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Chemical Composition and Digestibility of Six Species of Legumes (Fabaceae)

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ABSTRACT

Objectives: To determine the chemical composition and *in vitro* digestibility of *Acacia angustissima*, *Dalea* spp., *Desmodium* spp., *Leucaena leucocephala*, *Phaseolus vulgaris* and *Tephrosia vicioides* (Fabaceae).

Design/Methodology/Approach: Crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), crude lignin (CL), cellulose (Cel), hemicellulose (Hcel), cellular content (CC) and *in vitro* dry matter digestibility (IVDMD) were determined. The design was completely random with three replicates. The variables were correlated by pairs and the means of the species were compared with the Tukey's test ($P < 0.05$).

Results: *Dalea* spp. had the highest crude protein (17.7%), followed by *A. angustissima* (15.9%) and *L. leucocephala* (14.1%). *A. angustissima* (73.2%), *Dalea* spp. (74.9%) and *P. vulgaris* (77.5%) showed the highest IVDMD. *L. leucocephala*, *Tephrosia vicioides* and *Desmodium* spp. showed the lowest values of CP (14.1, 11.8 and 12.3%, respectively) and IVDMD (70.4, 70.2 and 64.9%, respectively). *Desmodium* spp. showed high levels of NDF (59.2%), ADF (41.4%), CL (17.5%), Cel (29.7%) and Hcel (17.8%) ($P < 0.05$). The IVDMD showed positive correlation with CC and negative correlations with NDF, CL, and Hcel ($P < 0.05$).

Study Limitations/Implications: *Desmodium* spp. showed high content of CL and low values of CP and IVDMD, therefore supplements should be added when used this legume in animal feed.

Findings/Conclusions: *Dalea* spp. showed low levels of lignin and high levels of protein and digestibility, making it possible to use it as feed for ruminants.

Keywords: Fabaceae, crude protein, neutral detergent fiber, *in vitro* digestibility.

INTRODUCTION

Forages are the main source of food for livestock, they can grow naturally, be sown and established for direct grazing, and they can be acquired through manual or mechanical cutting (Santos *et al.*, 2015). The challenge for livestock producers lies in improving production in order to cover the demand and conserve natural resources and the environment (Giraldo, 1999). An important factor in animal production is the composition and quality of the forages that make up the diet (Rojas *et al.*, 2005). Therefore it is important to know the forage resources available in a specific region, in order to develop systems that are more sustainable and productive (Lascano and Ávila, 1991). Legumes have nutritional quality and are cultivated as a protein bank in strips or in association with grasses (Poaceae) (Hess and Lascano, 1997). Since they have a short growing cycle, they can be used as emergency crops of high quality (Reta *et al.*, 2013). Moreover, forage Fabaceae are of better quality than grasses due to better digestibility, which is related to lower fiber content, and most of their digestible energy comes from soluble cell constituents, rather than from fiber (Buxton *et al.*, 1996). Although Fabaceae have higher protein content, there is little information in the literature reviewed about its nutritional value to justify including it in a diet, as either a principal or secondary component, in order to improve its efficiency for use by livestock (González and Cáceres, 2002; García and Medina, 2006). The objective was to determine the chemical composition and *in vitro* digestibility of six Fabaceae forage species native to the state of Morelos, Mexico.

MATERIALS AND METHODS

Six species of the Fabaceae family were used, and they were collected during the same time of year in several municipalities in Morelos, Mexico. Leaves, stems and fruits (aerial part) were collected in order to carry out a botanical identification up to genus (Table 1).

The samples were dried at a constant weight in an oven at 55 °C, and then each sample was analyzed in triplicate in order to determine the crude protein (CP), ether extract (EE) and ash (Ash) content or proximate analysis (AOAC, 1990), and the Van Soest *et al.* (1991) analysis: neutral detergent fiber (NDF), acid detergent fiber (ADF), crude lignin (CL), cellulose (Cel), hemicellulose (Hcel), cellular content (CC) and *in vitro* dry matter digestibility (IVDMD) with the methodology described by Giraldo *et al.* (2007). The study was carried out in the Animal Nutrition Laboratory of the Animal Science Department, in Texcoco, Mexico.

The variables of chemical composition and IVDMD were subjected to an analysis of variance (ANOVA) with the completely randomized experimental design. The means were compared with the Tukey's test ($P < 0.05$). Also, a correlation analysis was carried out by pairs of variables ($P < 0.05$) using the SPSS (2011) software.

RESULTS AND DISCUSSION

The results are expressed in dry basis (Table 2 and 3), and Table 4 shows the correlation between pairs of variables studied. *Desmodium* spp. showed the lowest IVDMD, CP and CC. Low CP values are associated with low levels of CC, and low CC levels are associated with low IVDMD. Inversely, *Dalea* spp. showed the highest IVDMD associated with elevated CP content. *Acacia angustissima* showed similar IVDMD values as *Dalea* spp., and slightly lower CP levels. Based on these results, it was inferred that with higher CP content there is higher IVDMD. These results can be explained by the following positive correlations: IVDMD vs CC and CC vs CP (Table 4). The positive correlation (0.96) between IVDMD (65.3%) and CP (22.5%) has been demonstrated ($P < 0.01$) in vetch by Gezahagn *et al.* (2014).

