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Use of *Tithonia diversifolia* (hemsl.) A. Gray in the diet of growing lambs

[*Uso de tithonia diversifolia (hemsl.) A. Gray na dieta de cordeiros em crescimento*]

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ABSTRACT

Two assays were conducted to study the *Tithonia diversifolia* (Td) plant: (1) chemical analysis and *in vitro* dry matter digestibility (IVDMD) of plant parts and (2) productive performance of lambs fed a traditional diet or a Td diet (30% of Td plus 70% of the traditional diet). The plant parts studied were leaves (L), leaves and petioles (LP); and leaves, petioles and stems (LPS). Feed intake, weight gain and feed conversion were registered weekly during five weeks of experimentation. The L showed higher (P<0.05) crude protein content (26.7%) than LP and LPS (25.5 and 19.7%, respectively). Crude fiber (11.2%), neutral detergent fiber (45.4%), cellulose (16.9%) and hemicellulose (33.5%) were lower in L than in LP (12.5, 46.7, 18.0 and 35.7%, respectively) and LPS (22.6, 59.2, 27.0 and 43.5%, respectively). The L and LP showed the highest IVDMD (89.2 and 88.2%, respectively vs. 77.2% of LPS). The Td diet resulted in greater feed intake and weight gain and lower feed conversion than the traditional diet. Therefore, *Tithonia diversifolia* is a forage plant of good quality for lambs which does not affect the productive performance.

Keywords: digestibility, feed intake, weight gain, feed conversion, lambs

RESUMO

Dois ensaios foram realizados para estudar a planta de Tithonia diversifolia (Td): (1) análise química e digestibilidade in vitro *da matéria seca (DIVMS) de partes de plantas e (2) desempenho produtivo de cordeiros alimentados com dieta tradicional ou dieta Td (30% de Td mais 70% da dieta tradicional). As partes vegetais estudadas foram folhas (L), folhas e pecíolos (LP); folhas, pecíolos e caules (LPS). O consumo de ração, o ganho de peso e a conversão alimentar foram registrados semanalmente, durante cinco semanas de experimentação. O L apresentou maior (P<0,05) conteúdo de proteína bruta (26,7%) que o LP e o LPS (25,5 e 19,7%, respectivamente). Fibra bruta (11,2%), fibra em detergente neutro (45,4%), celulose (16,9%) e hemicelulose (33,5%) foram menores em L do que em LP (12,5, 46,7, 18,0 e 35,7%, respectivamente) e LPS (22,6, 59,2, 27,0 e 43,5%, respectivamente). O L e o LP apresentaram o maior DIVMS (89,2 e 88,2%, respectivamente vs. 77,2% do LPS). A dieta Td resultou em maior consumo de ração e maior ganho de peso e menor conversão alimentar que a dieta tradicional. Portanto, Tithonia diversifolia é uma planta forrageira de boa qualidade para cordeiros que não afeta o desempenho produtivo.*

Palavras-chave: digestibilidade, consumo de ração, ganho de peso, conversão alimentar, cordeiros

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INTRODUCTION

In Mexico, sheep production is an important activity, given that from 2000 to 2014, the sheep inventory increased by 28.9%, from 6.0 to 8.5 million animals (Hernández-Marín *et al*., 2017). The extensive system that predominates with this activity has not been fully exploited, and farmers focus on concentrate supplements to improve production with the corresponding increase in costs and decrease in profits (Espinosa-García *et al*., 2015). In tropical areas, farmers also feed their lambs with concentrate supplements based on cereal grains and protein ingredients of high cost and low availability (Vázquez-Mendoza *et al*., 2012). This situation creates the need to implement feeding strategies based on forages that allow improving the productive performance of sheep in the tropics.

