MEDWELL PUBLISHING
Journal of Animal and Veterinary Advances 8 (3): 408-412, 2009
ISSN: 1680-5593

Dry Matter Digestion of Native Forages Consumed by Range Goats in North Mexico

[1,2]M. Guerrero-Cervantes, [1]R.G. Ramirez, [2]M.A. Cerrillo-Soto,
[2]R. Montoya-Escalante, [2]G. Nevarez-Carrasco and [2]A.S. Juarez-Reyes
[1]Department of Feed Autonomous, Faculty of Biological Sciences,
University of Nuevo Leon, Mexico
[2]Faculty of Veterinary Medicine, University Juarez of the State of Durango, Mexico

Abstract: Native trees (2), shrubs (11), forbs (4), cacti (3) and flowers, fruits and pods (8) that are consumed by range goats in North Mexico were evaluated to determine their Organic Matter (OM), Crude Protein (CP) and the rate and extent of Dry Matter (DM) digestion. The effective degradability of DM (EDDM) was determined by incubating nylon bags (5×10 cm; 50 μm) at 0, 3, 6, 12, 24, 48, 72 and 96 h in the ventral part of the rumen of mature Suffolk x Rambouillet sheep fed alfalfa hay (75%) and a commercial concentrate (25%). The CP (trees mean = 8.0% DM, shrubs = 14, forbs = 13, cacti = 5, flowers, fruits and pods = 8) was significantly different among all species within each group of plants. Moreover, EDDM (34, 56, 58, 70 and 65%, respectively) was significantly different among plants within each group. Nutritional analyses may allow to rank range plants in low nutritional quality (trees), medium (shrubs and forbs) and high (cacti, flowers, fruits and pods).

Key words: Range goats, native plants, effective degradability, North Mexico

INTRODUCTION

Range goats managed under semiarid conditions compose their diet of a wide variety of individual native forages. However, animals should be facing a great variability in availability of forage and nutrients throughout the year (Juarez *et al*., 2004). Under dry conditions, foliage of shrubs and trees are prominent sources of food for range small ruminants (Bhatta *et al*., 2004) and are even utilized as protein foods (Makkar, 2003). In addition, range animals readily consume immature pods of cacti, which are a good source of energy and water in harsh environments (Ramirez *et al*., 2000a). Forbs, on the contrary, are important during the wet season (Papachristou and Nastis, 1993), which may represent up to 30% of the goats diet (Papachristou, 1997). Fruits are also widely used for grazing cattle (Riveros, 1992).

Most laboratory techniques used in feed evaluation are still judged according to their ability to predict the nutritive value of feedstuffs. The degradability of DM and CP will directly influence the nutritional characteristics of feedstuffs for ruminants (Ørskov and Shand, 1997). Thus, the *in situ* digestion kinetics of forage consumed by livestock has been used to determine whether, degradation characteristics of individual vegetative species could provide a useful basis for the evaluation of their nutritive value (Apori *et al*., 1998). Results obtained with this technique are closely related to those *in vivo* procedures due to its capability to mimic the natural conditions, in which the chemical compounds of forages (DM, CP and NDF) are digested in the rumen and in other segments of ruminant digestive tract (Broderick and Cochran, 2000). Studies on *in situ* digestion kinetics of native shrubs from North and Northeastern Mexico have been reported (Ramirez *et al*., 1998; Ramirez-Orduna *et al*., 2003) and on native forbs as well (Ramirez and Nunez-Gonzalez, 2006); nonetheless, more research is needed concerning the rumen degradation characteristics of individual foliage of trees, shrubs, forbs, cacti and fruits, commonly selected by range goats, because this could provide a better nutritional characterization of such forages than that obtained by conventional chemical analyses. The objective of this study was to determine the organic matter, crude protein and *in situ* DM degradability of a wide variety of native foliage collected in the semiarid region of North Mexico.

