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Determination of the Nutritional Quality of Prickly Pear Forage (*Opuntia ficus-indica*) in the Diet of Ewe Lambs

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Abstract: The objective of the study was to determine the productive performance, daily weight gain (ADG), daily Feed Intake (FI) Feed Conversion (FC) and Total Weight Gain (TWG) of growing lambs. Eighteen crossed dorper-pelibuey and katahdin female lambs with an initial mean live weight of 17.6±1.8 kg were used and fed diets using different levels of Prickly Pear Forage (PPF). Treatments were: T0) A mixed diet+0% PPF; T1) T0 +15% of PPF, on dry basis and T2) T0+30% of PPF. The lambs were housed in individual pens where they were provided of feed and water for free access, giving the mixed diet separately from the chopped fresh PPF. The lambs were 69 days in an experimental period and were distributed in a completely random design with three treatments. Data were analyzed by analysis of variance and multiple comparison tests of means by tukey. The final live weight was obtained and no significant differences were observed ($p>0.05$) among treatments, T0: 30.5; T1: 29.0; T2: 28.7 kg; the same happened for ADG, TWG and FC but FI, ($p<0.05$) decreased as the PPF increased (T0: 1198, T1: 1050, T2: 951 g). No differences were observed in acetic, propionic, butyric acid and $N\text{-}_{NH3}$ in ruminal fluid. It is concluded that as the percentage of PPF in diet increased, the feed intake decreased which led to the reduction of ADG in lambs, without differences in FC, VFA and $N\text{-}_{NH3}$ in ruminal fluid.

Key words: Sheep, finishing lambs, *Opuntia*, distributed, increased, reduction

INTRODUCTION

Opuntia plantations for specialized for age production in Mexico are not common because wild populations act as natural forage reserves for livestock. However, these sites are at risk due to excessive use and damage from severe frosts observed in recent decades. *Opuntia* plantations to produce fodder could reduce the pressure on wild populations while at the same time improving the profitability of milk and meat production.

Prickly Pear Forage (PPF) is extensively used as an emergency feed for livestock during periods of extreme drought such as 'insurance against drought' (Le Houerou, 1994) in arid and semi-arid areas of the world (Northeast Brazil, Mexico, South Africa, USA and in the Mediterranean).

It is important the use of forage resources by domestic animals because they originate the largest percentage of direct costs in livestock companies. One way to improve the use of forages is to know and properly apply the nutritional properties they offer in the diet of cattle.

PPF is not a common feed for cattle nutrition, however, it is high in water and its nutritional content is high in non-structural carbohydrates and high digestibility, although, it is deficient in protein and phosphorus (Pimienta, 1993). The knowledge of the nutritional potential of forages is important for theformulation and balancing of rations; however, it isnecessary to understand the mechanisms thatdetermine the differences among farm animals, feed and their interactions to increase the efficiency of animal production.

The fresh cladodes without thorns contain approximately 90% of water which limits their use in intensive farms due to the low consumption of dry matter and nutrient deficiencies but in grazing systems, these properties of *Opuntia* are valuable in times of drought, since, this makes possible to

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keep sheep alive for up to 500 days without drinking water, if they have free access to fresh cladodes.

Unfortunately, *Opuntia* cladodes are low in crude protein and need to be supplemented with some ingredients high in protein, phosphorus and sodium which make it necessary to develop diets to supplement the deficient nutrients to obtain productive parameters that lead to profitability. In general, cactus cladodes do not resemble to a balanced feed but constitute a good and cheap source of energy and water (De Kock, 1980). The objective of the study was to determine the nutritional quality of PPF in the diet of ewe lambs.

