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Performance of beef cattle grazing oats supplemented with energy, escape protein or high quality hay

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Abstract

The objective was to evaluate the effect of supplementing with energy and energy–escape protein concentrates or hay, on animal productivity, rumen and blood parameters of cattle grazing oats pasture (OP). Two experiments (Exp 1 and Exp 2) were conducted in two consecutive years, with Aberdeen Angus heifers grazing continuously OP. In Exp 1, 24 heifers (204 kg initial-weight) were grazing 55 days. The treatments were: unsupplemented control (CON1), or 2 kg per animal per day of ground corn (CORN1), or 75% ground corn + 25% corn gluten meal (C-GM). In Exp 1 herbage mass of OP decreased from 1777 to 1209 kg dry matter (DM)/ha from July to September. The DM concentration averaged 296 g/kg of fresh OP, and crude protein (CP) was below 100 g/kg DM; initially NPN was 47% of CP, decreasing later. Ca increased with time from 3.5 to 6.0 g/kg DM, the other minerals were not affected by date. The ratio K/(Ca + Mg) was high on July (3.80 meq/kg DM) and decreased in August to September (2.73 and 1.94, respectively). Average daily gain (ADG) averaged 921 g per day for C-GM versus 670, 759 for CON and CORN1, respectively. A non-significant decrease in rumen pH was detected for CORN1 (mean of 6.26). Rumen NH_3-N was not affected by treatment, being the highest value 4.44 mg/dl in September ($P < 0.05$). Plasma levels of Ca and Na were normal and not affected by treatment or date; Mg and K showed higher levels for CORN1 and C-GM versus CON1, K and P increased with date ($P < 0.05$). In Exp 2, 36 heifers (192 kg-initial weight) were grazing OP during 140 days. Treatments in Exp 2 were: unsupplemented control (CON2), ground corn (CORN2) and alfalfa hay (AH). The animals did not

Abbreviations: OP, oats pasture; d, days; ADG, average daily gain; NPN, non-protein N; NH_3-N, rumen ammonia nitrogen; Exp 1 and Exp 2, experiments 1 and 2; CON1, control-Exp 1; CORN1, ground corn; C-GM, corn + corn gluten meal; CON2, control-Exp 2; CORN2, ground corn-Exp 2; AH, alfalfa hay

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reach the targeted intake level for supplements. Thus, daily intakes resulted 1.57 and 1.06 kg per animal for CORN2 and AH. In Exp 2, herbage mass was 1600–1700 kg/ha in May to September, decreasing in October. The lowest DM content was 20 g/kg of fresh OP in May to June, increasing in July. Initial CP was the highest (164 g/kg DM), it dropped in July increasing again in October; NPN content was 28% of CP in May, decreasing in October. Ca content raised from 3.6 g/kg DM in May to 6.0 g/kg DM in October. K decreased but Mg, P and Na have not changed their concentrations with time. The ratio K/(Ca + Mg) for OP was highest on May (6.23 meq/100 g DM), decreasing in October. ADG for CORN was 872 g, higher ($P < 0.05$) than 718 g (CON2) or 781 g (AH). No differences were found for ruminal pH (mean = 6.8); but for ruminal NH_3-N the highest value was for AH (3.35 mg/dl), also varying with sampling date ($P < 0.05$). Plasma levels of Ca and K decreased with time, being in July 8.76 and 19.22 mg/dl, respectively ($P < 0.05$). Mg was not affected by either treatment or sampling date, P was higher for CORN2 = 7.91 mg/dl. Na levels were larger for CON2 and AH than for CON2, with 272, 282 and 256 mg/dl, respectively ($P < 0.05$). Animal performance was improved by both energy and escape protein supplementation. However, treatments did not appear to modify to a great extent ruminal fermentation patterns or have any effect on blood mineral levels.
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Keywords: Oats pasture; Supplementation; Cattle; Weight gain; Rumen parameters; Plasma minerals

1. Introduction

Oat pastures (OP) are grazed by ruminants, particularly beef and dairy cattle in semiarid and subhumid Argentina. The grazing season runs from late fall until early spring (May, June, July, August and September in the southern hemisphere). Growing beef steers and heifers frequently graze winter annuals such as OP. Oat cropping is widespread because of simple cultivation procedure, rapid development, and high DM yield with proper management. Grazing of oats is also a common practice in other countries (Wheeler, 1981). An average daily gain of about 700 g is commonly expected for beef cattle grazing oats (Wheeler, 1981; Rosso and de Verde, 1992). However, regionally, many producers frequently find lower gains in cattle grazing oats at early maturity stages.

