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Technical note

NUTRITIONAL VALUE OF *Dasyphyllum diacanthoides* (Less.) Carb.: AN ENDEMIC TREE USED AS SUPLEMENTARY FORAGE IN AGROFORESTRY SYSTEMS

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ABSTRACT

In view of the evidence of the use of *Dasyphyllum diacanthoides* by peasants of the Region of the Araucanía, in the center-south zone of Chile, as winter food for their cattle, and the nonexistence of reports on the use of this forage, in this paper we determined the nutritional value of the species. Samples taken from different edible parts of *D. diacanthoides* were dried and subjected to a proximate analysis and detergent system to determine dry matter; crude protein, ether extract; phosphorus, crude fiber, acid detergent fiber, neutral detergent fiber, total ash and metabolizable energy. It was shown that shoots and leaves are the edible parts that have the best nutritional values among the analyzed variables. Additionally, by calculating the digestible energy, digestible dry matter and the average metabolizable energy, it was found that *D. diacanthoides* has intermediate values for these variables compared to those of forage tree species used in different parts of the world and to the main local forage species. The plant presents balanced energy-protein ratio values, turning into an important winter supplement forage in view of the low availability of forage in the mountain localities of the Region of the Araucanía, as compared to other forage species used in Chile.
Additional keywords: Agroecology, cattle, local resources, rural communities, trevo

RESUMEN

Valor nutricional de *Dasyphyllum diacanthoides* (Less.) Carb.: árbol endémico de uso forrajero suplementario para sistemas agroforestales

Ante la evidencia de la utilización de *Dasyphyllum diacanthoides* por parte de campesinos en la Region de la Araucanía, en la zona centro-sur de Chile, como alimento invernal para su ganado y, la inexistencia de registros que reporten este uso forrajero, se llevó a cabo este estudio para determinar el valor nutricional de la referida especie. Se tomaron muestras de las partes comestibles (hojas, brotes y ramas) de *D. diacanthoides* a las cuales, una vez secadas, se les realizaron análisis proximal y sistema detergente para determinar materia seca, proteína cruda, extracto etéreo, fósforo, fibra cruda, fibra detergente ácido, fibra detergente neutro, ceniza y energía metabolizable. Los resultados mostraron que las hojas y brotes presentan los mejores valores nutricionales en las variables analizadas. Por otra parte, luego de calcular los valores de energía digerible, materia seca digerible y el promedio de la energía metabolizable, se encontró que *D. diacanthoides* presenta valores intermedios para estas variables al compararla con especies forrajeras arbóreas utilizadas en otros países y con las principales forrajeras locales. La planta presenta valores equilibrados en la relación energía-proteína, constituyéndose en una importante forrajera de suplemento invernal ante la escasa disponibilidad de forraje en las localidades cordilleranas de la Región de la Araucanía en Chile.
Palabras clave adicionales: Agroecología, comunidades rurales, ganado, recurso local, trevo

INTRODUCTION

Providing food for cattle in rural communities has been based mainly on establishing pastures and their derivatives in their different forms. The use of elaborate supplies (silage and concentrates), in addition to increasing production costs involve the establishment of productive systems with

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species that are not adapted to the location (so they do not express their potential) in land that is not necessarily fit for agriculture. Most of them are soils fit for forestry, of which 60% are eroded (Sotomayor, 2010). Furthermore, if they are on the mountain slopes, the inclement weather and the frail ecological conditions generate a vulnerability situation that permanently, year after year, puts at risk the survival of the cattle, a central element of the economies of those rural communities.

Under these conditions, agroecology proposes the design of agroforestry (silvopastoral) systems incorporating and/or using local species (autoctonous, native, endemic) according to the place's environmental conditions (Prabhu et al., 2015). Agroforestry systems are the expression of the cultural identity of a locality where living systems that preserve the natural resources as the base material (among others) of their economy coexist. These resources present advantages due to the multifunctionality of the ecosystems services: food, medicinal, animal forage, firewood, shade, live hedges. References to these systems, at the world level, are diverse, mainly in (sub)tropical American zones. In Chile, on the other hand, the agroforestry systems developed by government´s institutions using *Prosopis tamarugo, Acacia caven, Atriplex* sp., *Populus* spp., *Pinus radiata* and *Pinus contorta*, in whose identification, design and execution peasants and farmers have participated, should be mentioned (Sotomayor, 2010).

