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Influence of hay quality and pasture location on performance of beef cattle grazing oats

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Abstract

Heifers grazing oat pasture (OP) at two locations in Argentina, Argerich (ARG) and Pasman (PAS), were subjected to one of three different dietary supplement treatments: (1) control (CON, no supplement), (2) sorghum hay (SH), or (3) alfalfa-grass hay (AGH), all provided *ad libitum* in individual pens. The variables measured were: dry matter (DM) yield and composition of OP, hay intake, average daily weight gain (ADG), rumen pH and NH_3-N, and blood mineral levels. DM availability did not limit OP intake. OP crude protein (CP) content ranged from 11.3 to 13% at ARG, and 10.7 to 13.3% at PAS. OP-minerals varied with location; the mean K/(Ca + Mg) ratios were 5.68 meq (ARG) and 4.82 meq (PAS). Heifers ate more AGH (785 g) than SH (684 g; $P = 0.08$). Hay consumption was 2.88 times greater at PAS than at ARG ($P < 0.05$). ADG was larger with SH (558 g) and AGH 594 g than with CON treatment (454 g); the average for ARG animals was 571 g compared to 500 g for PAS animals ($P < 0.05$). Rumen pH was lower at 14:30 h (pH 6.7) than at 10:00 h (pH 7.5; $P < 0.05$). NH_3-N values were higher at 14:30 h (19.59 mg dl^{-1}) than at 10:00 h (4.69 mg dl^{-1}; $P < 0.05$). Plasma Ca (15.50 mg dl^{-1}) and Mg (2.84 mg dl^{-1}) levels were higher in PAS cattle ($P < 0.05$). Animal performance improved with hay supplementation, but location affected response intensity.

Key words: dry matter availability, pasture composition, daily weight gain, rumen, pH, ammonia, blood, minerals.

Resumen

Influencia de la calidad del heno suplementario y la localización de la pastura sobre el rendimiento de bovinos de carne a pastoreo sobre avena

Se realizaron tres tratamientos con novillas pastoreando verdeos de avena (VA) en dos localidades de Argentina, Argerich (ARG) y Pasman (PAS): (1) Control (CON, sin suplemento), (2) heno de sorgo (HS), y (3) heno de alfalfa y gramíneas (HAG), suplementados *ad libitum* en corrales individuales. Evaluamos rendimiento de materia seca (MS) y composición en VA; y en los animales consumo del heno, ganancia diaria de peso (GDP), pH y N-NH_3 en rumen, y minerales en sangre. La disponibilidad de MS no limitó el consumo de VA; su proteína bruta (PB) osciló entre 11,3 y 13% (ARG), 10,7 y 13.3% (PAS). Los minerales en VA variaron entre localidades, la relación K/(Ca + Mg) promedió 5,68 meq (ARG) y 4,82 meq (PAS). Las novillas consumieron diariamente más HAG (785 g) que HS (684 g; $P = 0.08$), y 2,88 veces más heno en PAS que en ARG ($P < 0,05$). En GDP, HS (558 g) y HAG (594 g) superaron al CON (454 g), y la media de ARG (571 g) a PAS (500 g; $P < 0,05$). En el rumen el pH decreció a las 14:30 h (6,7) *vs.* 10:00 h (7,5; $P < 0,05$), y el N-NH_3 (mg dl^{-1}) aumentó a las 14:30 h (19,59) *vs.* 10:00 h (4,69; $P < 0,05$). Ca (15.50 mg dl^{-1}) y Mg (2.84 mg dl^{-1}) en plasma fue mayor en PAS ($P < 0,05$). El rendimiento animal mejoró con la suplementación, pero la magnitud de respuesta estuvo afectada por la localidad.

Palabras clave: disponibilidad materia seca, composición pastura, ganancia diaria de peso, rumen, pH, amoníaco, sangre, minerales.

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Introduction

Beef cattle frequently graze oat pasture (OP) in semiarid and sub-humid Argentina. In this temperate area of the southern hemisphere, the grazing season is from late autumn till early spring (May-October). Producers mainly use this forage for growing and finishing steers and heifers. Regionally, many producers find lower animal weight gains than the average usually reported for winter annuals (700 g d^{-1} per head; Wheeler, 1981; Rosso and de Verde, 1992).