Desmodium spp. showed higher content of all fibrous components (NDF, ADF, CL, Cel and Hcel; Table 2) and lower IVDMD (Table 3). *Dalea* spp. showed the lowest

Table 1. Species and collection sites in the state of Morelos, Mexico.

Species	Municipality	Collection site
<i>Acacia angustissima</i>	Ticuman	Tlaltizapan-Yautepec Highway, 5 km from Ticuman.
<i>Dalea</i> spp.	Tlalquitenango	At 200 m from the community of San Pablo, Tlalquitenango
<i>Desmodium</i> spp.	Nepoapulco	Next to the bridge "El Vigía".
<i>Leucaena leucocephala</i>	Tepoztlán	"El Puente" place, in the community of Santa Catarina, Tepoztlán
<i>Phaseolus vulgaris</i>	Nepoapulco	Before the bridge "El Vigía", towards Mexico City.
<i>Tephrosia vicioides</i>	Totolapan	Tlayacapan-Atlatlahuacan highway, after the deviation towards Mexico City

Table 2. Fibrous components of six species of legumes (Fabaceae) from Morelos, Mexico.

Species	% Dry basis				
	NDF	ADF	CL	Cel	Hcel
<i>Acacia angustissima</i>	42.9 ^c	29.0 ^c	15.6 ^{ab}	13.4 ^b	13.9 ^b
<i>Dalea</i> spp.	50.4 ^b	41.3 ^a	11.6 ^c	29.7 ^a	9.1 ^c
<i>Desmodium</i> spp.	59.2 ^a	41.4 ^a	17.5 ^a	29.7 ^a	17.8 ^a
<i>Leucaena leucocephala</i>	50.5 ^b	30.9 ^c	18.8 ^a	12.0 ^b	19.6 ^a
<i>Phaseolus vulgaris</i>	49.5 ^b	38.1 ^b	12.7 ^b ^c	25.4 ^a	11.4 ^c
<i>Tephrosia vicioides</i>	59.0 ^a	40.0 ^a ^b	13.4 ^b ^c	26.6 ^a	19.0 ^a
Standard error of mean	1.38	1.22	0.69	1.96	0.98

^{a, b, c} Different letters in the same column indicate significant differences ($P < 0.05$).

NDF: neutral detergent fiber, ADF: acid detergent fiber, CL: crude lignin, Cel: cellulose, Hcel: hemicellulose.

Table 3. *In vitro* digestibility and non-fibrous components of six species of legumes (Fabaceae) from Morelos, Mexico.

Species	% Dry basis				
	IVDMD	CP	CC	EE	Ash
<i>Acacia angustissima</i>	73.2 ^{ab}	15.9 ^b	57.1 ^a	2.7 ^d	4.2 ^d
<i>Dalea</i> spp.	74.9 ^{ab}	17.7 ^a	49.6 ^b	3.6 ^b	6.7 ^a
<i>Desmodium</i> spp.	64.9 ^c	12.3 ^d	40.8 ^c	3.0 ^c	4.7 ^c
<i>Leucaena leucocephala</i>	70.4 ^b	14.1 ^c	49.5 ^b	4.2 ^a	6.7 ^a
<i>Phaseolus vulgaris</i>	77.5 ^a	11.7 ^d	50.5 ^b	3.7 ^b	6.0 ^b
<i>Tephrosia vicioides</i>	70.2 ^b	11.8 ^d	41.0 ^c	2.8 ^c ^d	6.1 ^b
Standard error of mean	1.04	0.55	1.38	0.15	0.23

^{a, b, c, d} Different letters in the same column indicate significant differences ($P < 0.05$).

IVDMD: *in vitro* dry matter digestibility, CP: crude protein, CC: cellular content, EE: ether extract, Ash: ashes.

value of CL and Hcel (Table 2 and 3), associated with high levels of IVDMD. *Acacia angustissima* showed low amounts of NDF, ADF, Cel and Hcel, and higher IVDMD than *Desmodium* spp. This indicates a negative correlation between IVDMD and NDF, CL and Hcel (Table 4). These negative correlations by pairs ($P < 0.05$) between fibrous components and IVDMD were reported

by Ortíz-Domínguez et al. (2017) in pods of different Fabaceae (previously known as legumes) for IVDMD vs NDF (-0.848) and for IVDMD vs CL (-0.957).

Tephrosia vicioides showed similar NDF, ADF, CL, Cel and Hcel levels (Table 2) as *L. leucocephala* and its IVDMD values were also similar (Table 3). The elevated levels of IVDMD showed by *P. vulgaris* are probably due to its low values of CL and Hcel (Table 2). The negative correlations in Table 4 indicate that lower CL vs higher IVDMD (-0.601), and lower Hcel vs higher IVDMD (-0.713). At higher levels of NDF, there were high levels of ADF, Hcel or Cel. With higher levels of the fiber variables (NDF, CL or Hcel), there are lower values of IVDMD, CP or CC. Therefore, *Desmodium* spp., which resulted with high levels of NDF, ADF, CL, Cel and Hcel, produced the lowest values of IVDMD, CP and CC. At low values of CL and Hcel, there were high levels of IVDMD; therefore, *Dalea* spp., which produced low values of CL and Hcel, produced high levels of IVDMD.