MATERIALS AND METHODS

This study was carried out in the experimental unit of sheep of the Technological Institute El Llano, located at 18 km of the highway Aguascalientes-San Luis Potosi, Mexico, at 21°55 'N and 101°58'W at an altitude of 2020 masl and annual rainfall of 500-600 mm. A productive performance trial was carried out for 69 days with 18 weaned female lambs of 2 months of age and an average weight of 17.6+ -1.8 kg and crossed by Pelibuey x Black belly x Katahdin. The penultimate week, ruminal fluid was collected (about 150 mL) of each of the ewe lambs, 6 h after offering feed at 09:00 h by suction with a vacuum pump and a ½-inch plastic probe with blunt edges and one of the ends with holes. Subsequently, the ruminal fluid was used in the laboratory for the analysis of pH, Volatile Fatty Acids (VFA) and ammonia Nitrogen ($N\text{-}_{NH3}$). The ewe lambs were housed in individual pens equipped with feeders and drinker, internally dewormed with ivermectin and levamisole, (1 mL/20 kg BW), vaccinated against Pasterella and Clostridium and injected with vitamins (ADE, 1 mL/lamb). The period of adaptation to the diets and facilities was 15 days and they were provided with feed at 09:00 h. A completely randomized design with three treatments and six repetitions was used: T0, control (diet in intensive system, without PPF); T1, diet of T0 with 15% (BS) of fresh PPF and T2, diet of T0 with 30% PPF (Table 1). The *Opuntia* used was of the *Ficus-indicus* genus, mature cladodes were chopped to facilitate its consumption. The diets exceeded 17% of CP and 2.5 Mcal/kg; the fresh and chopped PPF was impregnated with molasses to add palatability and was offered separately from the mixture of the rest of the ingredients. The feed intake and orts were measured every day in each lamb and the lambs were weighed in a digital scale 2 consecutive days at the beginning and end of the experimental period. With the data of feed intake and weight gain, the feed conversion was calculated.

Table 1: Experimental diets and chemical composition

Ingredients	Control (T0)	15% PPF (T1)	30% PPF (T2)
Alfalfa	28	15.7	10
Soy bean meal	5	5	4.5
Molasses	8	8	8
Tallow	0	1.1	2.5
Rolled corn	40	19	3.8
Salt	0.28	0.28	0.3
Sodium bicarbonate	0.8	0.8	0.8
Aluminosilicates	0.3	0.3	0.3
Urea	0.62	0.82	0.80
Soy plus	2	4	4
Mezquite pad flour	0	20	20
Wheat bran	5	0	5
Chicken manure	10	10	10
PPF	0	15	30
Total	100	100	100
Chemical composition*			
DM (%)	90.98	90.99	91.31
CP (%)	21	19.4	17.1
EE (%)	2.44	3.40	4.84
Ashes (%)	11.22	12.72	13.71
NFC (%)	42.34	39.78	37.93
NDF (%)	23.00	24.7	26.4
ADF (%)	15.6	17.70	18.9
ME (Mcal/kg)	2.625	2.514	2.516
UIP (%)	29	33	35

*Analyses in lab, ADF = Acid Detergent Fiber. NDF = Neutral Detergent Fiber. NFC = Non-Fiber Carbohydrates. NFC% = 100-(%NDF+%CP+%EE +%Ashes); (NRC., 2001). ME- Metabolisable Energy, calculated from nutritional composition. UIP = Undegradable Intake Protein, calculated from Table

Feed samples were processed for DM, proximal analysis, according to Horwitz (2005) and neutral and acid detergent fiber (Van Soest *et al*., 1991). The response variables were: Feed Intake (FI) per day and per BW $kg^{0.75}$; Daily Weight Gain (ADG); Feed Conversion (FC), final live weight (final BW), Total Weight Gain (TWG), molar production of VFA and ammonia N in ruminal fluid.

For the determination of VFA, a solution of ruminal liquid and metaphosphoric acid at 20% was prepared in the ratio of 4:1 v/v and the samples were kept under refrigeration at 4°C, until analysis by gas chromatography (Perkin Elmer® Co., Clarus 560 D Gas Chromatograph) (Erwin *et al*., 1961). $N\text{-}_{NH3}$ was also measured by using a spectrophotometer (VARIAN CARY-1E) (McCullough, 1967). The pH was determined with a portable Hanna HI 98130 potentiometer at the time of obtaining the individual ruminal fluid sample.

The data were analyzed by analysis of variance using SAS (2008) and the means were compared with the Tukey test ($p<0.05$). The statistical model was as follows:

$$Yij = m+ti+eij$$

Where:

Yij = Variable response
m = Overall mean
ti = Effect of the ith treatment
eij = Experimental error

RESULTS AND DISCUSSION

Feed intake: The control group (T0) had a feed intake (g/d/lamb) higher ($p<0.05$) than T1 and T2 and the latter was lower than T1 (Table 2). As the percentage of fresh PPF in the diet increased, the feed intake decreased, expressed in grams per day as well as g kg $BW^{0.75}$, this was partly due to the low palatability and the large amount of water that the PPF contains. Terblanche *et al.* (1971) reported daily intakes of 346 g when the PPF was offered fresh and 507 g when the PPF was dry and 1678 mL of drinking water, respectively, in lambs fed only with PPF, which lost weight due to a low intake of nutrients. Table 2 shows the PPF intake on a dry basis and the mixed diet without PPF where it is observed that although diet was planned to contain 0, 15 and 30% (DM) of PPF offered fresh, the PPF intake was smaller corresponding to 0, 9.9 and 18% for T0-T2, respectively. This explains that the PPF is not preferred when the ewe lambs have a mixture of grains available and only it is consumed in low amounts to satisfy the thirst when available water in a drinker is limited. The fresh PPF intake per day per lamb was low (1-2 kg) compared to 6-8 kg that Flores and Aranda mentioned, S/F and 3-9 kg per Lopez where the rest of the feed ingredients was composed by fodder and not concentrate.