Fresh grasses usually exhibit low carbohydrate availability and high N content. At early maturity stages, a large proportion of this protein is non-protein N. Some research suggests that a low ratio of soluble carbohydrates to available N reduces the efficiency of N utilization by the ruminant (Hogan and Weston, 1969; Beever, 1984; Elizalde and Santini, 1992). Besides energy:protein relationship, marginal mineral content can also limit productivity. Thus, Ca and Mg content in small grain forages affected performance and health in pregnant or lactating cows (Grunes et al., 1984). Under certain conditions, these forages may also be Ca and Mg deficient for rapidly growing heifers or steers.

Appropriate supplementation programs should reduce variability and improve overall performance of cattle grazing OP. Hays are commonly fed to beef cattle grazing OP regardless their quality. Producers believe that feeding hay would increase total DM intake for cattle grazing lush pastures. However, low quality and fibrous supplement would affect total nutrient intake, and may actually reduce total energy intake because critical rumen distention would be reached at lower intakes with fibrous foods. Therefore, supplemental feed quality and type of supplement should affect productivity of beef cattle grazing fresh oat pasture. We studied the effect of supplementing with hay, energy or energy–escape protein concentrates on animal productivity, and rumen and blood parameters of cattle grazing OP in two consecutive years.

2. Materials and methods

Two experiments (Exp 1 and Exp 2) were conducted in 1992 and 1993 at Coronel Suarez Experimental Station at Pasman, Buenos Aires Province, Argentina (37°13′S, 62°11′W). Mean temperatures and precipitation of the months of May, June, July, August, September and October for both years as well as historical data was collected.

2.1. Pastures

Similar cultivation practices were used to establish OP for both experiments. *Avena sativa* cv. *suregrain* was planted on March 1992 and *Avena sativa* cv. *cristal* in 1993. Dry matter (DM) availability was determined on 27 July, 11 August and 27 September for Exp 1, and 17 May, 15 June, 13 July, 9 August, 6 September and 4 October for Exp 2. A 0.25-m^2 quadrate was randomly thrown across each paddock at 15 sites per date. The plants were hand-clipped to 8 cm height and the resulting samples were dried in a forced-air oven at 60 °C for 72 h, then, composited by date and ground to pass a 1 mm screen and saved for chemical analysis.

The samples were analyzed for DM, total crude protein (CP = g N/100 g DM × 6.25), NPN (by subtracting true protein from total CP) using macroKjeldahl N analysis and ash content (AOAC, 1984); NDF and ADF (Goering and Van Soest, 1970). The minerals Ca, Mg, Na and K were acid extracted from forage samples by wet digestion (AOAC, 1984) and determined via plasma emission spectrophotometry (ICPS Shimadzu model 1000III). The K/(Ca + Mg) ratio expressed in meq/100 g DM was calculated in the OP samples, to study the relationship with Mg blood levels (Kemp and t'Hart, 1957).

2.2. Experiment 1

2.2.1. Treatments and management

Twenty four Aberdeen Angus heifers (204 kg initial body weight) grazed OP continuously during 55 days. The animals received energy and energy–escape protein concentrates as supplemental treatments. The heifers grouped by weight were randomly assigned to one of these treatments: (1) control (CON1), no supplement; (2) ground corn (*Zea mays*, CORN1) and (3) mixture of 75% ground corn + 25% corn gluten meal (C-GM). This allocation kept animal weight similar among supplemental treatments.

The feed ingredients were ground and pelleted in a commercial feed mill. The pellets were 6 mm diameter. Supplements were fed at 09:00 h at a rate of 2 kg as fed per animal daily. The animals achieved the required intake levels rapidly. Both supplements were supplied in bunk feeders placed near the water supply facility in the corresponding grazing paddock. Chemical composition of supplements was determined by using the same procedures as for OP.

