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Annual and seasonal variation in nutritive quality and ruminal fermentation patterns of diets in steers grazing native rangelands

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The objective of the study was to evaluate the annual and seasonal changes in the nutritive quality and ruminal fermentation patterns of diet consumed by grazing cattle. Diet samples were collected with four esophageal cannulated steers and four ruminally cannulated steers were used to evaluate the ruminal fermentation patterns. Data were analyzed with a repeated measurements design. No year x season interactions were observed for nutritive quality and ruminal fermentation ($p > 0.05$). However, the crude protein (CP), *in vitro* digestibility dry matter (IVDMD), Calcium (Ca), metabolizable energy (ME), ammonia nitrogen (NH_3N), volatile fatty acids (VFA) and propionate were higher in 2008 and wet season and lowest in 2006 and dry season ($p < 0.05$). Results confirm that the nutritive quality and ruminal fermentation patterns of diet selected for grazing cattle were affected by year and season and that protein an energy supplementation is necessary to improve productive performance of cattle under these management conditions.

Key words: Grazing cattle, diets, nutritive quality, ruminal fermentation.

INTRODUCTION

Native rangelands are the main forage resources for beef cattle production in north Mexico. However, rangelands in semiarid environments tend to vary greatly in quality and quantity, which subsequently affects diet composition and selectivity of grazing cattle (Obeidat et al., 2002). Some studies report that, as a result of drastic climate change, animals in the northern region of México have periods of 90 to 100 days of favorable grazing conditions and if the number of days is reduced, the survival of these animals may be in jeopardy (Navarro et al., 2002). Cattle grazing native rangelands may require nutrient supplementation to optimize their performance. Evaluation of nutritive quality of the diet selected by grazing cattle across seasons is essential to make strategic supplementation management practices. However, these evaluations may be complemented with additional studies to more precisely establish dietary supplementation needs. Although the nutritive quality of the diet in grazing cattle is widely known, there is very little information about ruminal fermentation of the diet consumed by grazing cattle in native rangelands. pH of ruminal contents can influence fiber digestion (Mehrez et al., 1977), microbial protein synthesis (Russell et al., 1992) and finally, post-ruminal supply of energy and protein for the grazing

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cattle. Consequently, understanding the impacts of advancing season on nutrient supply, will aid in developing improved supplementation strategies. Therefore, information concerning seasonal changes in nutritive quality diet when coupled with estimates of ruminal fermentation provides a foundation for supplementation practices and sound nutritional programs. We hypothesized that quality nutritive and ruminal fermentation of diet consumed by grazing cattle are affected by seasonal changes. Objectives for this study were to evaluate diets consumed by grazing cattle across seasons for four years on nutritive quality and ruminal fermentation.

MATERIALS AND METHODS

Study area

The study was carried out over four years (2005, 2006, 2008, 2009) in a medium grassland located at the east of the city of Durango, Mexico (24° 22' N, 104° 32' W), at an altitude of about 1938 m above sea, which has a dry temperate (BS_1k) climate with average annual temperature and rainfall of 17.5°C and 450 mm, respectively. The study area covers 2,000 ha (6 ha/AU) with an average of forage biomass of 1,796 kg DM ha^{-1}. During the four years of the study, the vegetation cover was estimated using minimum area sampling with nested points (Bonham, 1989). Dominant grass species included: *Melinis repens* Willd (rose natal grass), *Chloris virgata* (feather fingergrass), *Bouteloua gracilis* (blue grama), *Aristida adscensionis* (six weeks threeawn) and *Andropogon barbinodis* (cane bluestem); bushes: *Acacia tortuosa* (poponax), *Prosopis juliflora* (mezquite), *Opuntia spp* (prickly pears and chollas), *Mimosa biuncifera* (cat claw); plus a wide variety of annual herbs. The pasture had not been grazed by previous four years and forage availability was never limiting during any of the sampling periods.