Comparison of CP and IVDMD values of this study with those from the literature

***Acacia angustissima* (CP: 15.9%, IVDMD: 73.2%).** Ncube et al. (2017) reported 23.4% of CP in *A. angustissima*. Aganga et al. (1997) found 12.52%, 17.14%, 13.67% and 12.74% of CP for *A. robusta*, *A. nigrescens*, *A. karoo*, and *A. rehmanniana*, respectively. Castrejón et al. (2017)

Table 4. Significant correlations between the response variables.

	IVDMD	CP	CC	EE	NDF	ADF	CL
IVDMD	1						
CC	0.587*	0.585*	1				
Ash				0.75*			
NDF	-0.587*	-0.585*			1		
ADF			-0.725**		0.725**	1	
CL	-0.601*						1
Cel			-0.579*		0.579*	0.884**	-0.79**
Hcel	-0.713**	-0.526*	-0.513*		0.513*		0.662**

The non-fibrous components are IVDMD: *in vitro* dry matter digestibility, CP: crude protein, CC: cellular content, EE: ether extract, Ash: ashes. The fibrous components are NDF: neutral detergent fiber, ADF: acid detergent fiber, CL: crude lignin, Cel: cellulose, Hcel: hemicellulose. (*): $P < 0.05$, (**): $P < 0.01$.

reported 16.8% of CP and 64.3% of IVDMD for *Acacia farnesiana*. Goel *et al.* (2015) found IVDMD values between 56.9% and 65.7% for *Acacia nilotica*. Ortiz-Domínguez *et al.* (2017) found IVDMD values of 44.5% for *Acacia pennatula*.

***Dalea* spp. (CP: 17.7%, IVDMD: 74.9%).** Huang *et al.* (2015) reported 13.3% (N×6.25) of CP in *Dalea purpurea*, and Peng *et al.* (2020) reported 70.5% of IVDMD in *Dalea purpurea*.

***Desmodium* spp. (CP: 12.3%, IVDMD: 64.9%).** Tessema and Baars (2006) reported CP values of 23.1% in *Desmodium uncinatum*, and Chamorro *et al.* (2005) reported an average of 76.4% of IVDMD in *Desmodium barbatum*.

***Leucaena leucocephala* (CP: 14.1%, IVDMD: 70.4%).** Gutiérrez *et al.* (2005), found 25% of CP in *Leucaena leucocephala*. Castrejón *et al.* (2017) reported 17.6% of CP and 74.9% of IVDMD for *Leucaena leucocephala* in Paso del Toro, Veracruz, six weeks after regrowth. Ortiz-Domínguez *et al.* (2017) found 46.4% of IVDMD for *Leucaena leucocephala*.

***Phaseolus vulgaris* (CP: 11.7%, IVDMD: 77.5%).** Alatorre-Hernández *et al.* (2018) found 11.7% of CP and 49.4% of IVDMD for *Phaseolus acutifolius*. Vojtíšková and Kráčmar (2013), found 41.0% of IVDMD in *Phaseolus vulgaris*.

***Tephrosia vicioides* (CP: 11.8%, IVDMD: 70.2%).** Ojo *et al.* (2012) reported 13.6% of CP for *Tephrosia bracteolata* 20 weeks after sowing, and Chamorro *et al.* (2005) reported 80.5% of IVDMD in *Tephrosia cinerea*, similar and superior when compared to the values reported in this study.

In general, the majority of the values of the variables in this study were 10% higher or lower than those in the literature consulted. For example, Tessema and Baars (2006) found values of NDF (46.50%) and ADF (35.4%) in *Desmodium uncinatum*, which are lower than those reported in this study (Table 2). For the Ash variable, Ncube *et al.* (2017) found values of 4.3% in *Acacia angustissima*, and Ojo *et al.* (2012) found values of 5.3% in *Tephrosia bracteolata*, similar to those in this study (Table 3). Ojo *et al.* (2012) reported 13.6% of CL and 2.2% of EE in *Tephrosia bracteolata*. García *et al.* (2008) reported ADF levels of 25.4% for *Leucaena* spp., while in this study 30.9% was obtained (Table 2). In most cases the values

of CL and Ash in the present study were similar; those of EE, CP and NFD were lower, and ADF and IVDMD were higher than those reported in the literature for the same species of Fabaceae.

CONCLUSIONS

Dalea spp. was the best forage species. With *Desmodium* spp. high supplementation with protein and non-fibrous carbohydrates should be used; and with *Dalea* spp. supplementation could be less or none. For the rest of the species that were not in the extreme positions, moderate supplementation could be used.

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