There were three grazing paddocks (one per treatment) of about 4 ha each, isolated from the others by electric fencing. The three groups of animals with their corresponding treatments were rotated among paddocks every 10 days. This was done in attempt to remove any variations in DM availability and quality that would occur from potential differences in grazing behaviour, plant growth or micro-environmental conditions. At the beginning of the trial, all animals were treated with Ivermectin to prevent parasite infections.

2.2.2. Animal measurements

Unshrunk initial and final body weights were recorded at 09:00 h. Samples of ruminal liquor and blood were obtained at 10:00 h from six randomly selected animals in each treatment. The same animals were sampled at each period. The sampling dates were: 18 August and 9 September. Ruminal fluid was obtained by applying vacuum to an esophageal tube fitted with a suction strainer and attached to a 500 ml flask. It was immediately filtered through four layers of cheesecloth and the pH was determined. To stop microbial activity, 50 ml of filtered fluid was acidified with 2 ml of a 6N HCl solution (Merchen et al., 1986). The samples were frozen until analyzed for NH_3-N content, by phenyl–hypochlorite method (Broderick and Kang, 1980). Blood was collected via jugular venipuncture from the same animals sampled for ruminal liquid at 10:00 h. The samples were allowed to clot at room temperature for 30 min, before centrifugation at $2300 \times g$ for 15 min, and plasma was separated and frozen for mineral analysis. Blood plasma was analyzed for Ca, Mg, P, Na and K via plasma emission spectrophotometry (ICPS Shimadzu model 1000III).

2.3. Experiment 2

2.3.1. Treatments and management

In this experiment, the supplemental treatments were pelleted corn or high quality alfalfa hay (AH) with heifers grazing OP. Thirty Aberdeen Angus heifers with an average initial weight of 192 kg grazed OP during 140 days. The animals were assigned to one of these treatments: (1) control (CON2), no supplement; (2) ground corn (CORN2) and (3) alfalfa hay. The management and grazing practices of the animals were similar to those of previous experiment. Each paddock of about 4.5 ha was randomly assigned to each treatment, and the treatments were rotated among the paddocks every 10 days. DM availability of OP and chemical analysis were also analyzed following the same procedures as for Exp 1.

The supplement CORN2 was ground and pelleted corn grain as indicated in Exp 1. The supplement AH was alfalfa hay made in early vegetative stage. Then, AH bales were placed as long hay into feeders. Both supplements were offered on a daily basis at 09:00 h, at rate of 2 kg as fed per animal. Supplement intake for treatment groups was observed three times during the trial for 5 days, starting on 31 May, 29 June and 23 August. The chemical analysis performed for supplements were the same as for Exp 1.

2.3.2. Animal measurements

Unshrunk initial and final body weights were recorded at 09:00 h before grazing. Samples of ruminal liquor and blood were obtained at 10:00 h from three randomly selected animals in each treatment. The sampling dates were: 26 May, 7 July, 18 August and 15 September;

the same procedures and analytical determinations described in Exp 1 were used for ruminal and blood samples, a determination of plasma P-content was also included.

2.4. Statistical analysis

Analysis of variance procedures for a completely randomized design were performed using the GLM procedure of SAS (1985), for both Exp 1 and Exp 2. For ADG data analysis of variance was performed and the effect of treatment were tested by using the residual error. Least square means were reported and *t*-test was used as the mean separation procedure. The model for rumen and blood data set included treatment, sampling date and the interaction; these effects were tested with the residual error. Least square means were compared using a *t*-test.

3. Results

Total rainfall from May through October was 380 mm in 1992 and 206 mm in 1993, compared with the 273 mm (40-year average). In 1993, a severe drought occurred in July (0.5 mm) and August (0 mm). July was particularly cold with mean monthly temperatures of 4.5 (1992) and 4.8 °C (1993) compared with 6.3 °C (40-year average). Low temperatures, low soil fertility and drought in 1993 may have limited DM yield of OP.