Animals and experimental periods

During the four years of study, twelve sampling periods, each 6 d long were conducted: January, February, March, April, May and June were considered to be dry season and July, August, September, October, November and December as wet season. During each sampling period, four steers Angus with esophageal cannulae of 350 ± 3 kg BW initial and 18 months age and four steer Angus cannulated of the rumen of 406 ± 5 kg BW initial and 20 months age were allowed to graze freely the study pasture. Surgery was performed on the steers according to procedures approved by the University of Durango Laboratory Care Advisory Committee. At end of the first two years study (2005, 2006), the steers with esophageal cannulae were replaced by others of same breed and body weight.

Nutritive quality

Diet samples were collected with the esophageal cannulated steers, during the first 4 days of each sampling period. Collections were made at 07. 00 h when steers were grazing most intensely. Steers were fitted with screen wire bottom collection bags and allowed to graze for 30 to 45 min periods. The samples from each steer were drained through 40 mm screen to remove saliva. Subsequently, samples (300 g) were thawed and pooled across the 4 d collection period for each animal (Holechek et al., 1982). The samples dried at 60°C for 48 h and later ground through a 1 mm screen in a Wiley mill. The esophageal samples were used for the determination of nutritive quality and mineral contents. Dry matter (DM), CP, (AOAC, 2005), Neutral Detergent Fiber (NDF) (Van Soest et al., 1991) and *in vitro* dry matter digestibility (ANKOM, 2008) were determined. We estimated ME content with the formulas used by Waterman et al. (2007): digestible energy (DE; Mcal/kg) = [0.039 x (OMD %)] – 0.10; ME (Mcal(kg) = DE (Mcal/kg) x 0.82. Where: OMD is the organic matter degradability obtained after 48 h incubation in the rumen. A subsample was incinerated in a muffle oven at 600°C during 5 h. The ashes obtained were digested in a solution $HCl\text{-}HNO_3$ and concentrations of Ca was determined by atomic absorption spectrophotometry; whereas, P content was quantified by ultraviolet-visible spectrophotometry (Cherney, 2000).

Ruminal fermentation

At 1200 h on days 5 and 6 of each sampling, ruminal liquid samples were extracted from the rumen of cannulated steers. Approximately 100 ml of whole ruminal liquid was extracted from the middle and ventral rumen each steers and the pH measured immediately with a combination electrode. The collected ruminal content was strained through four layers of cheesecloth and divided into two subsamples. The first subsample (10 ml) was acidified with 0.3 ml of 50% H_2SO_4 and frozen immediately at -40°C. After sample ruminal were thawed at room temperature and centrifuged at 10,000 x g for 10 min. Supernatant fluid was analyzed for NH_3N by phenol-hypoclorite procedure (Broderick and Kang, 1980) using ultraviolet spectrophotometer (Spectronic Genesys 2GP); the second subsample, (10 ml) was acidified with 2.5 ml of 25% metaphosporic acid and frozen at -40°C for later VFA analysis by gas chromatography (Autosystem XL, Perkin Elmer) (Galyean, 1997).

Statistical analyses

Data were analyzed as a repeated measurements design using MIXED procedure of SAS (2003). The model included effects for year, season and their interactions. Month was included as repeated effect, and animal within year x season was the subject for analysis. The variation between animals was specified by the RANDOM statement as animal within year x season. Individual animal was the experimental unit in all analyses. Least squares means and standard error of mean (SEM) were calculated and statistically separated by the PDIFF options of SAS (2003). Autoregressive Order 1 was used as the covariance structure, because it was better fitting structure, based on comparison of covariance structures with Akaike and Bayesian information criterions (Littell et al., 2006).

RESULTS

Climatic conditions

In this study, seasonal rainfall and mean air temperature that were recorded in the land meteorological stations located in study area are shown for reference in Table 1. Rainfall in 2008 was 793.2 mm and 2006 was drier than normal with 238.0 mm.

Table 1. Monthly mean temperature (oC) and accumulated rainfall (RF; mm) registered in the study area.

