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Productive Performance of Sheep in an Agropastoral System on the Coast of Oaxaca, Mexico

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ABSTRACT

Objective: To determine the prolificacy and weight of lambs at birth (BW) in two genotypes of hair sheep within an agropastoral system on the coast of Oaxaca, Mexico, and to evaluate the effect of two sources of selenium on the performance of lambs from said system during the fattening phase.

Design/Methodology/Approach: The study was carried out in an agropastoral system (coconut palm and *Cynodon dactylon* grass) in Río Grande, Oaxaca. Two experiments were conducted; the first studied 58 ewes distributed in a completely randomized design (CRD) with factorial arrangement of 2×2×3, and focused on the following fixed effects: genotype, number of births, and body condition (BC). The measured variables were prolificacy and BW. The second experiment studied 23 lambs of 4 months in age that were offspring of the females in experiment 1. They were distributed in a CRD with three treatments: T1, without selenium provided; T2, with barium selenate provided; T3, with selenomethionine provided. The dependent variables were daily weight gain (DWG), dry material consumption (DMC), and feed conversion (FC).

Results: The Pelibuey ewes with one and two births and the Black Belly ewes with one birth demonstrated the highest averages in prolificacy ($P \leq 0.05$). The lowest averages ($P \leq 0.05$) were detected in ewes with BC 4 irrespective of number of births. The BW was affected ($P \leq 0.05$) by genotype; Black Belly lambs weighed 680 g ($P \leq 0.05$) more that Pelibuey lambs. The DWG, DMC and FC behaved similarly ($P \geq 0.05$) between treatments and their general averages were 0.114 kg day^{-1}, 0.679 kg day^{-1}, and 6.18, respectively.

Study Limitations/Implications: In the agropastoral system, the BC of ewes limits their reproductive performance. The weight of the lambs at the start of fattening determines their performance during fattening.

Findings/Conclusions: In the agropastoral system, Pelibuey and Black Belly females present adequate prolificacy averages and BW; however, it is very important that they remain within BC 3. Neither of the two sources of selenium improves DWG, DMC, and FC of lambs fattened in pens in the agropastoral system.

Keywords: Pen finishing, tropical livestock systems, selenium.

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INTRODUCCIÓN

In agro-silvo-pastoral, silvo-pastoral, and agropastoral systems, the use and management of resources are directed toward sustainability (Russo, 2015) and they show the importance of livestock production under sustainable models in tropical regions (Ibrahim *et al*., 2006). Although these systems began in Latin America three decades ago, they have not been fully adopted despite the multiple goods and services that they offer (Clavero and Suárez, 2006). Thanks to their ethological behavior, sheep are the animal species that most easily and rapidly adapts to those sustainable production systems.

In 2017, sheep farming in Mexico produced 4,903 t of meat. Oaxaca contributed 3.36% (SIAP, 2018); this low production is attributed to extensive sheep farming management; in this regard, Hernández *et al*. (2017) characterized sheep production units and found that 62.3% are for subsistence, 33% are in transition, and only 4.7% are for business. These systems have developed under an extractive base with grass monocultures, large changes in land use, and desertification, which limit the environmental benefits of the biodiverse systems in the tropics (Alonso, 2011). In tropical regions, extensive livestock production systems are characterized by their low yield and negative environmental impact (Bacab *et al*., 2013). Martínez *et al*. (2011) mention that low profitability in sheep farming is mainly due to scarce application of technology. The Ministry of Agriculture and Rural Development, or SAGARPA (2011) considers it necessary to increase inventory, as well as to classify and integrate farmers to increase yields.

The alteration of ecosystems has resulted in the loss of vegetative cover, which could be recovered with the establishment of food systems where the tree-cover component is included in association with a variety of multi-purpose species (Bulgarín, 2012). In this respect, Milera (2013) reports that silvo-pastoral systems (SPS) that are agro-ecologically managed with a diversity of species and development patterns guarantee self-sufficiency and resilience to climate change. Agropastoral systems are an option for guiding livestock farming toward sustainability, and they are a productive alternative for small farmers (Febles and Ruiz, 2008). The study objective was to determine the prolificacy and weight of lambs at birth in two hair sheep genotypes within an agropastoral system on the coast of Oaxaca, Mexico, as well as to evaluate the effect of providing two sources of selenium on the performance of lambs from this system during the fattening phase.