To offer fresh PPF has several disadvantages such as the excess of water in its composition, the difficulty to incorporate it into a mixed diet and the high selectivity that the lambs present when it is offered separately from the rest of the ingredients of the concentrate, however, when PPF is offered dehydrated and integrated into the ration, these disadvantages disappear in this respect, Mejia Haro *et al.* (2018) used dehydrated PPF in concentrations of 0, 20, 30 and 40% in mixed diets, according to NRC (1985) and found no significant differences in daily weight gain (222, 236, 213 and 253 g, respectively) and feed conversion of lambs in fattening. Similar results were reported by Aguilar-Yanez *et al.* (2011) when using 17% fresh and dehydrated PPF in diets of weaned male lambs and concluded that PPF can be used both dehydrated and fresh but at low concentrations and in mixed diets where all the nutritional requirements are met.

Mejia Haro *et al.* (2018) observed lower DM intake in lambs Pelibuey x Katahdin than in lambs fed a diet

Table 2: Effect of level of PPF in diet on productive performance of female lambs

Variables	T0 0% PPF	T1 15% PPF	T2 30% PPF	EE
Initial BW (kg)	17.333	17.3	18.4	1.851
Final BW (kg)	30.5[a]	29.0[a]	28.7[a]	2.862
FI (g/d)	1210[a]	1062[b]	954[c]	52
FI (BW $kg^{0.75}$)	113[a]	101[b]	90[c]	6.08
ADG (g)	191[a]	169[ab]	149[b]	28
TWG (kg)	13.1[a]	11.6[ab]	10.2[b]	1.931
FC	6.13[a]	6.05[a]	6.13[a]	0.99
CPPF (g/d DM)	0	105	177	

[a,b,c]Means with different letter in a raw are different ($p<0.05$), Tukey $p = 0.05$, EE = Standard Error, BW = Body Weight, FI = daily Feed Intake, ADG = Average Daily Gain, TWG = Total Weight Gain, FC = Feed Conversion, PPF = Prickly Pear Forage (DM), CPPF = Prickly Pear Forage Intake

containing 30% ensiled apple pomace, partly due to the higher moisture content in this treatment and acid pH of the silage which can limit the feed intake and decrease the palatability of the diet in relation to treatment diets with a lower moisture content.

The NRC. (2001) for dairy cattle recommends reducing 0.02 kg per 100 kg of live weight for each percentage unit higher than this value when it is required to estimate the voluntary feed intake in fermented diets containing more than 50% moisture.

Rumsey and Lindahl (1982) supplemented pregnant sheep until parturition consuming a diet with 50 and 75% (DM) of fresh apple pomace and observed that in all treatments the energy intake was deficient, mainly in the last third of gestation in which the consumption of nutrients was limited mainly by the high content of moisture and low contribution of nutrients of apple pomace.

Weight gain: One of the most important productive parameters is the daily gain of weight of the ewe lambs in this study, no significant differences were observed ($p>0.05$) between the ewe lambs of T0 and T1 but T2 had lower gains ($p<0.05$) than T0 (Table 2). It was notorious that at a higher level of PPF in diet (30% DM), the ewe lambs reduced the intake of the mixture of grains and consequently the weight gain. These results are similar to those obtained by Aranda-Osorio *et al.* (2008) who fed lambs with mixed diets with 0, 15 and 30% (DM) of fresh PPF and reported lower intakes and weight gains in the lambs fed the diet with 30% PPF but not those of 15%. In our study, the lambs did not consume the amount of prickly pear planned for 15 and 30% of the total diet but part was replaced for the concentrate and the values of daily weight gain are according to sex and race used. Different from our results, Torres-Sales refers to a study with cows producing 26 kg of milk/day fed a diet with 36% PPF, 64% of corn silage and a supplement of a concentrate of 1/3 kg of milk produced in part this could be because dairy cattle have less developed the sense of

taste than sheep and can eat a greater amount of feed of low palatability which in PPF varies in *Opuntia* varieties.