Month	2005		2006		2008		2009	
	T (°C)	RF (mm)	T (°C)	RF (mm)	T (°C)	RF (mm)	T (°C)	RF (mm)
January	13.0	22.9	13.3	1.6	9.3	0.8	13.1	0.0
February	16.2	3.1	13.7	1.3	12.0	0.6	14.7	0.0
March	17.9	2.2	15.1	0.7	12.8	0.0	16.8	0.4
April	22.5	0.2	20.9	0.0	18.3	1.4	18.8	0.0
May	23.0	18.8	22.3	0.5	20.4	3.2	21.3	12.8
June	22.2	67.6	25.2	5.4	24.1	56.4	22.0	51.8
July	21.3	68.1	22.2	96.8	21.3	273.0	21.6	64.8
August	20.2	161.1	20.8	66.4	20.5	291.0	20.8	116.4
September	19.9	47.5	21.0	61.0	18.3	150.0	18.6	254.3
October	18.2	48.1	20.8	2.1	15.6	16.8	17.1	33.4
November	14.9	0.1	15.5	2.2	11.7	0.0	12.5	5.2
December	11.6	15.4	13.1	0.0	9.9	0.0	10.7	6.2
Total	18.4	455.1	18.6	238.0	16.1	793.2	17.3	545.3

Table 2. Nutritive quality of the diet consumed by grazing steers.

Year (Y)	CP% DM	NDF	DIVMS	ME (Mcal kg^{-1})	Ca (g Kg DM^{-1})	P
2005	8.9^{c}	75.6^{b}	64.2^{c}	1.5^{c}	5.2^{c}	1.2^{c}
2006	6.3^{d}	78.5^{a}	60.1^{d}	1.2^{d}	4.8^{d}	0.91^{d}
2008	12.7^{a}	69.9^{d}	70.1^{a}	2.3^{a}	6.8^{a}	1.6^{a}
2009	9.6^{b}	70.9^{c}	67.2^{b}	1.9^{b}	5.5^{b}	1.4^{b}
SEM	2.1	2.2	1.1	1.4	1.1	0.42
Season (S)						
Wet	12.1^{a}	68.2^{b}	66.1^{a}	2.2^{a}	6.2^{a}	1.3^{a}
Dry	5.8^{b}	74.3^{a}	57.3^{b}	1.9^{b}	4.7^{b}	0.97^{b}
SEM	1.3	1.8	2.4	1.2	1.6	0.58
Effects	P<	P<	P<	P<	P<	P<
Y	**	**	**	**	**	**
S	**	**	**	**	**	**
Y*S	NS	NS	NS	NS	NS	NS

[abcd]Means within a column with different superscripts differ **(P < 0.01). SEM: Standard Error Mean.

Nutritive quality

No year x season interactions ($p > 0.05$) were observed for CP, NDF, IVDMD and ME values (Table 2). However, the CP, NDF, IVDMD and ME, values were different among years ($p < 0.01$) and seasons ($p < 0.01$). The CP, IVDMD and ME, content, were higher in 2008 and lowest in 2005, 2006 and 2009 ($p < 0.01$). The CP, IVDMD and ME, values were greater in wet season as compared to dry season ($p < 0.01$); while NDF content was higher in dry season as compared to wet season ($p < 0.01$). Both year and season had a significant ($p < 0.01$) effect on the contents of Ca and P. There was no interaction of years and seasons ($p > 0.5$). The Ca and P contents were greater in 2008 versus 2005, 2006 and 2009 ($p < 0.01$); while Ca and P contents was higher in wet season as compared to dry season ($p < 0.01$).

Ruminal fermentation

The ruminal fermentation patterns are shown in Table 3. The pH value was lower in wet season as compared to dry season ($p < 0.05$). The ruminal NH_3N concentration

Table 3. Ruminal fermentation patterns of the diet consumed by grazing steers pH NH3N VFA Acetate Propionate Butyrate mg dL-1 mM L-1 mol 100 moles-1.