These forages must preferably contain between 14% and 18% crude protein and be available throughout the year (Vázquez-Mendoza *et al*., 2012). One of these forages could be *Tithonia diversifolia* (Hemsl.) A.gray (Td), a native shrub that reaches between 1.5 to 4.0 m height (González-Castillo *et al.*, 2014). This plant has a large annual biomass production, between 30 and 70 tha^{-1} as green forage; it requires little handling for its cultivation, it is fast-growing and up to 33% crude protein accumulates in its leaves (Ruíz *et al.*, 2014). The chemical composition of Td depends on the environment (Rodríguez *et al.*, 2008), therefore a chemical evaluation of this plant prior to its use as forage is advisable.

Ekeocha and Fakolade (2012) used this plant for ewes at up to 30% of the diet. Fasuyi and Ibitayo (2011) reported the presence of essential amino acids in Td based diets, particularly isoleucine, leucine and lysine and other aromatic amino acids such as phenylalanine and valine. Until today, the use of Td as forage for lambs has been scantly investigated, therefore, the objective of the present study was to evaluate the nutritional value of the morphological parts of *Tithonia diversifolia*, and the productive performance of lambs fed this plant at 30% of the diet.

MATERIALS AND METHODS

The animals were managed according to the technical specifications for the production, care and use of laboratory animals NOM-062-ZOO-1999. The forage samples were collected in Hueytamalco, Puebla, Mexico, at 97°16'37.2" W and 20°02'12.3" N and 446m altitude. The mean monthly temperature ranges from 16 to 26°C, and the mean annual rainfall fluctuates between 1,500 y 3,600 mm; the rainy season occurs from June to November and during part of the winter; the soil type is mainly Regosol (INEGI, 2009). The forage collection was carried out in July during rainy season while forage was in pre-flowering phenological stage.

Tithonia diversifolia (Hemsl. A.gray) plants, which are considered undesirable, were collected over a two hectare area of agricultural land. *Td* harvest took place in pre-flowering stage, 60 days after previous cutting to obtain the greatest amount of biomass from the plants. The plants were randomly sampled and cut at 1mhigh from the soil surface. A total amount of 100 kg of plants was collected. Subsequently, in order to obtain a gradient of protein concentration, plants were separated into their above ground morphological parts: leaves (L), leaves and petioles (LP); and leaves, petioles and stems (LPS). After being sun-dried, the samples were placed in paper bags and dried in a forced-air oven at 55 °C for 72 h; the dried material was ground throughout a 2mm mesh.

The percentage of moisture, ether extract (EE), crude fiber (CF), crude protein (PC), ash, neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, silica and IVDMD (in vitro dry matter digestibility, 72 hours of incubation time), were determined according to the AOAC (2000) official methodology. The experimental work was carried out in the sheep facilities of the Experimental Farm of the Animal Husbandry Department, Chapingo Autonomous University, located in Mexico at 98°52’15.36’’ W and 19°29’43.34’’ N, and 2250 m altitude. The climate is temperate subhumid with rains in summer, the average annual temperature is 15.2 °C and the average annual rainfall is 664.8 mm (García, 2004).

Twenty lambs of the Rideau Arcott breed (initial body weight between 22 and 30kg) were housed

in individual pens. The lambs were randomly distributed to one of two diets: (1) control or traditional diet = 70% concentrate plus 30% corn silage and (2) Td diet = 70% control diet plus 30% Td meal of complete plants (aboveground parts or LPS). The LPS fraction was used to include as much biomass as possible and it was determined that it was feasible to use this forage fraction due to its protein content. Voluntary food consumption is considered to be 3.5% of the live weight.

This percentage was divided by three, which results in 1.16%, and it was determined that this represents 33.14% of the ration. Upon rounding this figure, it was determined that 30% inclusion would be a good starting parameter. Therefore, the percentage of inclusion of the concentrated feed in the ration of fattening lambs was 80% concentrated feed and 20% corn silage, while Td diet consisted of 56% concentrated feed, 14% corn silage and 30% Td flour. The concentrate was the one normally prepared at the farm for intensive lamb production: 15% crude protein, minimum; 4% crude fat, minimum; 8% crude fiber, maximum; 8 % ash, maximum and 12%moisture, maximum.