Corresponding Author: Roque G. Ramirez, Department of Feed Autonomous, Faculty of Biological Sciences, University of Nuevo León, México, USA

MATERIALS AND METHODS

The plant species studied were obtained from 7 sites belonging to 4 counties (Durango, Guadalupe Victoria, Penon Blanco and Cuencame) of the state of Durango, Mexico, located at 23°57' and 26°26' LN and 103°48' and 104°43' LO. The sites have a dry climate with total annual rainfall ranging from 243-450 mm, annual mean temperature from 17-21°C and with altitude that varied from 1240-1910 m. The main soils types in the 4 counties are regosol, vertisol, rendzina, xerosol and litosol.

Foliage from trees such as *Quercus grisea* Liebm. and *Quercus eduardii* Trel. shrubs such as *Acacia shaffneri* (S. Watson) F.J. Herm, *Prosopis leavigata* (Willd.) M.C. Johnst, *Atriplex canescens* (Pursh) Nutt., *Celtis pallida* Torr., *Flourencia cernua* DC, *Cassia wislizeni* A.Gray, *Larrea tridentata* (Ses. et Mocex DC.) Felger and Lowe, *Condalia lycioides* (Gray) Weberb., *Acacia constricta* Standl., *Mimosa biuncifera* (Benth.) Britt. and Rose and *Cordia parvifolia* A. DC; forbs such as *Jatropha dioica* Cerv., *Parthenium incanum* Kunth., *Coldenia greggii* (Torr. and Gray) Gray and *Dalea bicolor* Humb. and Bonpl.; cacti such as *Opuntia leucotricha* DC, *Opuntia leptocaulis* DC and *Opuntia imbricata* (Haw.) DC; fruits and pods such as white prickly pears and red prickly pears (*Opuntia leucotricha* DC.), *Opuntia leptocaulis* DC, *Opuntia imbricata* (Haw.) DC, fruits *Atriplex canescens* (Pursh) Nutt., pods of *Prosopis leavigata* (Willd.) M. C. Johnst., pods of *Acacia shaffneri* (S.Watson) F.J. Herm. and flowers of *Yucca* sp. were collected for *in situ* digestibility analyses. Plants chosen for each species were selected at random, taking at least 10 plants of each species, considered as dominant in the range. Tree, shrub and forb samples were air dried until constant weight. Cacti samples were burned and air dried. Flowers, fruits and pods were dried in an air forced oven at 55°C until constant weight. All samples were ground in Wiley mill to pass a 2 mm screen for degradability measurements and 1 mm screen for chemical analyses.

Crude Protein (CP) in samples was determined by the micro Kjeldahl technique. The rate and Extent of Digestion of DM (EDDM) were estimated by incubating nylon bags (5×10 cm of size with a pore size of 50 μm; ANKOM Technology, Macedon NY, USA) containing 5 g of each species. Bags were incubated at 0, 3, 6, 12, 24, 48, 72 and 96 h in the ventral part of the rumen of three sheep fed alfalfa hay (75%) and a commercial concentrate (25%). During each incubation period, the bags were placed into the rumen at once. After withdrawal, bags were placed in polyethylene bags and washed several times until the rinsing water was clear (about 5 L of water for 3 bags; Juarez *et al*., 2004). The bags were dried in a convection oven during 24 h at 55°C and stored in plastic containers until chemical analyses were performed. The DM bag losses were estimated by weight change of nylon bags before and after washing and disappearance of DM for each incubation time was calculated by:

$$\text{DM disappearance (\%)} = \frac{\text{Initial DM or CP} - \text{final DM or CP}}{\text{Initial DM or CP}} \times 100$$

Digestion characteristics of DM were obtained by fitting data to the equation (Ørskov and Shand, 1997):

$$P = a + b\,(1 - e^{-ct})$$

where:

- a = Represents the immediately soluble fraction
- b = The insoluble but slowly rumen degradable fraction
- a + b = The potential degradation
- c = The rate constant of degradation of b and t is the time of incubation

Effective degradability of DM (EDDM) was calculated by the following equation:

$$\frac{(a+b)c}{(c+k)\,(e-(ct)LT)}$$

The EDDM of samples was estimated assuming a rumen out flow rate of 5% h^{-1}. Data were analyzed among species within each group of plants by one way analysis of variance using the General Linear Model (GLM) of SAS (Cody and Smith, 1997). Mean differences were separated using Tukey's test.