3.1. Experiment 1

The herbage mass of OP decreased towards the end of the trial (Table 1). The values were 1777, 1425 and 1209 kg DM/ha in July, August and September, respectively. DM concentration was similar across sampling periods averaging 296 g/kg fresh OP. The CP content varied between 93 at the beginning and 89 g/kg DM for the last sampling date. The NPN content of OP was about 47% of CP, for the first sampling date and decreased later. The Ca content increased with time from 3.5 to 6.0 g/kg DM. Other minerals showed similar values through sampling dates. The average ratio K/(Ca + Mg) in OP was highest on July 23 (3.80) and decreased to 2.73 and 1.94 meq on 11 August and 7 September, respectively.

Supplements composition for Exp 1 is reported in Table 2. Total ADG, rumen and blood parameters for Exp 1 are shown in Table 3. The total ADG for CON1, CORN1 and C-GM was: 670, 759 and 921 g per day, respectively, being only C-GM higher then the other two treatments ($P < 0.05$). A non-significant numeric trend in ADG was shown by the animals in the treatment CORN1 as compared to CON1.

The lowest ruminal pH was 6.26 for CORN1, then pH increased with date reaching a value of 6.93 on 9 September. However, differences for either treatment or date were non-significant. Rumen NH_3-N concentrations were currently low with a maximum of 4.44 mg/dl on 9 September ($P < 0.05$), and no differences among treatments. Plasma levels of Ca and Na were not affected by treatment or date; Mg and K showed higher values for CORN1 and C-GM versus CON1; K also increased through sampling dates ($P < 0.05$); P was significantly higher only for the second sampling date, with no differences among treatments.

Table 1
Oat pasture dry matter availability and nutrient composition on DM basis by sampling date for both experiments[a]

Item[b]	Experiment 1			Experiment 2					
	23 July	11 August	7 September	17 May	15 June	13 July	9 August	6 September	4 October
Yield (kg/ha)	1777	1425	1209	1616	1630	1723	1649	1445	980
DM (g/kg)	282	309	297	201	195	335	379	373	351
Ash (g/kg)	97	100	153	105	104	110	124	131	138
NDF (g/kg)	468	486	501	373	431	425	494	515	525
ADF (g/kg)	240	245	326	182	196	191	241	262	277
CP (g/kg)	93	91	89	164	118	80	85	85	97
NPN (g/kg)	44	30	32	46	41	29	22	30	31
Ca (g/kg)	3.5	4.3	6.0	3.6	4.2	4.5	5.4	6.1	6.0
Mg (g/kg)	0.8	0.9	1.3	1.3	1.3	1.3	1.4	1.5	1.7
P (g/kg)	1.9	2.1	1.8	2.3	2.2	1.5	2.1	2.1	2.6
Na (g/kg)	0.3	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2
K (g/kg)	17.9	15.4	15.4	34.9	24.7	19.6	18.9	22.3	18.2
K/(Ca + Mg)[c]	3.80	2.73	1.94	6.23	3.99	3.03	2.51	2.67	2.12

[a] Experiments conducted in 1992 and 1993, respectively.
[b] DM on a fresh forage basis. Yield and chemical composition on a dry matter (DM) basis.
[c] Cation ratio for OP. Listed as meq/100 g DM of OP.

Table 2
Nutrient composition of supplements on a DM basis in Experiments 1 and 2

Item	Experiment 1		Experiment 2	
	CORN1[a]	C-GM[b]	CORN2[a]	AH[c]
DM content (g/kg)[d]	878	885	953	942
Ash (g/kg)	21	24	24	115
ADF (g/kg)	34	40	60	266
CP (g/kg)	87	216	108	220
Ca (g/kg)	0.1	0.5	0.3	11.5
Mg (g/kg)	0.9	0.8	2.9	3.4
P (g/kg)	2.2	2.7	6.5	3.2
Na (g/kg)	0.1	0.8	0.1	0.6
K (g/kg)	2.3	2.0	6.3	40.0

[a] CORN1 and CORN2: 100% pelleted yellow corn grain.
[b] C-GM: 75% corn grain + 25% corn gluten meal (pelleted).
[c] AH: 100% alfalfa hay.
[d] DM on a fresh forage basis.