7 days before the start of the experiment, the lambs were submitted to preventive medicine treatment, where vitamins A, D and E (2 mL per lamb of Vigantol®, Bayer, Mexico mixed with 2mL sterilized water) were applied orally, and an antiparasitic medication (5 mg of ivermectin and 125 mg of closantel per 25kg of body weight) was injected subcutaneously. Feed intake was determined daily in the mornings, by weight difference of feed offered and rejected. Weekly body weight of animals was used to estimate daily weight gain and feed conversion. All data were analyzed with the PROC GLM SAS® procedure (SAS, 2012). The comparison of means was carried out using the Tukey test at P≤0.05.

RESULTS AND DISCUSSION

Table 1 and 2 show the results of chemical analyses. In general, as expected, crude protein was higher (P≤0.05) in L and LP than in LPS. However, crude fiber, neutral detergent fiber, acid detergent fiber, cellulose, hemicellulose and lignin were lower (P≤0.05) in L and LP than in LPS. Therefore, while the nutritional values of leaves and petioles are similar, together they are better than the value of the stem.

Table 1. Ether extract, crude protein, ash and silica of *Tithonia diversifolia* (aboveground parts, % dry basis)

	Aboveground part			
	L	LP	LPS	SEM
EE	3.71±0.16	3.47±0.11	2.40±0.19	5.36
CP	26.72±0.62[a]	25.25±0.37[b]	19.04±0.92[c]	2.68
Ash	13.05 ±1.36	14.66± 1.47	13.01±1.38	3.85
Si	1.25±0.1	0.91±0.01	0.99±0.01	1.72

EE: ether extract, CP: crude protein, Si: silica, L: leaves, LP: leaves and petioles, LPS: leaves, petioles and stem, SEM: standard error of mean. a, b, c Values in the same row with different superscript are statistically different (P≤0.05). Although LPS presents the lowest value, the LPS samples (aboveground part of *Tithonia diversifolia* or Td), showed a good level of CP content for sheep (19%). The CP values of LPS observed in this study were similar to those reported by La *et al.* (2012) who studied 9 Td-ecotypes ranging from 18.3 to 26.4% CP content. Likewise, Gutiérrez *et al.* (2014) reported a value of 16.5% CP, lower than the value of LPS determined in the present assay. Lezcano *et al.* (2012) reported that leaf and tender stems contain low CF content, however, as time passes CF increases in the stems, while in the leaf CF remains unchanged.

Verdecia *et al.* (2011) observed NDF values between 43.6 and 50.5% at different cutting intervals; while Gallego *et al.* (2017) observed a percentage of NDF similar to that of the present study (53.81%). In contrast, Naranjo and Cuartas (2011) when measuring NDF in leaf and petiole samples of *Tithonia diversifolia*, obtained a lower percentage (38.62%) than that observed in this investigation (46.7%). The ADF values of the present study (12.0, 11.0 and 15.8% for L, LP and LPS, respectively) were lower than those reported by Verdecia *et al.* (2011), Meza *et al.* (2014) and Gallego *et al.* (2017) who reported values in the range of 30.0 to 48.5%. Odedire and Oloidi (2014) reported that during the dry season in Nigeria,

non-cultivated *Tithonia diversifolia* harvested before flowering presented 21.1% CP, 18.9% crude fiber, 14.1% ash, 43.2% ADF, 63.2% NDF, 20.0%hemicellulose and 3.7% lignin.