Numerous factors can affect the weight gain of cattle grazing lush grasses. Climatic conditions may influence animal requirements and voluntary intake (NRC, 1996). An extremely low dry matter content in pasture can also diminish forage intake and animal response (Vèrité and Journet, 1970). Additionally, the variability in chemical components of the forage (Beever *et al.*, 1978; Elizalde and Santini, 1992) and dry matter availability per hectare have a major impact on forage utilization and animal productivity (Wheeler, 1981; Allison, 1985; NRC, 1987).

Some authors suggest that a low ratio of soluble carbohydrate to available N reduce the efficiency of N use (Hogan and Weston, 1969; Beever, 1984; Elizalde and Santini, 1992). The Ca and Mg contents of small grain forages can also limit the productivity of pregnant or lactating cows (Grunes *et al.*, 1984). Under certain circumstances, growing ruminants may suffer sub-clinical Ca and Mg deficiencies.

Though geographically close, different locations can cause variability in animal responses because of their different soils, level of solar radiation, photoperiod or bioclimate (Johnson, 1987). The growth of grazing animals is the result of a multiple interaction of all these variables. In this complex model, diverse factors would have a different impact in distinct periods of the grazing season, leading to changes in animal performance from one year to the next.

Adequate supplementation programs may reduce the variability in the growth rate of beef cattle grazing fresh oats. However, regionally, producers frequently include hay in the diet. They believe that dry forage prevents a fall in dry matter intake and lowers the incidence of diarrhoea. Unfortunately, the nutritive value of such hay is frequently lower than that of the pasture, and this probably affects weight gain.

Supplemental feed quality, as well as geographic location of the pasture (with different DM yield and composition) are important factors affecting the productivity of cattle grazing fresh OP. The present work evaluated how supplementing oat-grazing cattle with hays of different nutritional quality affected beef productivity and related variables in two locations.

Material and Methods

Two simultaneous experiments were conducted at two locations in Argentina: the Pasman Experimental Station (PAS; 37º 13'S, 62º 11'W) and the Argerich Experimental Station (ARG; 38º 46'S, 62º 38'W). Mean temperatures and precipitation for May, June, July, August, September and October were collected and contrasted with historical data. The soil at PAS was a typical Argiudoll fine loam, while at ARG it was a typical Haplustoll loam.

Pastures

Oat pastures (*Avena sativa* cv. Suregrain) were planted at PAS and ARG in the first week of March following two tillages with a disk plough, once in mid November and once prior to seeding (plant density approx. 300 seeds m^{-2}). The size of the grazing paddocks was 12 ha at both locations. Dry matter (DM) availability was determined at 25 (ARG) and 28 (PAS) day intervals. The sampling dates were July 4th, August 1st, August 28th and September 17th at ARG, and June 26th, July 16th, August 12th and September 6th at PAS. The first sampling date for the two locations —June 26th (PAS) and July 4th (ARG)— were considered equivalent sampling dates (ESD I). The remaining sampling date pairs were named similarly: ESD II, III and IV. A 0.25 m^2 quadrat was thrown 15 times at random across every paddock on each sampling date. Plants were hand-cut at a height of 8 cm and samples dried in a forced-air oven at 60ºC for 72 h. These samples were then composited by date, ground to pass a 2 mm sieve and saved for chemical analysis. All were analysed for DM, total crude protein (CP = %N × 6.25), NPN (by subtracting true protein from total CP), and ash content (AOAC, 1990), NDF and ADF (Goering and Van Soest, 1970). Ca, Mg, Na and K were acid extracted from forage samples by wet digestion (AOAC, 1990) and determined via plasma emission spectrophotometry (ICPS Shimadzu model 1000III). The K/(Ca + Mg) ratio, expressed in meq, was calculated for the OP samples to check the validity of this relationship with Mg plasma levels in growing animals (Kemp and Hart, 1957).

Animals and treatments

The cattle (Aberdeen Angus heifers, 36 in PAS and 30 in ARG with an initial liveweight of 164 and 154 kg respectively) grazed OP continuously for 84 days at PAS and 75 days at ARG. Grouped by weight, the animals were randomly assigned to one of the following supplemental treatments: 1) control (CON), no supplement, 2) sorghum hay (SH) or 3) alfalfa-grass hay (AGH). This allowed animal weights to be kept similar throughout the supplemental treatments. The cows were treated with Ivermectin to control parasites at the beginning of the trial. To protect pasture from trampling, the heifers grazed from 10:00 to 17:00 h daily. During the night they were housed in individual pens where they received the supplementary hay.