3.2. *Experiment 2*

The herbage mass was almost constant from May to September, varying between 1600 and 1700 kg DM/ha, but decreased to 980 kg DM/ha in October (Table 1). The DM concentration was lowest in May to June (about 200 g/kg of fresh OP), but increased very fast to 335 g/kg in July and stabilized towards the end of the experiment. Cell wall components were 373

Table 3
Average daily weight gain, rumen fluid parameters and mean plasma mineral concentration by treatment and sampling dates of beef cattle grazing oat pasture in experiment 1

Item	Treatment[a]			S.E.M.	Date		S.E.M.
	CON1	CORN1	C-GM		18 August	9 September	
Initial weight (kg)	209	201	205	8.5	–	–	–
Total ADG (g per day)[b]	670 a	759 a	921 b	23.6	–	–	–
Rumen							
pH	7.03	6.26	7.00	0.41	6.60	6.93	0.34
NH_3-N (mg/dl)	2.92	4.09	3.20	0.58	2.36 a	4.44 b	0.48
Plasma (mg/dl)							
Ca	11.66	10.80	12.98	0.89	10.83	12.80	0.73
Mg	1.69 a	2.61 b	2.90 b	0.18	2.29	2.51	0.14
P	8.62	8.53	9.08	0.93	7.28 a	10.20 b	0.75
K	14.77 a	17.48 b	18.09 b	1.15	14.60 a	18.96 b	0.94
Na	249	275	282	15.16	256	281	12.40

Letters a, and b denote that row means within treatment or dates are different ($P < 0.05$).
[a] Treatments in experiment 1: CON1: unsupplemented control; CORN1: 100% pelleted yellow corn grain; C-GM: 75% corn grain + 25% corn gluten meal (pelleted).
[b] Total ADG between initial and final live weights.

and 525 g/kg (NDF) and 182 and 277 g/kg of DM (ADF) for May and October, respectively. The CP values dropped from 164 g/kg at the beginning of grazing season to 80 g/kg in July, increasing again in October to 97 g/kg DM. The NPN represented a 28% of the total CP in May; then, with advancing season NPN decreased, still accounting for an elevated portion of total CP.

The Ca content increased from 3.6 g/kg DM in May to 6.0 g/kg DM in October; K decreased from 34.9 g/kg DM in May to 18.2 g/kg DM in early October. The Mg, P and Na contents did not vary much through sampling dates. The ratio K/(Ca + Mg) of OP was highest on 17 May (6.23), decreasing progressively to 2.12 meq/100 g DM on 4 October.

The chemical composition for the supplements CORN2 and AH in Exp 2 are reported in Table 2. The supplement AH resulted a 22% CP high quality hay. The daily average intake for both supplements was below the intended level, resulting 1.57 and 1.06 kg DM per animal for CORN2 and AH, respectively. Diminished consumption of CORN2 could be attributed to processing of grain with a higher moisture content than usual, which may have affected palatability.

The data for total ADG, rumen and blood parameters are presented in Table 4. Total ADG was: 718, 872 and 781 g per day for CON2, CORN2 and AH, respectively, being higher for CORN2 ($P < 0.05$). No significant differences were found for rumen pH either by treatment or date. Ruminal NH_3-N was found to be higher ($P < 0.05$) for AH with a concentration of 3.35 mg/dl, it was also different ($P < 0.05$) among dates with values of 2.82, 1.15 and 3.73 mg/dl for CON2, CORN2 and AH, respectively.

Plasma concentration levels of Ca and K were not affected by treatment, however both decreased with time. The highest values were detected in the first sampling date: 8.76 and

Table 4
Average daily weight gain, rumen fluid parameters and mean plasma mineral concentration by treatment and sampling dates of beef cattle grazing oat pasture in experiment 2