Feed conversion: The feed conversion did not show significant differences (p>0.05, Table 2) among treatments in part, it could be due to the fact that the three diets had a similar energy concentration and exceeded 17% of CP, according to the requirements suggested by NRC. (1985) and both the feed intake and the weight gain were less when the amount of PPF in the diet was increased, without affecting the feed conversion or nutritional efficiency. Aranda-Osorio *et al.* (2008) did not obtain differences in the feed conversion in lambs fed a diet with 0% (5.73) and 30% (5.79) of PPF (DM), although, the feed intake and weight gain was lower in lambs fed the 30% PPF diet.

Mejia Haro *et al.* (2018) in crossed lambs of Pelibuey fed diets with 30% ensiled apple pomace in combination of 0 and 20% of chicken manure and obtained feed conversions of 6.24 and 5.72, respectively, values similar to those of this study.

It is well known that feed conversion of ewe lambs is not as efficient compared to that of male lambs, this is partly due to the fact that females deposit a greater amount of fat than males. De Alba used fermented apple pomace and reported feed conversions of 3.79 and 4.92 in growing male sheep and 4.57 and 4.93 in fattening and Soria reported values of 4.4, 4.1 and 4.4 in growing male lambs fed diets containing 0, 15 and 30% mesquite pod flour and 5.1, 5.5 and 5.6, respectively, in fattening.

Ruminal fermentation products: In values of the products of the ruminal fermentation, no significant differences were observed (p>0.05) among treatments (Table 3) in the molar production of total VFA. The ratios of acetic and propionic acids were similar (p>0.05) among treatments and that of butyric was lower in T2 than T0 and no difference between T1 and T2. The total VFA molar production was similar in the lambs fed with each of the diets, this could be due in part to the fact that the diets contained a similar energy concentration, since, part of the alfalfa was replaced by PPF in the T1 and T2 both ingredients with a high digestion rate. In butyric acid, T2 was lower than T0 which could be due to the inclusion of fat in the diets with PPF. Also, the acetate:propionate ratio did not show differences among treatments (p>0.05); the A:P ratio remained close to the range of 2.48-2.84. Mora *et al.* obtained acetate: propionate ratios of 2.0 evaluating diets with 50% sorghum and 30% stubble corn and using enzymes to increase the digestibility of the diet where they expected that the concentration of Propionate were higher due to the greater ruminal digestibility of starch, however, this did not happen.

Table 3: Mean values of ruminal pH, products of ruminal fermentation and nitrogen excreted in feces by female lambs

Variables	T0	T1	T2	EE
VFA total (mM/L)	30.000^{a}	34.867^{a}	35.40^{a}	13.8900
Acetic (%)	64.45^{a}	63.83^{a}	66.66^{a}	3.4600
Propionic (%)	21.96^{a}	25.05^{a}	22.75^{a}	3.5490
Butyric (%)	13.58^{a}	11.09^{ab}	10.60^{b}	1.7001
Acetic:propionic	02.96^{a}	02.62^{a}	03.03^{a}	0.5452
Ruminal pH	06.67^{a}	06.77^{a}	06.81^{a}	0.2240
$N\text{-}_{NH3}$(mg/dL)	04.8^{a}	04.32^{a}	05.58^{a}	2.2390
N excreted in feces (%)	05.96^{a}	05.19^{b}	04.86^{b}	0.3600

$^{a-c}$Means with different letter in a raw are different (p<0.05); EE = standard Error. VFA = Volatile Fatty Acids; N_{NH3} = Amonia Nitrogen

In experiments where low and high concentrate diets have been studied, it has been observed that even when the acetate concentration is reduced using a high level of concentrate, its level of production does not change considerably, it is possible, since, at the same time that the production of propionate increases, the rate of absorption of all fatty acids is significantly increased too.

The concentration of $N\text{-}_{NH3}$ in rumen is the result of the balance between production and absorption; $N\text{-}_{NH3}$ is also a critical nutrient for ruminal microorganisms and has been reported in concentrations with a wide range, from 1-22.1 mg/100 mL, cited by Villalobos (1993). There are several factors that are considered to influence its concentration in the rumen fluid. In this study significant differences were reported among treatments (Table 3) and the two treatments that included PPF maintained an average value close to 5 mg/dL, value within the range of 5-8 mg/100 mL and reported as optimal by Satter and Slyter (1974) for a good production of microbial protein.

CONCLUSION

As the percentage of prickly pear forage in diet increased, the feed intake in general decreased which led to the reduction of weight gains in lambs without differences in the values of feed conversion, molar production of volatile fatty acids and ammonia nitrogen in ruminal fluid.

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