Year (Y)						
2005	6.8^{a}	5.2^{c}	91.3^{c}	66.6^{b}	12.1^{c}	7.8^{a}
2006	6.7^{a}	4.0^{d}	87.4^{d}	68.0^{a}	11.5^{d}	8.2^{a}
2008	6.5^{a}	12.7^{a}	103.1^{a}	61.8^{d}	18.3^{a}	5.3^{c}
2009	6.7^{a}	10.9^{b}	98.7^{b}	63.6^{c}	15.3^{b}	6.0^{b}
SEM	0.1	0.5^{8}	2.6	1.5	1.1	2.7
Season (S)						
Wet	6.4^{b}	11.9^{a}	101.0^{a}	62.5^{b}	15.8^{a}	4.6^{b}
Dry	6.7^{a}	4.7^{b}	89.3^{b}	65.7^{a}	12.8^{b}	6.8^{a}
SEM	0.72	0.83	2.6	1.3	2.6	2.2
Effects	P<	P<	P<	P<	P<	P<
Y	NS	**	**	**	**	**
S	*	**	**	**	**	**
Y*S	NS	NS	NS	NS	NS	NS

[abcd]Means within a column with different superscripts differ **(P < 0.01). SEM: Standard Error Mean.

was greater in 2008 versus 2005, 2006 and 2009 ($p < 0.01$); whereas NH_3N concentration was higher in wet season ($p < 0.01$). Volatile fatty acids concentrations were affected by years and seasons ($p < 0.05$). Both year and season had effect ($p < 0.01$) on the acetate, propionate and butyrate ruminal concentrations. Acetate concentration was greater in 2006 than 2005, 2008 and 2009 ($p < 0.01$) and lowest during wet season. The propionate concentration was greater in 2008 than 2005, 2006 and 2009 ($p < 0.01$). The highest propionate concentration was observed in wet season and the lowest in dry season ($p < 0.01$). Butyrate concentration was greater in 2006 than 2005, 2008 and 2009 ($p < 0.01$). The highest butyrate concentration was obtained in dry season and the lowest in wet season ($p < 0.01$).

DISCUSSION

Nutritive quality

The differences observed in chemical composition of diets may be induced by registered rainfall in the four years of study (Cline et al., 2009). Seasonal variations in diet quality are attributed to corresponding variations in the chemical composition of forages utilized by grazing ruminants (Van Soest, 1994). During the wet season, diet consumed by grazing cattle normally meeting nutritional requirements because plants are actively growing and have access to succulent leafy green forage (Minson, 1990). An 8% CP level is considered as an adequate forage quality for grazing ruminant (NRC, 2000). The low CP value found in the present study in 2006, and dry season is insufficient for meeting the minimum requirements of degradable protein for grazing ruminants (Kearl, 1982). Therefore, except for 2006 and dry season, the CP content can be considered to be adequate nutritive quality for grazing cattle. Nevertheless, a minimum of 12% CP is required for growing and finishing cattle (NRC, 2000). In the present study, all the values of CP among years and seasons, resulted in CP below this recommended value. According to Paterson et al. (1996) feedstuffs with CP content lower than 7% require a supplementation of nitrogen to improve their intake and digestion by the ruminant. The NDF content was 10.9% higher in 2006 than in 2008, while IVDMD was 16.6% lower in 2006 as compared to 2008. Increasing fiber content across the growing season has been observed by Johnson et al. (1998). In addition, similar responses have been attributed to increased plant maturity by other researchers (Brokaw et al., 2001).