Participative research carried out with farmers and peasants from different parts of the world dealing with forage trees highlight the importance of knowing their preferences for establishing long-term strategies (Chettri and Sharma, 2009), the potential of local vegetation, and the importance of traditional knowledge in the characterization of forage resources (Nunes et al., 2015), the improvement of the local economy due to the multifunctionality of the environmentally friendly systems (Jiménez et al., 2008), the quality levels of the native forage bush species (Mekoya et al., 2008), the material as well as the emblematic value (Martínez et al., 2012) and the knowledge that the farmers have of the forage quality of the trees used is very consistent with the information level generated in the analyses made at the laboratory level (Thorne et al., 1999).

Although studies of the nutritional value of forage trees are recorded in other countries, in Chile this kind of studies have been made only on tree forage species in silvopastoral systems for the exotic species C*hamaecytisus proliferus* ssp. *palmensis* (Avendaño et al., 2003) and *Morus alba* leaves (Manterola et al., 2004) as a supplement for lactating goats. In the case of native species there are studies on the leaves and fruits of *Prosopis tamarugo* and *Prosopis chilensis* (Silva et al., 2000). However, there are no records of the use of *Dasyphyllum diacanthoides* as forage (nor of its nutritional value), as shown by observations made in the field in joint work with peasants and farmers of the Huechelepún community (Melipeuco, Region of the Araucanía). This species belongs to the family Asteraceae and is known as trevo or palo santo. It is an evergreen tree, with dense foliage and thorny branches, that can reach a height of up to 20 meters with trunk diameter more than one meter (Abarzúa et al., 2007).

The objective of this paper is to determine the nutritional value of this plant as an endemic tree species used as forage supplement for cattle in mountain zones of the Region of the Araucanía. It is aimed to find out the nutritional contribution of the different parts of *D. diacanthoides* eaten by cattle, its nutritional values in relation to the main food sources used for feeding ruminants in the region, and the nutritional value in relation to other forage trees.

MATERIALS AND METHODS

After 2 years of technical support and based on observations made in the native forest of the locality of Huechepelún, Melipeuco, Region of the Araucanía, plant material (branches) from *D. diacanthoides* trees (which are browsed by the cattle), was collected in the area between 38°53’20” S, 71°29’31” W, 947 masl and 38°53’52” S, 71°30’23” W, 1003 masl. A total of 100 branches were selected (50 branches with northern exposure from different trees, and 50 branches with southern exposure), with their duplicate for the analyzes. The edible parts (leaves, shoots and stems) of the year's shoots in 3- to 5-m tall plants were chosen. The samples were weighed fresh and then dried at 60 ºC during 24 h in a forced-air oven.

Once the samples were dry they were ground to determine dry matter (DM), crude protein (CP), crude fiber (CF), ether extract (EE), phosphorus (P) by proximate analysis (Weende method). Total ash (TA) was determined after calcination of the samples in a muffle furnace at 550 °C during 5 h (AOAC, 1998). The CP content was determined by the Kjeldahl method using a factor of 6.25 according to the AOAC method, and the values of P by the vanadomolybdate method. ADF (acid detergent fiber) and NDF (neutral detergent fiber) were determined by the method of Van Soest et al. (1991). The determination of metabolizable energy (ME) was based on the ADF using the following equation: ME = (14.68-0.0182 * % ADF * 10) * 0.239. For the comparative analysis with other forage species the values of *D. diacanthoides* were averaged and the following equations were applied: ME=DE (McalKg$^{-1)}$ *0.8210, where DE is digestible energy, which was determined as DE=0.628+0.984*DDM, and where DDM is the digestible dry matter, determined from DDM=88.9-(ADF+0.779) according to Khalil et al. (1986). The results of the nutritional values are presented as their averages and standard deviations.