The SH bales (*Sorghum bicolor*) were made from forage sorghum harvested in an advanced state of maturity. The AGH bales were made of a mixed pasture —about 90% alfalfa (*Medicago sativa)* and 10% canary grass (*Phalaris bulbosa*)— harvested when the alfalfa was in the midbloom stage. SH an AGH bales were randomly allocated to each pasture location. The hay was chopped and provided *ad libitum* in bunk feeders. Subsamples obtained from several bales were composited as a single sample for each type of hay and saved for chemical analyses. The analytical determinations made with the hay were the same as those made with OP.

Animal measurements

Daily hay intake was estimated from the difference between the material offered and rejected by 12 animals at both locations over two 7 days periods during the trial (end of July and end of August). Animal liveweights were obtained at intervals of about 25 days at ARG and 28 days at PAS to calculate partial and total average daily gains (ADG). Partial ADG between two consecutive weighing dates were determined by measuring the liveweight change and then assigning the recorded ADG values to Periods I, II and III.

The evaluations of ADG were coincident with DM availability measurements. Animals were weighed at 09:00 h before grazing. Samples of ruminal fluid were obtained from three randomly selected animals from each treatment before 10:00 h and after grazing at 14:30 h. The rumen sampling dates were July 25th, August 16th and September 13th at ARG, and July 23rd, August 18th and September 3rd at PAS. Ruminal fluid was obtained by applying vacuum to an oesophageal tube fitted with a suction strainer attached to a 500 ml bottle. The extracted fluid was immediately filtered through 4 layers of cheesecloth and the pH determined. To stop microbial activity, 50 ml of filtered fluid was acidified with 2 ml of a 6 N HCl solution (Merchen *et al*., 1986). Samples were then frozen until analysis for $N\text{-}NH_3$ content by the 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 2,300 × g for 15 min. Plasma was separated and frozen for mineral analysis. Blood plasma was analysed for Ca, Mg, Na and K by plasma emission spectrophotometry (ICPS Shimadzu model 1000III).

Statistical analysis

ANOVA for a completely randomised design was performed using the GLM procedure of SAS (1985). A t test was used to compare means. Supplemental DM intake was analysed by location, treatment, and by weighing period between two consecutive dates in the model. Since location by treatment was not significant, it was used to test for the main effects. For ADG data, the effects of location, treatment and the interaction *location x treatment* were tested with the residual error. For the rumen data, location, treatment, sampling date and hour affected the model. Then, the effect of location was tested with the interaction *hour x location* as the error. The effects of treatment and location by treatment were tested with the sum of the interactions *treatment x hour* plus *treatment x location x hour* as the error term. The effect of sampling date was treated as a repeated measure, where date, *treatment x date* and *location x date x treatment* were tested with the residual error. For blood data, the model effects were location, treatment and sampling date. The main effects and interactions were tested with the residual error.

Results

The total rainfall of 393 mm for PAS and 335 mm for ARG (May-October) was 44% and 50% higher, respectively, than the 40-years mean historic data for these locations. The lowest daily mean temperatures we-

Table 1. Oat pasture dry matter availability and nutrient content at Argerich (ARG) and Pasman (PAS)

Item*	Equivalent sampling date							
	I		II		III		IV	
	ARG Jul 4	PAS Jun 26	ARG Aug 1	PAS Jul 16	ARG Aug 28	PAS Aug 12	ARG Sep 17	PAS Sep 6
Yield (kg ha^{-1})	3,102	2,910	3,866	3,375	2,309	3,795	1,636	1,492
DM content (%)	17.7	20.1	24.6	20.8	32.6	28.6	28.8	24.1
Ash (%)	10.8	10.2	11.0	8.3	15.0	10.5	15.4	14.0
NDF (%)	44.2	44.1	45.2	40.5	61.6	47.6	59.6	62.9
ADF (%)	24.4	22.1	24.3	20.7	21.3	24.4	31.7	34.2
CP (%)	12.7	13.3	11.3	11.3	11.6	10.7	13.0	12.0
NPN (%)	3.7	3.3	3.0	3.0	2.8	3.8	2.0	3.1
Ca (%)	0.20	0.26	0.17	0.25	0.24	0.27	0.26	0.46
Mg (%)	0.13	0.10	0.14	0.09	0.21	0.10	0.20	0.13
Na (%)	0.12	0.11	0.20	0.04	0.16	0.08	0.13	0.07
K (%)	3.05	2.66	2.75	2.13	2.01	1.80	2.68	2.11