MATERIALS AND METHODOS

The study was carried out in an agropastoral system located in the community of Río Grande, Villa de Tututepec, on the coast of Oaxaca, located between the coordinates 97° 26' 1.57'' LW and 15° 59' 27.2'' LN, and at 16 masl (Trejo, 1999). The climate was Aw1, warm dry, with a temperature greater than 26 °C and annual precipitation oscillating from 1,175 to 1,550 mm (INEGI, 2018). The soil is eutric regosol, with a pH of 5.5, not gravelly, deep and with medium fertility. The agropastoral system was established on a surface area of 10 ha and consisted of a 30-year-old coconut palm (*Cocus nucifera*) plantation, laid out in rows in a square system (5×8 m), and three-year-old forage grass (*Cynodon dactylon*).

Experiment 1

Fifty-eight (58) ewes were submitted for study (29 Pelibuey breed and 29 Black Belly breed) with an average of 31 months in age and an average weight of 32.6±2 kg.

Experimental design

The 58 ewes were distributed in a completely randomized design with a factorial arrangement of 2×2×3, having as fixed effects the genotype (Pelibuey and Black Belly), the number of births (1 and 2), and the body condition (2, 3, and 4; according to the scale described by Russel, 1984).

Feeding strategy

Zacate grass (*Cynodon dactylon*) was offered through daily grazing, in a timeframe from 8:00 to 16:00 h. Feeding was complemented by providing, in feedlots, a concentrate with 18% crude protein concentrate and 2.7 mcal EM day^{-1}. Each head was given 50g/day during the whole reproductive cycle.

Period and type of mating

It was done by natural mating in a 45-day period, during the months of March and April, 2018, using two studs.

Evaluated variables

Prolificacy. Determined by recording the number of lambs born alive, at the time of birth, for each of the ewes in the study.

Individual weight at birth. The weight of each one of the live-birth

lambs was registered, 4 h after birth, in both groups of ewes; the study used a digital Torrey[MR] scale with a 20 kg capacity.

Weight of the litter at birth. Obtained by adding up the weights of each lamb born alive in the litter.

Data analysis

The data obtained was subjected to variance analysis through a completely randomized model. The fixed effects were genotype with two levels (Pelibuey and Black Belly), the number of births with two levels (1 and 2), and the body condition with three categories (2, 3, and 4); in addition, double and triple interactions were considered. To determine the difference between means, the least mean squares test was used, using $\alpha=0.05$.

Experiment 2

Twenty-three (23) weaned males were studied, a cross between Pelibuey and Black Belly with 4 months of age that were offspring of the ewes evaluated in experiment 1.

Experimental design

The 23 male lambs were distributed in a completely randomized design, with three treatments. Treatment one (T1) was a control group with eight repetitions, without selenium provided. Treatment 2 (T2) had eight repetitions, where each animal was administered an intramuscular dose of 1 mg/kg of live weight of barium selenate (Selenate, L.A. 50 mg/ml). Treatment 3 (T3) consisted of seven repetitions and 0.2 mg/kg of live weight of selenomethionine (Bioways selenium 2000 ppm[MR]) was provided orally. The experimental unit was one lamb in an individual pen.

The pens had an area of 1.95 m^2, with an individual drinking and feeding trough. The study had a duration of 125 days divided in three stages: initial (42 days), intermediate (42 days), and final (41 days).

Feeding strategy

All the lambs were fed with a wholegrain ration, formulated with 16% protein and 2.6 Mcal EM kg^{-1}, in accordance with the nutritional requirements suggests by the NRC (2007); Table 1 shows the proportions used of each of the ingredients. The ration was offered *ad libitum* with feeding recorded twice per day, at 8:00 a.m. and 4:00 p.m.