RESULTS AND DISCUSSION

The results of the proximate analysis made of the different edible parts of *D. diacanthoides* show differences between them (Table 1), with the CP and CF values standing out, as they are smaller and larger, respectively, in the stem, due to the higher degree of lignification. The lower of CP, ME and P values in this fraction, together with the higher fiber values, would indicate that the best sections in terms of nutrition are found in the younger parts. However, since we are dealing with feeding based on browsing, the field observation indicates that there is no selection by the cattle.

Table 1. Chemical composition of the organs of *D. diacanthoides* eaten by cattle (mean ± SE)

	DM %	CP %	EE %	P %	CF %	ADF %	NDF %	TA %	ME Mcal·kg^{-1}
Shoot	39.95 ± 1.52	7.76 ± 0.15	2.36 ± 0.07	0.13 ± 0.004	23.53 ± 0.56	32.91 ± 0.92	39.42 ± 0.82	11.11 ± 0.45	2.49 ± 0.02
Leaf	39.49 ± 1.52	8.72 ± 0.25	2.78 ± 0.25	0.15 ± 0.004	19.15 ± 0.68	32.38 ± 0.82	36.68 ± 0.18	13.34 ± 0.68	2.68 ± 0.03
Stem	46.53 ± 1.08	5.03 ± 0.10	2.28 ± 0.27	0.10 ± 0.01	35.97 ± 1.06	46.38 ± 0.25	57.15 ± 0.21	5.33 ± 0.22	1.94 ± 0.05

DM: dry matter; CP: crude protein; ME: metabolizable energy; EE: ether extract; P: phosphorus; TA: total ash; CF: crude fiber; ADF: acid detergent fiber; NDF: neutral detergent fiber

According to Anrique et al. (2014), the energy-protein ratio is the most relevant to optimize the absorption of nutrients in ruminants. Based on that ratio, and considering the main food sources for the center-south zone of Chile, Table 1 shows that the CP values of crude protein of *D. diacanthoides* (7.76-8.72 % shoot-leaf) are below those of forage species shown in Table 2 like *Medicago sativa* (18.9 %), *Trifolium pratense* (12.9 %) and *Avena nuda* (14.4 %), but above *Triticum aestivum* (3.5 %) and similar to *Zea mays* (7.5 %). Although hay has increased its values due to improved handling and application of technology (Anrique et al., 2014), its average value (7.3 %) approaches that of *D. diacanthoides*.

The calculated average values were 2.38 and 2.66 Mcal·kg^{-1} for ME and DE, respectively, and 61.56 % for DDM. Thus, as to energy values (DE) expressed as Mcal·kg^{-1}, *D. diacanthoides* (2.38) is exceeded only by some species shown in Table 2, such as *A. nuda* (3.34) and *Z. mays* (2.62), it is slightly greater than *M. sativa* (2.35), and it is even considered in a good range (2.3-2.6) compared to energy contribution values of prairie sillage (Irara and Saldaña, 2002).

The balanced energy-protein ratio of *D. diacanthoides*, according to the chemical composition delivered by the proximate analysis, places it as an important supplementary nutritional alternative, considering, also, its availability in winter as an important source of energy.

Considering the above, based on the calculated average values obtained for *D. diacanthoides*, compared to studies made of other woody species used as forage in different parts of the world (Annex I), the plant stands out as an important energy source, taking relative positions 24 and 28 for ME and DE, respectively, among 58 registered species. This is an important fact considering that

D. diacanthoides is used as a nutritional source in mountain zones where temperatures below zero are recorded during more than one half of the year during the months of March through September (an accumulation of 2540 hours of temperatures below 7 ºC, and a total of 36 below freezing per year), so it can be determinant for keeping body temperature under those conditions (Bondi, 1989), and in this way make up for the growth rate (Zea and Díaz, 1990).