With the exclusion of ADF, hemicellulose and lignin, the other values reported by these authors were similar to those observed with LPS in the present study. In general, some variation was observed when the nutritive values of *Tithonia diversifolia*, reported in the literature were compared with those found in the present study. Hence, the importance of determining the nutritive content of this plant, mainly at the regional level and possibly at different cutting intervals. All the samples had high digestibility (Table 2), L and LP recorded values of 89.2% and 88.2%, respectively, which were higher (P<0.05) than that of the LPS sample (77.2%).

Table 2. The IVDMD and fiber components of *Tithonia diversifolia* (aboveground parts, % dry basis)

	Aboveground part			
	L	LP	LPS	SEM
IVDMD	89.24[a]	88.16[a]	77.19[b]	5.36
CF	11.19[b]	12.46[b]	22.57[a]	2.68
NDF	45.42[b]	46.74[b]	59.22[a]	3.85
ADF	11.95[b]	11.01[b]	15.76[a]	1.72
Cellulose	16.86[b]	17.95[b]	27.00[a]	3.47
Hemicellulose	33.47[b]	35.72[b]	43.45[a]	3.91
Lignin	7.89[ab]	6.84[b]	9.05[a]	0.69

IVDMD: *in vitro* dry matter digestibility, CF: crude fiber, NDF: neutral detergent fiber, ADF: acid detergent fiber, L: leaves, LP: leaves and petioles, LPS: leaves, petioles and stems. SEM: standard error of mean. [a, b, c] Values in the same column with different superscript are statistically different (P≤0.05).

Soto and Reinoso (2007) found 57% IVDMD of *Tithonia diversifolia* (*Td*) at 10 weeks of cutting interval. When studying a diet for rabbits with 9 and 18% of *Td*, Nieves *et al.* (2011), reported values of 53.5 and 51.3% IVDMD, respectively. However, in agreement with the present study, La *et al.* (2012) reported that the IVDMD of this forage is in the range of 72.3 to 79.8%, while the *in vivo* digestibility varies in the range of 81.1 to 85.7%. In this sense, the high digestibility of Td probably allows good absorption of nutrients in the rumen, as well as a greater contribution of energy for the ruminant, and consequently, it is possible to have favorable animal behavior if Td is included in the diet of lambs.

In the first week of the experimental period, lambs fed the traditional diet had (P≤0.05) higher feed intake (FI) than those with the Td diet. In the other weeks, no differences (P>0.05) in FI were observed between diets (Table 3). To this respect, Costa *et al.* (2018) while investigating the requirements of energy and protein for weight gain and carcass quality of lambs (Santa Inés and Morada Nova, 28 to 31 kg BW), reported a FI of 1 kg day^{-1}, a value lower than that found in this study (FI>1, for both diets, every week). Furthermore, Ma *et al.* (2019) evaluating the growth and nutrient utilization of Dorper lambs and their crosses (average initial BW of 28.3 kg), found a FI of 1.2 to 1.3 kg day^{-1}, values similar to those obtained in the present study (Table 3).

Forbes (2007) affirmed that the sheep's ability to select among parts of forages is very important to regulate the voluntary FI. Additionally, there exists evidence that feed intake is limited by rumen filling and physiological factors (Forbes, 2007). Fiber limits FI due to rumen filling (Bambi *et al.*, 2011), however, a fully ground and mixed plant as was the case of *Tithonia diversifolia*, is not easy to select. In this study, the Td diet produced slightly lower FI per animal than the traditional one (1.13 *vs.* 1.2 kg day^{-1}, respectively; Table 3 first week). Therefore, the decrease of FI on the first week of experimentation was due to both the filling effect and the physiological factor; that is, more fiber (22.6% CF) of the Td diet vs. 8% CF of the traditional diet, and new odors and flavors (substances necessarily consumed due to the difficulty of selection) of the Td diet. From the second week of experimentation onwards, the lambs were fully adapted to the new Td diet and FI remained the same between both diets (Table 3).