Item	Treatment[a]			S.E.M.	Date			S.E.M.
	CON2	CORN2	AH		7 July	18 August	25 September	
Initial weight (kg)	190	193	197	10.3	–	–	–	–
Total ADG (g per day)[b]	718 a	872 b	781 a	50.5	–	–	–	–
Rumen								
pH	7.01	6.77	6.84	0.13	6.83	6.75	7.03	0.13
NH_3-N (mg/dl)	2.20	2.17 a	3.35 b	0.20	2.82 a	1.15 b	3.73 c	0.20
Plasma (mg/dl)								
Ca	8.29	6.75	7.14	0.58	8.76 a	6.68 b	6.74 b	0.58
Mg	2.77	2.74	2.43	0.15	2.92	2.51	2.52	0.15
P	6.17 a	7.91 b	5.57 a	0.43	5.04 a	7.34 b	7.27 b	0.43
K	13.00	14.39	12.39	1.16	19.22 a	10.61 b	9.94 b	1.16
Na	272 a	282 a	256 b	7.96	264	270	276	7.96

Letters a, b, and c denote that row means within treatment or dates are different ($P < 0.05$).

[a] Treatments in experiment 2: CON2: unsupplemented control; CORN2: 100% pelleted yellow corn grain; AH: 100% alfalfa hay.

[b] Total ADG between initial and final live weights.

19.22 mg/dl for Ca and K, respectively ($P < 0.05$). Blood levels of Mg were not affected by either treatment or sampling date. P was found to be highest for CORN2: 7.91 mg/dl, and lowest in the first sampling date: 5.04 mg/dl ($P < 0.05$). Plasma Na levels did not change with time, however, they were different between treatments: 282 versus 256 mg/dl for CORN2 and AH, respectively ($P < 0.05$).

4. Discussion

4.1. Forage availability and composition

Although monthly mean precipitation was almost 180 mm lower in 1993 and it could have affected DM content and composition, it did not appear to influence DM yield of OP. Maximum animal growth rate could be reached with 750–1000 kg DM/ha with a forage digestibility of 50–60% (Duble et al., 1971). Between 900 and 1300 kg DM/ha of standing forage, calves grazing continuously would achieve about 90% of their potential DM consumption (NRC, 1987). According to these reports DM availability did not appear to limit voluntary consumption in these trials.

We also assume that DM content of OP was not a primary constraint for animal performance. Cow intake grew linearly when DM content of pasture increased from 120 to 220 g/kg of fresh forage, with no further increase for higher DM values (Vèrité and Journet, 1970). Only in Exp 2, DM values were around 200 g/kg in the first two dates, all the other DM values were over 220 g/kg. Additionally, pasture DM concentration may depend on the climatic conditions of each year. Water stress decreases plant growth but DM concentration increases at equivalent development stages (Nelson and Volenec, 1995). The DM content for both experiments was over 300 g/kg fresh OP since mid July, but in a previous trial with more intense precipitation the DM content resulted lower (Arelovich et al., 1999).

The CP content of OP was below expected values and likely marginal to sustain high growing rates in both experiments (NRC, 1996). Many authors reported higher CP levels for small grains pastures, either with or without fertilization (Hogan and Weston, 1969; Croy, 1983; Fay et al., 1991; Elizalde and Santini, 1992). Poor soil N may have contributed to low CP content of OP; but it can also be a consequence of advanced plant maturity because of deficient rainfall.

Usually, fresh forages have a high content of soluble protein (100–300 g/kg); a large proportion of this soluble N is NPN (Beever, 1984; Van Vuuren et al., 1991; Elizalde and Santini, 1992). We found that NPN averaged 38.5 and 31.4% of total CP in Exp 1 and Exp 2, respectively. The NPN seems independent of total CP content, since for the highest CP values NPN remained proportionally lower. In a different location, Elizalde and Santini (1992) reported that soluble N fraction for OP was 48.4% of total CP, and CP values ranged from 231 to 103 g/kg of DM from May to October. Geographic location and environmental factors may affect substantially N content and relationship between N fractions in OP.