Table 1. Proportion of inputs used in the elaboration of the integral ration offered to lambs from an agropastoral system during the fattening period.

Ingredient	Percentage of dry matter
Rolled corn grain	44.00
Soybean paste	18.30
Corn stubble	26.64
Urea	1.00
Common salt	2.00
Molasses	8.06

Evaluated variables

Weight gain. The lambs were weighed every 42 days and weight gain per period was calculated using the difference. The result was divided by number of days to calculate daily weight gain. The study used a digital hanging Crane[MR] scale, with a 300 kg capacity.

Food consumption. The amount of food offered daily was regulated using feeding trough records. The rejected food was weighed every seven days. Food consumption was calculated by the difference of food offered minus food rejected.

Feed conversion. Estimated based on the consumption of dry material and the weight gain per day; it was expressed in kilograms of dry material per kilogram of live weight generated.

Information analysis

The data were analyzed using variance analysis under a completely randomized model. The fixed effect was the treatment, and the covariable was initial live weight. To determine the difference between averages, the least mean squares test was used, using $\alpha=0.05$.

RESULTS AND DISCUSSION

Experiment 1

Prolificacy was affected ($P\leq0.05$) by two double interactions, genotype × number of births, and body condition × number of births. Figure 1 shows the prolificacy averages in the two genotypes according to the number of births per ewe. It can be seen that the Black Belly ewes with two births presented the lowest average ($P\leq0.05$) in prolificacy. The Pelibuey ewes with one and two births, and the Black Belly ewes with one birth presented the highest averages ($P\leq0.05$); between them, the averages were similar ($P\geq0.05$).

Figure 2 shows the prolificacy averages in ewes with different number of births and body condition, the highest average ($P\leq0.05$) was seen in first-birth sheep with body condition 3, followed by those that presented body condition 2 with two births. The lowest averages

(P≤0.05) were detected in ewes with body condition 4 irrespective of number of births, in ewes with body condition 2 with one birth, and in ewes with body condition 3 with two births.

Martínez *et al*., (2011) report that prolificacy in the Mexican dry tropics, in semi-extensive systems and for said genotypes, is 1.55±0.8; these values are close to those found for first-birth ewes, due mainly to the farming conditions. In other studies performed by Dickson *et al*. (2004) and Macedo and Alvarado (2005), data were compiled from established extensive systems in Mexico and they found averages of 1.23±0.49 and 1.2±0.39. The described values are below those reported in the present study.

For the Black Belly genotype, Andrade *et al*. (2015) report that the prolificacy in a semi-extensive system in Campeche was 1.74±0.06 lambs. Rojas and Rodríguez (1995) report values of 1.4±0.08 for yearling Black Belly sheep (1-2 years), value lower than that of juveniles (2-4 years) with 1.67±0.06, adults (4-7 years) with 1.75±0.07, and seniors (8-10 years) with 1.80±0.29. Lastly, Hinojosa *et al*., (2015) indicate that the F1 crosses of Pelibuey and Black Belly generate values of 1.23±0.03 in lamb prolificacy within a tropical system in Tabasco. Comparing the averages found in the present study with those described in the literature, it can be said that the prolificacy averages in Pelibuey and Black Belly ewes in the agropastoral system compete with those observed in semi-extensive systems in the tropics.

The individual weight of lambs at birth was only affected (P≤0.05) by the genotype. Figure 3 shows the averages obtained by Pelibuey and Black Belly ewes. The highest value (P≤0.05) was shown by lambs from Black Belly mothers; those lambs weighed 680 g more than the lambs from Pelibuey mothers.