Normally, advancing maturity is associated with increased cell wall constituents (Van Soest, 1982). The value obtained of ME in 2005, 2006, 2009 and dry season indicated that the energy requirements for maintenance of growing beef cattle (2.0 Mcal/Kg DM; NRC, 2000) would not be satisfied. Gutiérrez (1982), using similar methods of sample collection as employed in the present study, found that during the wet season increased CP, IVDMD and ME compared with dry season and attributing the differences to the phenology of rangelands plants. With the exception of P, the diet consumed for cattle throughout the years and seasons had appropriate amounts of Ca to meet requirements of beef cattle grazing native rangelands (2.3 g of P/ Kg DM and 4.6 g of Ca/Kg DM for beef cattle; McDowell (2003). Under conditions similar to those of our study, Arthington and Swenson (2004) found differences between seasons in contents of Ca and P. According to McDowell (1997) and Haenlein and Ramirez (2007) these differences in the mineral content of diets may be attributed to the interaction of a number of factors including soil, plant species, yield, pasture management, climate (temperature and rainfall) and stages of maturity. A sizable amount on the total Ca is associated with the NDF fraction (Van Soest, 1994). The association of certain minerals with fiber or other insoluble plant components could also decrease the rate and extent of mineral release from forages in the ruminant gastrointestinal tract (Van Soest, 1992).

Ruminal fermentation

Differences in ruminal pH were observed among season and similar pH values have been reported in grazing cattle (Gunter et al., 1993). The pH values below 6.2 can reduce ruminal digestion fiber (Orskov, 1982). Therefore, the ruminal pH observed during all years and seasons in this study, can be regarded as appropriate for fiber digestion and cellulolytic bacterial growth. Similar results to this study with respect to ruminal NH_3N concentrations in grazing cattle were reported by Choat et al. (2003). Other researchers have observed decreases in ruminal NH_3N concentrations when diet CP content decreases with advancing rangelands maturity (McCracken, 1993; Park et al., 1994). The suggested concentration of ruminal NH_3N for microbial growth is 5 mg/dl (Satter and Slyter, 1974) and 1 to 2 mg/dl for degradation fiber (Petersen, 1987). In this study, with the exception of 2006 and dry season, the diet consumed for cattle allowed appropriate concentrations of NH_3N to meet requirements of microorganisms that inhabiting in the rumen. These findings for acetate, propionate and VFA are in general agreement with other reports for grazing cattle (Funk et al., 1987; Krysl et al., 1987). Decreases in total ruminal VFA concentrations with advancing of the season have been reported by Adams et al. (1987).

Acetate is considered to be reflective of cell wall fermentation and increased acetate levels are normally associated with declining forage quality (Branine and Galyean, 1994); while the propionate concentration is associated with soluble carbohydrate ruminal fermentation during periods of active rangelands growth (Van Soest, 1994). Acetate is a necessary component for the formation of milk fat, whereas propionate is used for glucose production through hepatic gluconeogenesis and is needed for synthesis of milk lactose (Bergman, 1990). In this study, a low molar concentration of acetate and high molar concentration of propionate observed in wet season suggested the supply of glucogenic precursor in the rumen for glucose production in the grazing cattle. McCollum et al. (1985) reported somewhat low the butyrate concentration in steers grazing during the wet season than in this study. However, higher butyrate levels generally are associated with ruminant consuming actively growing rangelands (Langlands and Sanson 1976).

Conclusion

Our results allow us to conclude that nutritive quality and ruminal fermentation of diet selected for grazing cattle were affected by annual and seasonal weather changes. Rainfall and temperature influenced nutritive quality and ruminal fermentation patterns. The drought induced by low rainfall, results in decreased diet nutritive quality because of the decrease of CP and increase of NDF. These changes were accompanied by decrease in the ammonia nitrogen and volatile fatty acids concentrations. A significant decreased in nutritive quality and ruminal fermentation patterns of diet consumed cattle were observed during the dry season. Therefore, the protein and energy supplementation as well as P might be beneficial for grazing cattle during this season to improve their productive and reproductive performance since these nutrients are related to the secretion of reproductive hormones (LTH, Leptin) and metabolites (glucose, urea-N, non-esterified fatty acids).

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REFERENCES

Adams DC, Cohran RC, Currie PO (1987). Forage maturity effects on rumen fermentation, fluid flow and intake in grazing steers. J. Range. Manage. 40(6):404-408.

ANKOM (2008). Procedures for fiber and *in vitro* analysis.