Cell wall components increased towards the end of grazing period in September and October, as previously observed for small grain forages (Cherney and Marten, 1982; Elizalde and Santini, 1992). Previously reported mean mineral contents for OP from March through September were: 3.7, 1.7, 34.4 and 0.6 g/kg DM for Ca, Mg, K and Na, respectively (Fay et al., 1991). Except for Ca, these values were higher than the average from both experiments: 4.8, 1.2, 19.7 and 0.3% g/kg DM for Ca, Mg, K and Na, respectively. As with major fractions, mineral concentration would vary with time and location. The P concentration in OP averaged 2.0 g/kg DM with low variability for both studies. According to the suggested minimum values of NRC (1996) except for Na content, the average concentration of reported minerals should not limit animal growth. However, changes in relative proportions of some of these minerals in a particular period of the grazing season may cause complex mineral interactions, altering digestion and absorption patterns and affecting animal performance.

Hypocalcemia and hypomagnesemia may affect lactating cows grazing small grain lush pastures under certain conditions, but, they are uncommon in young growing animals (Grunes et al., 1984). Nevertheless, similar conditions may induce a subclinical mineral deficiency. If so, it would reduce growth rate by either directly affecting the mineral requirements or impairing the rumen digestion. When the ratio K/(Ca + Mg) exceeds 3.0 meq, the incidence of hypomagnesemia increases in a cow herd by more than 15% (Minson, 1990). In the present study, the ratio K/(Ca + Mg) decreased with advance of plant maturity. It was above 3.0 meq in July; and May, June and July for Exp 1 and Exp 2, respectively. Therefore, during these months there were conditions in OP that could trigger a decrease in blood Mg.

4.2. Animal performance

The type of supplement affected animal performance. Animals grazing continuously on lush pastures probably eat small and erratic amounts of hay offered ad libitum regardless of hay quality. In Exp 2, AH offered ad libitum did not significantly improved ADG. However, a larger intake was observed with CORN2, which induced a significant 21% increase in ADG. Similarly, intake of poor quality hay was only 0.41–0.78 g hay DM/kg of metabolic weight for calves and steers respectively, when grazing OP; however, ADG was 948 g per day (Arzadún et al., 1989).

When hay is similar or lower in quality than the pasture, the supplement may actually depress rather than stimulate animal performance. A study with steers grazing wheat pasture also indicated that voluntary intake of low quality roughages was not significant, and did not affect live or carcass weight (Mader et al., 1983). Besides, the same hays have not altered ruminal turnover rate or modified wheat forage utilization (Mader and Horn, 1986). Likely, the main advantage of hay supplementation to OP would result in increased carrying capacity by substitution, rather than improvement in individual performance.

Corn grain (CORN1 and CORN2) fed at approximately at 1% of initial body weight increased numerically ADG by 89 g per day in Exp 1; but 154 g per day increase in ADG was significant in Exp 2, which represented a 13 and 21% increase over CON1 and CON2, respectively. Although faster growth rates should be expected, these results are in agreement with Elder (1967), who found that grain supplementation of rye and wheat pastures resulted in ADG's of 640 and 790 g per day for control and supplemented treatments. Grain supplementation to winter annual pastures will usually yield about 150 g per day advantage in mean ADG, as well as a 25% increase in carrying capacity (Wagner et al., 1984). Utley and Mccormick (1976) reported increased carrying capacity and faster gains on rye pasture with steers that received 1.8% of their body weight as corn or sorghum grain; ADG's were 1340 and 1357 g per day, respectively versus 1058 g per day of control treatment.

Fresh forages on immature stages have low soluble carbohydrate content (Weston and Hogan, 1968; Beever, 1984; Elizalde and Santini, 1992). Then the supply of moderate levels of high energy supplements generally improved animal performance for animals grazing winter annuals (Wagner et al., 1984). This effect have to be attributed to the additional energy supply and increased total digestible DM intake, since substitution would only be partial. When grains are supplemented to ruminants with highly digestible pastures, expected substitution rates are 60–90 g for each 100 g of grain (Holmes and Jones, 1964; Gulbransen, 1974).

In our studies, supplementation with readily available carbohydrates have not reduced substantially rumen pH. The animals receiving CORN1 and CORN2 exhibited the lowest pH values, however this trend was not significant. A pH reduction from 6.8 to about 6.0 causes only a moderate depression in fermentation, while decrease below 6.0 causes a severe depression in digestibility, mainly in dietary fiber and protein (Hoover and Miller, 1991). Then, we have not expected significant changes in digestibility or rumen fermentation patterns because of a decreased pH.