The litter weight at birth was affected by the interaction of body condition and number of births of the ewe. The lowest averages were

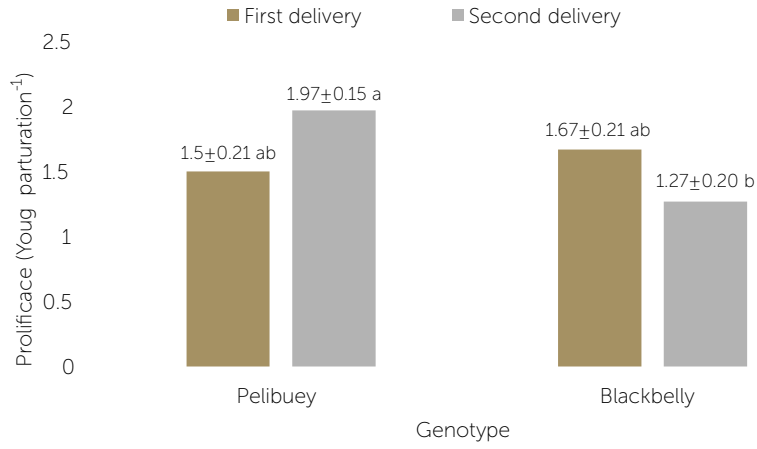

Figure 1. Prolificacy averages of ewes of two genotypes and different number of calvings, in an agropastoral system established in a warm dry climate on the coast of Oaxaca, Mexico. Different letters on the columns indicate significant statistical differences (P≤0.05).

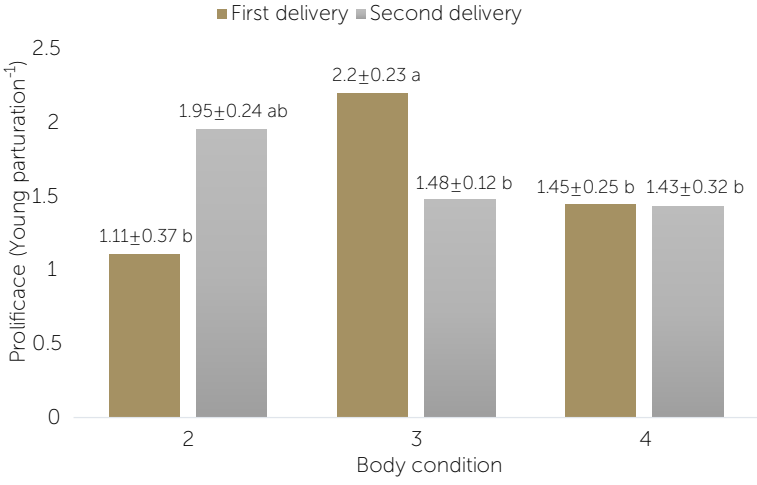

Figure 2. Prolificacy averages in ewes of different body conditions and number of calvings, in a warm climate agropastoral system on the coast of Oaxaca, Mexico. Different letters on the columns indicate significant statistical differences (P≤0.05).

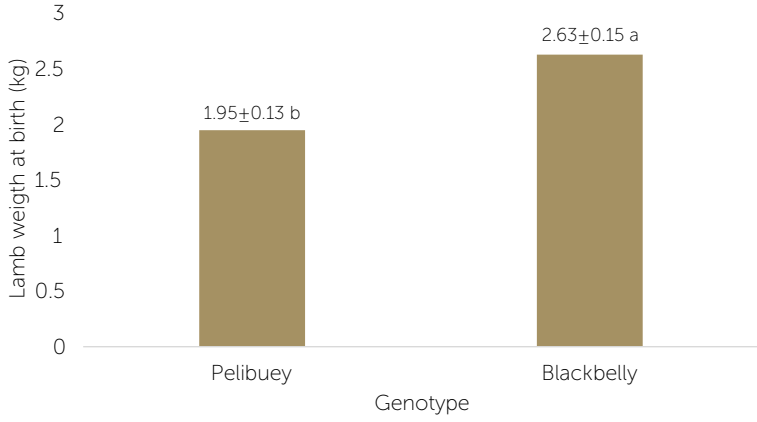

Figure 3. Averages of birth weight of Pelibuey and Black Belly ewes, in a warm climate agropastoral system on the coast of Oaxaca, Mexico. Different letters on the columns indicate significant statistical differences (P≤0.05).

found in lambs from mothers with body condition 4, irrespective of number of births, followed by lambs from ewes with body condition 2 and first birth. The highest averages were for lambs from ewes with one birth and body condition 3 (Figure 4).