AOAC (2005). Official Methods of Analysis, AOAC International. 18th Edn., Association of Official Analytical Chemist, Washington DC., USA., pp. 212-220.

Arthington JD, Swenson CK (2004). Effects of trace mineral source and feeding method on the productivity of grazing Braford cows. Prof. Anim. Sci. 20(2):155-161.

Bergman EN (1990). Energy contribution of volatile fatty acids from the gastrointestinal tract in various species. Physiol. Rev. 70(2):567-590.

Bonham CHD (1989). Measurements for terrestrial vegetation, John Wiley and Son, P. 91.

Branine ME, Galyean ML (1990). Influence of grain and monensin supplementation on ruminal fermentation, intake digesta kinetics and incidence and severity of frothy bloat in steers grazing winter wheat pastures. J. Anim. Sci. 68(4):1139-1150.

Broderick GA, Kang JH (1980). Automated simultaneous determinations of ammonia and total amino acids in ruminal fluid and *in vitro* media. J. Dairy Sci. 63(1):64-45.

Brokaw L, Hess BW, Rule DC (2001). Supplemental soybean oil or corn for beef heifers grazing summers pasture: Effects on forage intake, ruminal fermentation and site and extent of digestion. J. Anim. Sci. 79(8):2704-2712.

Cherney DJR (2000). Characterization of Forages by Chemical

Analysis. In: Axford RFE, Omed HM (eds) Forage Evaluation in Ruminant Nutrition, Wallingford: CAB Publishing. pp. 275-300.
Choat WT, Krehbiel CR, Duff GC, Kirksey RE, Lauriault LM, Rivera JD (2003). Influence of grazing dormant native range or winter pasture on subsequent finishing cattle performance, carcass characteristics and ruminal metabolism. J. Anim. Sci. 81(12):3191-3201.
Cline HJ, Neville BW, Lardy GP, Caton JS (2009). Influence of advancing season on dietary composition, intake, site of digestion and microbial efficiency in beef steers grazing a native range in western North Dakota. J. Anim. Sci. 87(1):375-383.
Funk MA, Galyean ML, Branine ME, Krysl LJ (1987). Steers grazing blue grama rangeland and throughout the growing season. I. Dietary composition, intake, digesta kinetic and ruminal fermentation. J. Anim. Sci. 65(5):1342-1348.
Galyean ML (1997). Laboratory Procedures in Animal Nutrition Research, Texas Tech University, 77 pp. Available from: http://www.app.depts.ttu.edu (Accessed 17 June, 2012).
Gunter SA, McCollum FT, Gillen RL, Krysl LJ (1993). Forage intake and digestion by cattle grazing midgrass praire rangelands or sideoats grama/sweetclover pasture. J. Anim. Sci. 71(12):3432-3441.
Gutiérrez JL (1982). Nutritive value of diets selected by grazing cattle in Northwest Chihuahua. PhD. Thesis, New Mexico State University. USA.
Haenlein GJW, Ramirez RG (2007). Potential mineral deficiencies on arid rangelands for small ruminants with special reference to Mexico. Small Rumin. Res. 68(1):35-41.
Holechek JL, Vavra M, Pieper RD (1982). Methods for determining the nutritive quality of range management diets: a review. J. Anim. Sci. 54(2):363-376.
Johnson JA, Caton JS, Poland W, Kirby DR, Dhuyvetter DV (1998). Influence of season in dietary composition. Intake and digestion by beef steers grazing mixed-grass prairie in the northern Great Plains. J. Anim. Sci. 76(6):1682-1690.
Kearl LC (1982). Nutrient requirements of ruminants in developing countries. Agricola Experimental Station, Utha State University, Logan, Utha, USA. P. 11.
Krysl LJ, Galyean ML, Judkins MB, Branine ME, Estell RE (1987). Digestive physiology of steers grazing fertilized and nonfertilized blue grama rangeland. J. Range Manage. 40(6):493-501.