A rumen NH_3-N level of 5 mg/dl is widely accepted as the minimum concentration at which maximum microbial growth and activity would occur (Satter and Slyter, 1974). The NH_3-N concentration in both experiments was below 5 mg/dl, thus, N availability to rumen microbes may limit fermentation rate. A small but significant increase in ruminal NH_3-N was noticed in September towards the end of the experimental period. Because CP in OP was critical for high animal performance, the additional CP supply by AH which seems to improve rumen NH_3-N level, could partially explain the increased trend in ADG for this treatment.

Positive effects of protein supplementation on animal performance is expected with forages of a nutritive value lower than OP (Clark et al., 1987; Cecava et al., 1990; Arelovich et al., 1992). However, additional protein (Beever, 1984) or escape protein fed to animals grazing fresh pastures (Minson, 1990) may also produce responses of both biological and economic significance. Indeed, corn gluten meal, a source of escape protein used in Exp 1 (C-GM) increased ADG by 37.5% compared to CON1. Since OP had a lower CP content than expected, this positive response to supplement C-GM may be attributed to improvement in both the ruminal supply of N, as well as dietary amino acids for direct absorption from the small intestine.

In contrast growing steers grazing a high CP wheat pasture, supplied with 908 g per day of a supplement containing escape protein, did not increase ADG compared with a corn supplement (Smith et al., 1990). However, total CP supplied by wheat pasture was higher and supplementation level was lower than the corresponding values for Exp 1. Besides, ADG for unsupplemented wheat pasture was 1098 g per day, 64% higher than the 670 g per day observed for CON1 in Exp 1. Wheat and OP were grazed to equivalent maturity stages in both trials; also supplement components were similar; therefore, the different CP content in both pastures would explain the differences in ADG to protein supplementation.

Van Soest (1982) suggested that for a diet with intermediate N level, the protein requirement of the animal can be larger than its microbial supply; then, escape protein would improve animal response. Additionally, starch supply increases microbial use of recycled urea and microbial protein synthesis. In Exp 1 both supplements (CORN and C-GM) were consumed at the same level and had similar energy density. Therefore, we can conclude that the positive effect of escape protein on animal performance was additive to the energy source of the supplement.

Deficiencies of Ca, Mg, P and K may induce subclinic blood levels, which can decrease growth rate and productivity. According to suggested levels (Puls, 1990) most observations in these studies indicated they were variable but adequate. The only relevant observation was the significant decrease in plasma levels of K by sampling date in Exp 2. This decrease is difficult to explain because K levels were high in pasture and similar to those in previous year. In the same experiment a significant decrease of Ca level by date was also found, but within normal range.

For blood Mg, only the CON1 treatment exhibited the lowest mean value in agreement with the lowest Mg content in OP. The high ratio K/(Ca + Mg) observed at several dates do not appear to influence the Mg blood levels. Any differences detected in blood mineral levels in these studies had neither biological nor practical significance. Increased ADG response to the concentrate supplements showed that energy and protein were the primary constraints in animals grazing OP. Responses to mineral supplementation can only be anticipated when energy or protein supply are not limiting (Doyle, 1987).

Wheeler (1981) stated that ADG may vary between 700 and 1000 g per day for ruminants grazing small grain forages, and other authors reported similar ADG values (Wagner et al., 1984; Arzadún et al., 1989). We observed ADG's within this range of values in these studies. The supply of energy–escape protein supplements would diminish variability between years in beef cattle response when grazing OP.

5. Conclusion

Chemical composition and herbage mass for OP were different for both experiments. They influence animal productivity between years (CON1 compared to CON2). Hay supply would not substantially affect animal performance. However, ADG can be much improved by feeding concentrates rather than hays to cattle grazing OP. When CP content in OP is limiting to sustain fast growth rates in beef cattle, ADG would be increased by the addition of a escape protein source to energy supplementation. Although not measured, we have also to consider an increased efficiency of protein absorption and utilization with escape protein supply. The type of supplement and supplementation level did not appear to modify to a large extent rumen fermentation or have any major effect on blood mineral levels.

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