Despite its low FI, the Td diet resulted in a higher daily weight gain (DWG, g day^{-1}) per animal and

better feed conversion (FC, g g^{-1}) than the traditional diet (240 g day^{-1} and 5.8 g g^{-1}) on the second week of experimentation (Table 3). This highlights the great nutritional value of this plant for lamb feeding. From the third week of experimentation onwards, DWG and FC were the same every week when comparing both diets (Table 3). In an assay on feed efficiency and microbial profile of Suffolk and Rambouillet lambs (heavier than those of the present study), Ellison *et al.* (2017) reported a daily FI per animal of 2.3 and 3.3 kg day^{-1}, respectively, values greater than those found in this investigation. Furthermore, when studying an herbaceous plant (*Pelegonia*) for growing lambs, Christodoulou *et al.* (2007) reported a FI per animal of 1.6 and 2.0 kg day^{-1}, values similar to those of the present work. Based on the previous discussion, it is possible to say that the FI of lambs in this study is in the range of the literature values. Therefore, when comparing with the traditional diet, neither FI and DWG nor FC changed by the inclusion of Td (at the 30% level) in the diet of the lambs.

Table 3. Daily feed consumption (kg day^{-1}), daily weight gain (g day^{-1}) and feed conversion (g g^{-1}), of lambs fed a diet containing 30% of *Tithonia diversifolia (Hemsl.) A.gray* in the diet, all values as dry matter per animal

	Week				
	1	2	3	4	5
		FI (kg d^{-1})			
Traditional diet	1.2± 0.01[a]	1.39±0.02	1.48±0.04	1.42±0.04	1.45±0.04
Td diet	1.13±0.01[b]	1.41±0.01	1.49±0.03	1.46±0.03	1.50±0.03
DWG (g d^{-1})					
Traditional diet	250±38	240±53[a]	270±38	230±20	270±20
Td diet	310±41	290±35[b]	280±40	260±60	280±20
FC (g g^{-1})					
Traditional diet	4.59±0.58	5.79±0.37[a]	5.48±0.52	5.82±0.63	5.72±0.67
Td diet	3.82±0.66	4.82±0.15[b]	5.32±0.57	5.61±0.81	5.40±0.43

FI: feed intake; DWG: daily weight gain; FC: feed conversion. [a, b, c] Values for each variable in the same column with different superscript are statistically different (P≤0.05). Traditional diet: control or conventional diet of the farm. Td-diet: diet based on *Tithonia diversifolia* plant.

Cunha *et al.* (2013) reported a DWG per animal of 228 g day^{-1}, of lambs finished in paddock; this value is lower than ours. With respect to this, Sormunen-Cristian (2013) when studying the use of several grains in lamb feeding, reported daily weight gains per animal of 201 to 260 g day^{-1} and Rihawi *et al.* (2010) reported 300 to 322 g day^{-1}; values similar to those observed in the first two weeks of the present study. These studies corroborate that the use of Td for the growth of finishing lambs maintains the productive performance and produces similar results to those reported previously.

With the exclusion of the second week, where the Td-diet showed better FC, no differences were observed between diets in the remaining weeks of the study. The FC values observed in the present study were greater (3.8 to 5.6 g g^{-1}) than those reported by Costa *et al.* (2018) using Santa Inés and Morada Nova lambs (4.3 to 4.8 g g^{-1}). The weight of these lambs ranged between 25 and 31 kg, very similar to that of the preset study. These authors report that the greater the weight gain, the greater the FC; a similar trend was observed in the present study. The results obtained with FC also indicate (as is the case with FI and DWG) that *Tithonia diversifolia* meal can be used at the 30% level as an ingredient in the diet for lambs.

CONCLUSIONS

The nutritional content of *Tithonia diversifolia* leaves and petioles are similar, however, they are better than that of the stems. Due to the good content of nutrients and a greater amount of forage of the whole plant, its inclusion is possible, given that it does not affect the weight gain, feed consumption and feed conversion of growing lambs, making it a good option where this resource is available or its cultivation is possible.

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