Table 2. Chemical composition of green forage species used in the south of Chile (adapted from Anrique et al., 2014)

Specie	Family	DM %	CP %	EE %	P %	CF %	ADF %	NDF %	TA %	ME $Mcal\cdot k\cdot g^{-1}$	DE $Mcal\cdot k\cdot g^{-1}$	DDM %
Avena nuda (hay)	Poaceae	87.9	14.4	5.89	0.44	2.7	2.8	13.8	2.2	3.34	3.74	86.8
Hay (several species)	---	85.4	7.3	1.12	0.16	33.9	38.7	62.0	6.5	2.17	2.54	58.8
Medicago sativa	Fabaceae	27.9	18.9	3.30	0.30	24.4	29.1	37.0	8.0	2.35	2.86	66.3
Trifolium pratense (hay)	Fabaceae	86.1	12.9	0.96	0.28	27.7	36.6	48.5	7.6	2.27	2.61	60.4
Triticum aestivum (hay)	Poaceae	86.1	3.5	0.79	0.08	42.7	55.4	82.9	5.3	1.46	1.98	45.7
Zea mays	Poaceae	22.1	7.5	3.00	0.13	27.7	33.3	53.0	4.6	2.62	2.72	62.9

DM: dry matter; CP: crude protein; EE: ether extract; P:phosphorus; TA: total ash; CF:fiber crude; ADF: acid detergent fiber; NDF: neutral detergent fiber, ME: metabolizable energy; DE: digestible energy, DDM: digestible dry matter

Another outstanding characteristic is its relative intermediate position (28 out of 58) in relation to the percentage of DDM, indicating its relative potential as food (Ayala et al., 2006). Additionally, despite belonging to the Asteraceae family, the plant does not accumulate alkaloids, thus being completely safe for cattle consumption (Zampini et al., 2007).

If to the above we add palatability (Abarzúa et al., 2007), an endemic condition (therefore, adapted to the ecosystem), the use and knowledge by the peasants, and the reproductive strategy (Peredo et al., 2015), *D. diacanthoides* represents an endogenous resource appropriate for the establishment of agroforestry systems for mountain conditions in the center-south zone of Chile.

CONCLUSIONS

D. diacanthoides presents balanced values in the energy-protein relationship, constituting an important forage of winter supplement due to the scarce availability of forage in the cordilleran localities of the Region of Araucanía in Chile. Being an endemic species, the plant is an easily accessible resource for farmers and is adapted to the agroecosystems of the area. However, management plans should be established for their sustainable use.