* Yield and nutrient content are expressed as dry matter. DM: dry matter. NDF: neutral detergent fibre. ADF: acid detergent fibre. CP: crude protein. NPN: non protein nitrogen.

re 6.8°C and 7.5ºC in the months of June-July for PAS and ARG respectively. Temperatures were no different from their respective 40-year average, but ARG was about 1.5ºC warmer than PAS when averaged over the five months.

Oat pasture availability and hay composition

Table 1 shows the monthly DM yield and composition for PAS and ARG. Herbage mass was similar for both locations, decreasing at the end of the experimental period. The highest values for DM yields were 3,866 for ARG and 3,795 kg ha^{-1} for PAS, both in August. The lowest DM concentration was recorded at ESD I (17.7% at PAS and 20.1% at ARG).

Unexpectedly, the CP concentration almost constantly showed relatively low values, with a small decrease during July and August but increasing again in September. This pattern was similar for both locations. The highest CP values were 13 and 13.3%, and the lowest 11.3 and 10.7% for ARG and PAS respectively. NPN averaged about 26% of total CP across sampling periods and locations. The OP levels of Mg, Na and K were higher in ARG, with Ca higher for PAS. The mean K/(Ca + Mg) ratio in the OP throughout the period was high: 5.68 and 4.82 meq for ARG and PAS respectively.

The nutritive value of AGH was higher than that of SH, with CP, Ca and K contents markedly higher and NDF lower (Table 2). The interaction between location and treatment was not significant for either hay intake or ADG. Treatment and location means are shown in Table 3. The higher DM intake of AGH (785 g d^{-1}) compared to SH (684 g d^{-1}) in both locations resulted in a non-significant but important trend ($P = 0.08$). Regardless of the experimental treatment, PAS heifers consumed 2.88 times more hay than ARG heifers ($P < 0.01$).

Animal performance

No significant differences between supplements were detected with respect to ADG, 558 and 594 g for SH and AGH respectively compared to 454 g for

Table 2. Nutrient composition of supplemental hays

Composition*	Sorghum hay (%)	Alfalfa-grass hay (%)
Total dry matter	91.1	92.4
Neutral detergent fibre	74.9	62.6
Acid detergent fibre	46.0	46.4
Crude protein	3.8	14.4
Total ash	9.5	10.4
Calcium	0.29	0.90
Magnesium	0.10	0.13
Sodium	0.02	0.03
Potassium	1.35	2.82

* All components expressed as dry matter.

Table 3. Dry matter intake of supplemental hay and average daily weight gain by treatment and location

Item	Treatment			SEM	Location		SEM
	CON	SH	AGH		ARG	PAS	
Hay DM intake (g d^{-1})	—	684	785	30.2	378[a]	1,090[b]	30.2
Initial weight (kg)	156	163	159	6.0	155	164	6.0
ADG (g)							
— Period I	373[a]	547[b]	671[b]	58.2	579	481	47.5
— Period II	523	584	618	49.2	552	597	40.1
— Period III	476	552	496	34.6	588[a]	428[b]	28.3
Total	454[a]	558[b]	594[b]	23.6	571[a]	500[b]	19.3

CON: control, no supplement. SH: sorghum hay. AGH: alfalfa-grass hay. SEM: standard error of the mean. [a,b] Row means within treatment or location are different ($P < 0.05$). Non-significant trend for supplemental DM intake by treatment ($P = 0.08$).

CON ($P < 0.05$). A significant location effect was evident with an average of 571 g for ARG compared to 500 g for PAS heifers. Only in ADG-Period II there were no differences with respect to treatment or location (Table 3).