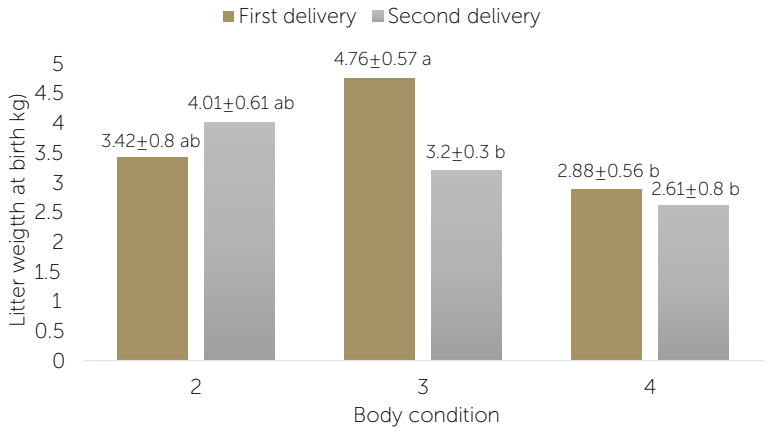

Figure 4. Averages of litter weight at birth in ewes with different body conditions and number of farrowings, in an agropastoral system established in a warm dry climate on the coast of Oaxaca. Different letters on the columns indicate significant statistical differences (P≤0.05).

González *et al.* (2002) report averages of 2.7±0.06 kg in lambs of the Black Belly genotype, which are similar values to those described by Ríos *et al.* (2014), who report averages of 2.6±0.07 kg in lambs of the same genotype and of 2.7±0.08 kg for cross-breed lambs. The average obtained in the present study for Black Belly lambs is similar to those described by other authors. The Pelibuey ewes showed values lower than those found in other studies; it is possible that the Black Belly breed adapts more easily to the agropastoral system.

In a study conducted by Macedo and Arredondo (2008), they found litter weights of 6.42 kg in ewes with double births and 6.39 kg for triple births, within an intensive farming system. The averages are above those described in the present study, and the difference is due to a lack of control in number of lambs per birth and to the farming system.

Experiment 2

Table 2 shows the averages in weight gain, food consumption, and feed conversion of lambs in the fattening phase treated with two sources of selenium (organic and inorganic). The variance analysis showed that the selenium source affected (P≤0.05) two of the three variables in the study.

In the intermediate stage, the administration of sodium selenite decreased (P≤0.05) daily weight gain by 33%, compared with the averages obtained by the animals in the control treatment and the selenomethionine treatment. In the other two stages (initial and final) and the total period, the daily weight gain averages were similar (P≥0.05); hence, only the general averages per stage are reported: initial, 0.106 kg day^{-1}; final, 0.117 kg day^{-1}; and total, 0.114 kg day^{-1}.

Food consumption was not affected (P≥0.05) by the administration of a different source of selenium in any of the three evaluated stages. The general averages were 0.506 kg day^{-1} in the initial stage, 0.584 kg day^{-1} in the intermediate stage, 1.039 kg day^{-1} in the final stage, and 0.679 kg day^{-1} in the total period.

Concerning feed conversion, in the intermediate and final stages, animals from the control and selenomethionine treatments showed the best averages (P≤0.05), while sheep in the sodium selenite treatment showed the least efficient averages. Despite this tendency, the total averages were similar (P≥0.05) in the three treatments.

Weight gain averages obtained in the present study are lower than those described by other authors. Macedo and Castellanos (2004) found weight gain averages of 182 g animal day^{-1} with commercial diets, Pérez *et al.* (2011) determined averages of 163 g animal day^{-1}, and Salinas *et al.* (2013) reported increments of 234 g animal day^{-1} on diets with polished rice. The animals used in the present study had a low live weight at the start of fattening (13.86 kg), due to the fact that most lambs were born in double births, and as described by Macedo and Arredondo (2008) in their study, the superiority in growth and live weight of lambs from single births, compared to multiple births, is maintained after weaning. Another factor that influenced this outcome was the genotype; as it is known, animals bred with

meat breeds demonstrate better performance than the Black Belly and Pelibuey breeds (Quintana, 2018).