RESULTS AND DISCUSSION

The OM content was significantly different among all species within each group of plants (Table 1). The OM content in trees varied from 93-95%, shrubs from 80- 94, forbs from 86-93, cacti from 68-71 and flowers, fruits and pods from 79-94. The CP content was significantly different among all species within each group of plants (Table 1). Trees were in a range from 7-9%, shrubs 10-17, forbs 10-16, cacti 5-6 and flowers, fruits and pods 4-19. Shrubs and forbs exhibited higher CP content than other groups. High CP values in forbs (Ramirez and Nunez-Gonzalez, 2006) have also been reported. However, while great proportion of nitrogen content, in species such as *Atriplex canescens* and most cacti, is highly soluble, in others such as *Acacia* shrubs, nitrogen solubility, ruminal

Table 1: Organic matter and crude protein (dry matter basis) content of native plants selected by range goats in North Mexico

Plant species	OM (%)	CP (%)
Trees		
Quercus eduardii	93	7
Quercus grisea	95	9
Mean	94	8
SEM	1	0.4
Significant level	***	***
Shrubs		
Acacia constricta	93	17
Acacia shaffneri	93	16
Atriplex canescens	82	12
Cassia wislizeni	90	10
Celtis pallid	80	15
Condalia lycioides	91	14
Cordia parvifolia	84	13
Flourencia cernua	89	15
Larrea tridentate	91	13
Mimosa biuncifera	94	16
Prosopis leavigata	94	17
Mean	12	14
SEM	3	0.4
Significant level	***	***
Forbs		
Coldenia greggii	93	10
Dalea bicolor	93	14
Jatropha dioica	86	14
Pathenium incanum	87	16
Mean	90	13
SEM	4	0.8
Significant level	***	***
Cacti		
Opuntia imbricata	68	5
Opuntia leptocaulis	73	6
Opuntia leucotricha	73	5
Mean	71	5
SEM	1	0.4
Significant level	***	***
Flowers, fruits and pods		
Flowers of *Yucca* sp.	96	19
Fruits of *Atriplex canescens*	79	5
Fruits of *Opuntia imbricata*	86	8
Fruits of *Opuntia leptocaulis*	80	5
Pods of *Acacia shaffneri*	87	10
Pods of *Prosopis leavigata*	86	12
Red prickly pear of *Opuntia leucotricha*	95	5
White prickly pear of *O. leucotricha*	92	4
Mean	88	8
SEM	2	0.5
Significant level	***	***

OM = Organic Matter; CP = Crude Protein; SEM = Standard Error of the Mean; ***(p<0.001)

Table 2: *In situ* digestibility characteristics of dry matter of native plants selected by range goats in north Mexico

Plant species	DM (%)[a]	DM (%)[b]	DM h^{-1} (%)[c]	EDDM DM (%)
Trees				
Quercus eduardii	24	18	3.1	31
Quercus grisea	25	30	3.4	36
Mean	24	24	3.2	34
SEM	0.3	1	0.1	0.8
Significant level	***	***	***	***
Shrubs				
Acacia constricta	27	54	6.5	58
Acacia shaffneri	21	20	2.7	28
Atriplex canescens	41	49	6.4	68
Cassia wislizeni	31	45	4.5	52
Celtis pallida	21	64	7.5	59
Condalia lycioides	30	54	4.1	54
Cordia parvifolia	26	54	4.5	52
Flourencia cernua	28	61	10.5	69
Larrea tridentata	33	60	5.2	62
Mimosa biuncifera	23	61	3.5	48
Prosopis leavigata	28	39	6.7	58
Mean	28	50	6.6	56
SEM	1	1.3	0.2	1.1
Significant level	***	***	***	***
Forbs				
Coldenia greggii	30	52	7.8	61
Dalea bicolor	31	53	4.2	55
Jatropha dioica	27	70	3.2	55
Pathenium incanum	36	47	5.0	59
Mean	31	55	5.1	58
SEM	0.8	0.9	0.1	0.7
Significant level	***	***	***	***
Cacti				
Opuntia imbricata	49	46	3.0	66
Opuntia leptocaulis	56	32	5.9	73
Opuntia leucotricha	55	36	4.4	71
Mean	52	38	4.4	70
SEM	1.1	0.9	0.1	1
Significant level	***	***	***	***
Flowers, fruits and pods				
Flowers of *Yucca* sp.	56	41	24.7	90
Fruits of *Atriplex canescens*	34	26	3.9	46
Fruits of *Opuntia imbricata*	46	31	5.3	62
Fruits of *Opuntia leptocaulis*	51	21	37.8	69
Pods of *Acacia shaffneri*	41	37	12.9	55
Pods of *Prosopis leavigata*	35	20	11.0	49
Red prickly pear of *Opuntia leucotricha*	52	22	22.0	70
White prickly pear of *Opuntia leucotricha*	59	24	11.4	75
Mean	47	28	14.9	65
SEM	1.2	1.3	0.3	1.1
Significant level	***	***	***	***