Langlands JP, Sanson J (1976). Factors affecting the nutritive value of the diet and composition of rumen fluid grazing sheep and cattle. Aust. J. Agric. Res. 27(5):691-698.
Littell RC, Milliken GA, Stroup WW, Wlfinger RD, Schanberger O (2006). SAS for Mixed Models (2nd Edn), SAS Institute, Care, NC. P. 42.
McCollum FT, Galyean ML, Krysl LJ, Wallace JD (1985). Cattle grazing blue grama rangeland. I. Seasonal diets and rumen fermentation. J. Range Manage. 38(6):539-542.
McCracken BA, Krysl LJ, Park KK, Holcombe DW, Judkins MB (1993). Steers grazing endophyte-free tall fescue: Seasonal changes in nutrient quality forage intake. digesta kinetics, ruminal fermentation and serum hormones and metabolites. J. Anim. Sci. 71(6):1588-1595.
McDowell LR (1997). Feeding minerals to cattle on pasture. Anim. Feed Sci. Technol. 60(3-4):247-271.
McDowell LR (2003). Mineral in Animal and Human Nutrition, 2th Edn, Elsevier Science. P. 103.
Mehrez AZ, Orskov ER, McDonald I (1977). Rates of rumen fermentation in relation to ammonia concentration. Brit. J. Nutr. 38(3):437-441.
Minson DJ (1990). The chemical composition and nutritive values of tropical grasses. In: Skerman PJ, Riveros F. (eds.) Tropical Grasses, Rome FAO, pp. 163-180.
Navarro JN, Galt D, Holechek J, McCormick J, Molinar F (2002). Long-term impacts of livestock grazing on Chihuahua desert rangelands. J. Range Manage. 55(4):400-405.
NRC (2000). Nutrient Requirements of Beef Cattle (7th ed). National Academic Press, Washington D.C., USA.
Obeidat BS, Thomas MG, Hallford DM, Keisler DH, Petersen MK, Bryant WD, Garcia MD, Narro L, Lopez R (2002). Metabolic characteristics of multiparous Angus and Brahman cows grazing in the Chihuahua Desert. J. Anim. Sci. 80(9):2223-2233.
Orskov ER (1982). Protein Nutrition in Ruminants, Academic Press, London. 38 P.
Park KK, Krysl LJ, McCracken BA, Judkins MB, Holcombe W (1994). Steers grazing intermediate wheatgrass at various stages of maturity: Effects on nutrient quality, forage intake, digesta kinetics, ruminal fermentation and serum hormones and metabolites. J. Anim. Sci. 72(2):478-486.
Paterson J, Cohran R, Klopfenstein T (1996). Degradable and undegradable protein response of cattle consuming forage-based diets. In: Proceedings of the Western Section American Society Animal Science. P. 103.
Petersen MK (1987). Nitrogen supplementation of grazing livestock. In: Proceedings of the Grazing Livestock. University of Wyoming. P. 115.
Russell JB, O`Connor JD, Fox DG, Van Soest PJ, Sniffen CJ (1992). A net carbohydrate and protein system for evaluating cattle diets: I. Ruminal fermentation. J. Anim. Sci. 70(11):3551-3561.
SAS (2003). SAS/STAT Users Guide. Version 9.1, SAS Institute Inc., Cary, N.C., USA.
Satter LD, Slyter LL (1974). Effect of ammonia concentration on rumen microbial protein production *in vitro*. Brit. J. Nutr. 32(1):199-208.
Van Soest PJ (1982). Nutritional Ecology of the Ruminant, Corvallis, O and Books. 182 P.
Van Soest PJ (1994). Nutritional Ecology of the Ruminant, 2nd Edn, Corvallis, O and Books. P. 92.
Van Soest PJ, Robertson JB, Lewis BA (1991). Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74(10):3583-3597.
Waterman RC, Grings EE, Geary TW, Roberts AL, Alexander LJ, MacNeil MD (2007). Influence of seasonal forage quality on glucose kinetics of young beef cows. J. Anim. Sci. 85(10):2582-2595.