With regard to feed conversion, values ranging from 4.2 to 8 are reported. Concerning this, INIFAP (2011) reported FC of 4 in whole-grain based diets. Salinas *et al*. (2013) describe averages of 4.23, 5.12, and 5.41 FC in sheep with diets where polished rice was included, at 0, 11 and 22% respectively. This means that feed conversion is unfavorably affected as the percentage of fiber increases in the ration.

Results obtained in this study for feed conversion are similar to those obtained by Berumen et al. (2003) by fattening confined male F1 Katahdin-Pelibuey lambs for 90 days, with a live weight of 15 kg. Regarding the experiments performed with selenium, Reséndiz *et al*. (2012) observed an increase in weight gain when using doses of 0.90 mg/kg (Biotecap®) added with chromium as well (1.4 mg/kg). However, Rodríguez *et al*. (2011) did not find differences in weight gain, dry material consumption, and feed conversion ($P>0.05$) when supplemented with premixes of selenium and chromium with final concentrations of 0.3 mg/kg and 0.4 mg/kg in final-stage sheep. Domínguez *et al*. (2013) mention that adding organic selenium (0.3 mg/kg) and chromium (0.25 or 0.35 mg/kg) to a finishing diet for sheep does not affect the productive variables, but when combined, there is an interaction between them ($P<0.05$) since food consumption and feed conversion decrease, while weight gain and carcass characteristics rise when chromium is increased.

It is possible that lambs from agropastoral systems do not require selenium administration at the start of fattening because they begin consuming green forage containing selenium during the nursing stage.

CONCLUSIONS

In the agropastoral system, Pelibuey and Black Belly ewes present adequate averages in prolificacy; nevertheless, it is very important that they maintain body condition 3, since any change in category affects prolificacy unfavorably.

In the agropastoral system, the Black Belly breed produces heavier lambs than the Pelibuey breed; however, it is necessary to monitor the body condition of the ewe, since litter weight decreases in underweight and obese ewes.

Ewes managed in the agropastoral system present better averages in prolificacy and weight in newborn lambs when compared to extensive farming systems.

The addition of organic or inorganic selenium does not improve weight gain, food consumption, and feed conversion in pen-fattened lambs within an agropastoral system.

Lambs from agropastoral systems present low weight at the time of weaning, which results in a reduction in weight gain and food consumption during the fattening period. Despite this behavior, the averages in feed conversion are efficient; thus, it is necessary to prolong the fattening period in order to obtain an optimum live weight for slaughter.

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Table 2. Averages (± standard error) of weight gain, food consumption, and feed conversion of sheep finished in pens with different sources of selenium, from an agropastoral system established in a warm dry climate on the coast of Oaxaca, Mexico.

Variables	Treatment		
	Witness	Barium selenate	Selenomethionine
Weight gain (kg día^{-1})			
Initiation	0.100±0.015	0.133±0.014	0.084±0.014
Intermediate	0.158±0.015 a	0.100±0.0144 b	0.144±0.014 ab
Ending	0.115±0.017	0.103±0.017	0.134±0.016
Global	0.126±0.011	0.103±0.011	0.113±0.011
Food consumption (kg de MS día^{-1})			
Initiation	0.527±0.030	0.480±0.028	0.511±0.020
Initermediate	0.602±0.035	0.568±0.033	0.582±0.033
Ending	0.977±0.062	1.113±0.062	1.028±0.58
Global	0.670±0.031	0.696±0.031	0.670±0.295
Feed conversión (kg kg^{-1})			
Initiation	8.921±1.558	6.593±1.578	10.883±1.458
Intermediate	4.038±0.583 b	5.903±0.583 a	5.210±0.545 b
Ending	6.119±0.856 ab	10.754±0.856 a	5.672±0.800 b
Global	5.499±0.511	6.950±0.511	6.088±0.478

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