (Alhidary *et al* 2016).

The use of TMR in ruminants can improve efficiency and feed conversion through optimal ruminal fermentation, cholesterol metabolism, development of the gastrointestinal tract, improvement of weight gain (Zhong *et al* 2018). Additionally, a better feed efficiency and feed conversion has been observed in lambs fed a diet containing an adequate amount of fiber than those fed a low-fiber diet (Reséndiz *et al* 2013). Therefore, the lambs fed the integral feed, in spite of receiving only 75% of their DM requirements, had the highest BW gains. The ADG of lambs fed the integral feed were in the optimum range for lambs between 20 to 40 kg live weight (300-400 g d^{-1}; NRC 1985) which was probably the effect of a better DM digestibility. Steers fed with a TMR restricted to 30% of BW compared with steers fed a corn silage diet offered *ad libitum*, had better feeding efficiency and DM digestibility (Loerch 1990, Lee *et al* 2015). This may be due to the fact that when diets high in energy are used, a substantial increase in the DMI is observed (Cherif *et al* 2018), and when the energy level increases, as reported by Muhammad *et al* (2011), the DMI and the weight gain also increase. This could be observed in the lambs fed the integral feed in the present study, where the higher DMI and better ADG were the result of an adequate supply of energy and protein in the diet, which led to a more effective use of the nutrients contained in the food (Przemyslaw *et al* 2015), which is related to a better feeding efficiency (de Souza-Cardoso *et al* 2017). In adition, an amount of grains that is greater than that contained in a traditional diet made possible to have a greater synthesis of propionic acid, and with it a greater use of energy, which results in a greater amount of net energy for weight gain. It has been shown that in the fattening of lambs, the use of energy has a greater efficiency when it increases the proportion of propionic acid. Consequently, the increase in the molar proportion of propionic acid generates greater weight gain in lambs (Judson *et al* 1968).

Lambs fed integral feed in this study had a homogeneous body growth, showing better bone and muscle development than lambs fed the traditional diet. This is important, since a better body development is a key feature in meat animals and is directly related to the economic income (Kumar *et al* 2018). However, the information that describes the relationship between feeding and growth development in lambs is limited; it has been pointed out that BW gains are positively related to body growth measures in Kajli lambs (Iqbal *et al* 2014). Also, a positive relationship was observed among body growth variables with high correlation coefficients between the thorax circumference and BW (Afolayan *et al* 2006) which coincides with the observations made in the present study. In this sense, the determination of animal live weight, linear body measures, and their inter-relationships and correlation is imperative for determining genetic potential, breed standards, and improved breeding programs for higher meat production (Assan 2015).

Maximising the productive behaviour in animals and reducing the cost of production are two indicators that must be taken into account to achieve a successful feeding program (Ben-Salem and Smith 2008). The use of restricted-feeding of an integral feed in the present study positively influenced the productive parameters in the lambs and although the total cost per kg of integral feed was higher compared to the traditional diet, the productive performance of the lambs allowed to reduce the total cost of feeding in $2.46 and the duration of the finishing phase in 120 days. The findings of this study agreed with the recommendations of previous studies (Hauss de Sousa *et al* 2012, Cirne *et al* 2013, Abbasi *et al* 2014) which reported that the use of diets with high energy and CP contents (between 16 and 20%), allowed for better ADG, less fattening time, reducing the cost and maximising the economic profit.

The restricted-feeding program using an integral feed for finishing lambs under intensive management conditions in Northern Mexico represents a viable alternative, since it decreased to a greater extent the fattening time and represented considerable economic savings. The use of high inclusion rates of corn silage to feed lambs for finishing negatively affected the productive performance. Further studies on restricted-feeding of an integral feed are needed since the profitability of intensive farms in Northern Mexico constantly demands better feeding programs.

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