SEM = Standard Error of the Mean, ***(p<0.001), [a]Intercept representing the portion of DM solubilized at the beginning of incubation (time 0); [b]Portion of DM that is slowly degraded in the rumen; [c]Rate constant of disappearance of fraction b; EDDM = Effective Degradability of DM calculated with a rumen outflow rate of 5.0% h^{-1}

degradation and intestinal digestion are low because of great proportion of N is binding to cell wall fraction (Ben Salem *et al*., 2002). The amount of N-NDF has been estimated being in a range of 21-56% in individual species (Apori *et al*., 1998; Ramirez-Orduna *et al*., 2003) and 50% in the diet selected by goats (containing a wide array of individual species; Ramirez *et al*., 1991) and as a consequence, this nitrogen will be partially metabolized in the gut (Ramirez-Orduna *et al*., 2003). In this study, with exception of cacti species and some fruits, most plants had CP content within a range of 8.0 and 14%, these values provide CP levels above the minimum required (7%) by rumen microorganisms to support optimum growth (Yousef and Rouzbehan, 2008).

The soluble fraction of DM, the rumen degradable fraction, rate constant and EDDM were significantly different among all forages within each group of plants (Table 2). Higher EDDM values were observed in cacti

group (range = 71-73%) followed by the group composed by flowers fruits and pods (46-90), forbs (55-61), shrubs (48-69; 28-69) and trees (31-36). Low values in tree foliage may be related to the presence of secondary plant metabolites such as lignin and tannins that may limit ruminal microbial activity because of their ability to bind with dietary proteins, carbohydrates and minerals (Jung and Casler, 1991; Getachew *et al*., 2002), then reducing the degradability of plant material.

In this study, EDDM of studied plant species may be ranked in three categories: Tree foliage (mean = 34%), shrubs and forbs (mean value >50%) and cacti and flowers, fruits and pods (mean value >64%). Plant species of the latter category showed the fastest ruminal digestion since the very beginning of forage degradation (fraction a; Dhanoa *et al*., 1999) and the fastest constant rate of degradation c that represents the rhythm of degradation (h^{-1} (%)) of the plants studied (Huntington and Givens, 1995). The constant rate of degradation c, is a key variable that not only describe the digestion process of feed nutrients in the rumen, but also the rate of degradation of the insoluble but slowly degraded fraction b (Mertens, 1993). Thus, they have good nutritional potential for range ruminants. Similar findings were reported by Ramirez *et al.* (2000b), these researchers mentioned that flowers, fruits and pods produced in rangelands at northeastern Mexico, when available, are prominent energetic foods for range goats.

CONCLUSION

Among all groups of plants studied, shrubs may be considered as prominent protein sources and forbs, cacti, flowers, fruits and pods as important energy foods for maintaining productivity of range goats growing in semiarid regions of North Mexico. Range managers should practice management techniques, which provide a diversity of plant species, allowing grazing ruminants the opportunity to select the highest quality diet available. Common brush management technique such as creating a vegetational mosaic using root plowing or shredding will open the canopy. This would allow an increase in native plant diversity and density, with its associated increase in nutritional value.

ACKNOWLEDGEMENT

Funds provided by CONACYT for a Ph.D. scholarship (201282) are widely recognized. Support provided by Ankom Technology, Inc (Macedon, NY. USA) is fully appreciated.