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Annex I

Energy and digestible values of woody forage species used in the world

Species	Family	ME $Mcal \cdot kg^{-1}$	DE $Mcal \cdot kg^{-1}$	DDM %	Reference	Species	Family	ME $Mcal \cdot kg^{-1}$	DE $Mcal \cdot kg^{-1}$	DDM %	Reference
Acacia amentacea	Fabaceae	2,10	2,66	61,64	6, 7	*Picus hispida*	Moraceae	2,02	2,46	56,81	5
Aesculus indica	Sapindaceae	8,20	2,97	68,65	31, 34	*Picus lacor*	Moraceae	1,89	2,30	53,10	5, 20, 33
Ailanthus chinensis	Somaroubaceae	8,58	2,97	68,65	31	*Picus roxburghii*	Moraceae	2,03	2,48	57,27	5, 18, 25
Albizia chinensis	Fabaceae	1,87	2,27	52,52	33	*Picus semicordata*	Moraceae	7,70	2,96	68,49	5, 17
Albizia lebbeck	Fabaceae	3,41	2,60	60,18	3, 12, 20	*Picus subinisa*	Moraceae	N/I	N/I	N/I	5
Artocarpus lakoocha	Moraceae	3,12	2,60	60,18	5, 14, 18, 30	*Garuga pinnata*	Burseraceae	2,10	2,56	59,14	18, 33
Arundinaria alpina	Poaceae	1,85	2,25	51,90	29	*Gliricidia sepium*	Fabaceae	8,60	3,29	76,12	10, 22, 24, 36
Azadirachta indica	Meliaceae	N/I	N/I	N/I	2, 8	*Gliricidia sepium*	Fabaceae	2,43	2,96	68,49	9, 11, 21, 26
Balanite aegyptica	Zygophyllaceae	2,22	2,70	62,57	29	*Grewia bicolour*	Tiliaceae	2,00	2,43	56,26	23, 29
Bauhinia purpurea	Fabaceae	2,03	2,47	57,19	18	*Guazuma ulmifolia*	Malvaceae	2,29	2,79	64,44	9
Brassaiopsis hainla	Araliaceae	2,00	2,44	56,39	5	Hay (several species)	---	2,17	2,54	58,79	1
Castanopsis indica	Fagaceae	1,38	1,68	38,64	25	*Leucaena leucocephala*	Fabaceae	S/I	2,88	66,70	9, 11, 16
Celtis Africana	Cannabaceae	2,46	3,00	69,50	29	*Listea monopetala*	Lauraceae	1,79	2,18	50,19	5, 33
Celtis australis	Ulmaceae	6,53	2,27	52,36	20, 28, 31	*Machilus odoratissima*	Lauraceae	N/I	N/I	N/I	5
Celtis caucasica	Cannabaceae	6,07	2,70	62,41	31	*Maytenus arbutifolia*	Celastraceae	2,46	3,00	69,50	29
Celtis pallida	Cannabaceae	2,71	3,30	76,44	6	*Melia azedarach*	Meliaceae	8,50	2,90	67,09	20, 31
Chamaecytisus palmensis	Fabaceae	2,45	2,98	69,04	11, 16	*Moringa oleifera*	Moringaceae	N/I	N/I	N/I	8
Colophospermum mopane	Caesalpiniaceae	2,31	2,81	64,98	19	*Olea europea*	Oleaceae	2,34	2,85	65,92	29
Combretum apiculatum	Combretaceae	2,47	3,01	69,66	19	*Olea ferruginea*	Oleaceae	6,11	2,53	58,52	31
Combretum molle	Combretaceae	2,17	2,65	61,25	19	*Peltophorum africanum*	Caesalpiniaceae	2,52	3,07	71,14	19
Combretum zeyheri	Combretaceae	2,32	2,83	65,37	19	*Premia schimperi*	Lamiaceae	2,27	2,77	63,97	29
Cordia africana	Ehretiaceae	1,78	2,17	50,03	29	*Pygeum africanum*	Rosaceae	2,16	2,63	60,86	29
Cordia ovalis	Ehretiaceae	2,18	2,65	61,40	29	*Quercus incana*	Fagaceae	5,52	2,56	59,30	15, 32
Dichrostachys cinera	Fabaceae	1,85	2,25	51,98	29	*Rhus natalensis*	Anacardiaceae	2,29	2,80	64,67	29
Diospyros lotus	Ebenaceae	7,74	2,87	66,31	31	*Robinia pseudoacacia*	Fabaceae	7,03	3,10	71,76	31
Erythrina fusca	Fabaceae	N/I	N/I	N/I	4, 10	*Sesbania grandiflora*	Fabaceae	N/I	N/I	N/I	11
Ficus carica	Moraceae	N/I	N/I	N/I	8	*Sesbania sesban*	Fabaceae	2,60	3,17	73,40	11, 16, 35
Ficus cunia	Moraceae	2,02	2,46	56,90	20, 25	*Trichanthera gigantea*	Acanthaceae	15,00	2,88	66,62	8, 10, 13, 27
Ficus glaberrima	Moraceae	2,06	2,51	58,07	5, 33	*Ziziphus mucronata*	Rhamnaceae	2,41	2,94	67,94	29
Ficus gnaphalocarpa	Moraceae	1,94	2,36	54,62	29						

ME: metabolizable energy; DE: digestible energy, DDM: digestible dry matter, N/I: not indicated

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