REFERENCES

Apori, S.O., F.B. Castro, W.J. Shand and E.R. Orskov, 1998. Chemical composition, *in sacco* degradation and *in vitro* gas production of some Ghanaian browse plants. Anim. Feed Sci. Technol., 76: 129-137. DOI: 10.1016/S0377-8401(98)00205-3. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T42-3V91.

Bhatta, R., A.K. Shinde, D.L. Verma, S.K. Sankhyan and S. Vaithiyanathan, 2004. Effect of supplementation containing Polyethylene Glycol (PEG)-6000 on intake, rumen fermentation pattern and growth in kids fed foliage of *Prosopis cineraria*. Small Rumin. Res., 52: 45-52. DOI: 10.1016/S0921-4488(03)00222-0. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TC5-49FR8BF-4.

Ben Salem, H., A. Nefzaoui and L. Ben Salem, 2002. Supplementation of *Acacia cyanophylla* Lindl. Foliage-based diets with barley or shrubs from arid areas (*Opuntia ficus-indica*, *F. inermis* and *Atriplex nummularia* L.) on growth and digestibility in lambs. Anim. Feed Sci. Technol., 96: 15-20. DOI: 10.1016/S0377-8401(01)00338-8. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T42-44KWMYC.

Broderick, G.A. and R.C. Cochran, 2000. *In vitro* and *in situ* Methods for Estimating Digestibility with Reference to Protein Degradability. In: Theodorou, M.K. and J. France (Eds). Feeding Systems and Feed Evaluation Models. CABI Publishing. Wallingford Oxon, UK, pp: 75-87. ISBN-13: 978-0851993461. http://www.cabi.org/bk_BookDisplay.asp?SubjectArea=Ani&Subject=Animal+Nutrition&PID=1449.

Cody, R.P. and J. Smith, 1997. Applied Statistics and the SAS Programming Language. 4th Edn. Prentice Hall, Upper Saddle River, New Jersey USA, pp: 445. ISBN: 978-0-13-146532-9. http://ftp.sas.com/samples/A55984.

Dhanoa, M.S., J. France, S. Lopez, J. Dijkstra, S.J. Lister, D.R. Davies and A. Bannik, 1999. Correcting the calculation of extent of degradation to account for applying the polyester bag method. J. Anim. Sci., 77: 3385-3391. http://jas.fass.org/cgi/reprint/77/12/3385.

Getachew, G., H.P.S. Makkar and K. Becker, 2002. Tropical browses: Contents of phenolic compounds, *in vitro* gas production and stoichiometric relationship between short chain fatty acid and *in vitro* gas production. J. Agric. Sci., 139: 341-352. DOI: 10.1017/S0021859602002460. http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=138079&fulltextType=RA&fileId=S0021859602002460.

Huntington, J.A. and D.I. Givens, 1995. The *in situ* Technique for Studying the Rumen Degradation of Feeds: A Review of the Procedure. Nutr. Abst. Rev. (Series B), 65: 63-93. http://www.fao.org/agris/search/display.do?f=./1996/v2212/GB9523583.xml;GB9523583.

Juarez, R.A.S., E.R. Montoya, C.G. Nevarez, S.M.A. Cerrillo and F.L. Mould, 2004. *In situ* degradability of dry matter and neutral-detergent fibre of thorn scrublands forage consumed by goats in the semi-arid region of North Mexico. Anim. Sci., 79: 505-511. http://www.bsas.org.uk/Publications/Animal_Science/2004/Volume_79_Part_3/505.

Jung, H.G. and M.D. Casler, 1991. Relationship of lignin and esterified phenolics to fermentation of smooth bromegrass fibre. Anim. Feed Sci. Technol., 32: 63-68. DOI: 10.1016/0377-8401(91)90010-P. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T42-49NRDR0-31.

Makkar, H.P.S., 2003. Effects and fate of tannins in ruminant animals, adaptation to tannins and strategies to overcome detrimental effects of feeding tannin-rich feeds. Small Rumin. Res., 49: 241-256. DOI: 10.1016/S0921-4488(03)00142-1. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TC5-48WB6YF-1.

Mertens, D.R., 1993. Rate and Extent of Digestion. Quantitative Aspects and Ruminant Digestion and Metabolism. In: Forbes, J.M. and J. France (Eds.). CAB International, Wallingford Oxon, UK, pp: 123. ISBN: 9780851998145. http://www.cabi.org/bk_BookDisplay. asp?PID=1868.

Ørskov, E.R. and W.J. Shand, 1997. Use of the nylon bag technique for protein and energy evaluation and for rumen environment studies in ruminants. Livest. Res. Rural Dev., 9: 1-10. http://www.cipav.org.co/lrrd/lrrd9/1/orskov.htm.

Papachristou, T.G. and A.S. Nastis, 1993. Nutritive value of diet selected by goats grazing on kermes oak shrublands with different shrub and herbage cover in northern Greece. Small Rumin. Res., 12: 35-44. DOI: 10.1016/0921-4488(93)90036-H. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TC5-49NY1JC-53.

Papachristou, T.G., 1997. Foraging behaviour of goats and sheep on Mediterranean kermes oak shrublands. Small Rumin. Res., 24: 85-93. DOI: 10.1016/S0921-4488(96)00942-X. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TC5-3RH0CHX-3.

Ramirez, L.R.G., A. Loyo, R. Mora, E.M. Sanchez and A. Chaire, 1991. Forage intake and nutrition of Range goats in a shrubland in northeastern Mexico. J. Anim. Sci., 69: 879-887. http://jas.fass.org/cgi/reprint/69/3/879. PMID: 1648070.

Ramirez, R.G., L.A. Hauad, R. Foroughbachkch, J. Moya-Rodriguez, 1998. Extent and rate of digestion of the dry matter in leaves of 10 native shrubs from Northeastern Mexico. FYTON. Int. J. Exp. Bot., 62: 175-180.

Ramirez-Lozano, R.G., G. Alanis-Flores and M.A. Nunez-Gonzalez, 2000a. Seasonal dynamics of dry matter digestion of *Opuntia cladodes*. Ciencia Uanl., 3: 267-273. http://w3.dsi.uanl.mx/publicaciones/ciencia-uanl/vol3/3.html.

Ramirez, R.G., R.R. Neira-Morales, R.A. Ledezma-Torres and C.A. Garibaldi-Gonzalez, 2000b. Ruminal digestion characteristics and effective degradability of cell wall of browse species from Northeastern Mexico. Small Rumin. Res., 36: 49-55. DOI: 10.1016/S0921-4488(99)00113-3. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TC5-3YJ9X7W.

Ramirez-Orduna, R., R.G. Ramirez-Lozano, M. Gomez-Meza, J.A. Armenta-Quintana, J.M. Ramirez-Orduna and R. Cepeda-Palacios, 2003. Seasonal dynamics of ruminal crude protein digestion of browse species from Baja California Sur, Mexico. Interciencia, 28: 408-414. http://www.scielo.org.ve/scielo.php?pid=S0378-18442003000700009&script=sci_arttext.

Ramirez, R.G. and M.A. Nunez-Gonzalez, 2006. Chemical composition, digestion and mineral content of native forbs consumed by range sheep. J. Anim. Vet. Adv., 5: 1158-1164. http://medwelljournals.com/new/5/detail.php?id=5&jid=java&theme=5&issueno=50&articleno=768#.

Riveros, F., 1992. The Genus Prosopis and its Potential to Improve Livestock Production in Arid and Semi Arid Regions. In: Speedy, A. and P. Pugliese (Eds). Legume Trees and Other Fodder Trees as Protein Sources for Livestock. FAO Animal Production and Health Paper 102. held at the Malaysian Agricultural Research and Development Institute (MARDI) in Kuala Lumpur, Malaysia, pp: 257-276. ISBN: 92-5-103203-3. http://www.fao.org/DOCREP/003/T0632E/T0632E00.htm#TOC.

Yousef, M. and Y. Rouzbehan, 2008. Characterization of *Quercus persica*, *Quercus infectoria* and *Quercus libani* as ruminant feeds. Anim. Feed Sci. Technol., 140: 78-89. DOI: 10.1016/j.anifeedsci.2007.02.009. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T42-4NCK298-2.