The ruminal fluid data collected are shown in Table 4. The pH for CON was 7.22, higher than that for animals fed supplemental treatments ($P < 0.05$). Differences in average pH for location were also detected. The mean pH values were above 7 for both treatments and locations. However, the largest effect on pH was due to sampling hour; at 14:30 h the pH averaged 6.70 compared to 7.50 at 10:00 h. High variability was seen in the NH_3-N determinations. A non-significant trend was observed for higher rumen NH_3-N concentrations with AGH treatment (13.73 mg dl^{-1}) and ARG location (14.70 mg dl^{-1}). Nevertheless, the NH_3-N concentration was higher at 10:00 h than that at 14:30 h, with values of 4.69 and 19.59 mg dl^{-1} respectively ($P < 0.01$). Interactions were non-significant both for pH or NH_3-Nconcentration.

Plasma Ca, Mg, K and Na levels were unaffected by hay supplementation (Table 5). Although within the normal range, Mg plasma concentrations were higher in PAS heifers (2.84 mg dl^{-1}, $P < 0.05$). However, the interactions *location x date*, and *location x treatment* ($P < 0.01$) were present for Ca and K, and Na respectively.

Table 4. Mean pH values and ammonia-N concentration in ruminal fluid by treatment, location and sampling hour

Item	Treatment			SEM	Location		SEM	Hour		SEM
	CON	SH	AGH		ARG	PAS		10:00	14:30	
pH	7.22[a]	7.05[b]	7.05[b]	0.03	7.19[a]	7.03[b]	0.08	7.50[c]	6.70[d]	0.04
NH_3-N (mg dl^{-1})	11.88	10.81	13.73	0.72	14.70	9.58	2.52	4.69[c]	19.59[d]	1.07

CON: control, no supplement. SH: sorghum hay. AGH: alfalfa-grass hay. SEM: standard error of the mean. [a,b] Row means within treatment or location are different ($P < 0.05$). [c,d] Row means within sampling hour ($P < 0.01$).

Table 5. Mean blood mineral concentrations by treatment and location

Item	Treatment			SEM	Location		SEM
	CON	SH	AGH		ARG	PAS	
Ca (mg dl^{-1})	14.05	14.78	13.58	0.67	12.77[a]	15.50[b]	0.55
Mg (mg dl^{-1})	2.37	2.41	2.39	0.13	1.94[a]	2.84[b]	0.11
K (mg dl^{-1})	14.44	15.34	15.52	0.66	15.84	14.36	0.53
Na (mg dl^{-1})	262	263	271	5.8	271	260	4.7

CON: control, no supplement. SH: sorghum hay. AGH: alfalfa-grass hay. SEM: standard error of the mean. [a,b] Row means within location are different ($P < 0.05$). The interactions *location × date* for Ca and K and *location × treatment* for Na were significant ($P < 0.01$).

Discussion

Oat pasture availability and composition

Mean temperatures were almost 1.4°C higher at ARG than at PAS. PAS received 20% more rainfall than ARG, and the mean precipitation for May-October was higher than that of the historic data in both locations. Apparently, the magnitude of climatic differences did not substantially influence the mean DM yield ha^{-1} –2,728 kg for ARG and 2,893 kg for PAS. The DM availability of OP did not appear to limit voluntary consumption or animal performance. Mott (1984) reported maximum animal performance with forage masses of 1,200-1,600 kg DM ha^{-1}.

Producers are usually concerned about low DM content of OP since they believe it affects total DM intake and consequently decreases weight gain. However, the content of water in feeds *per se* should not be expected to influence DM intake until total expected water intake per unit of DM is exceeded (NRC, 1987). In dairy cows, the DM intake grows linearly from 12 to 22% with increasing pasture DM content (Vèrité and Journet, 1970). In the present work, the lowest DM percentages were seen in ESD I with 17.1 and 20.1% for ARG and PAS respectively. The DM contents of OP for ESD II, III and IV were 20% higher. Therefore, except for ESD I, the DM content of the OP do not appear as a primary constraint for DM consumption and animal performance. Pasture DM content may be related to the climatic features of each year, particularly precipitation.

Some authors have reported higher CP values for fertilized as well as non-fertilized small grain pastures (Hogan and Weston, 1969; Croy, 1983; Fay *et al*., 1991; Arelovich *et al.*, 1996). In this study, the CP concentration in OP was lower than expected for each ESD. Therefore, according to protein requirements for heifers (NRC, 1996), the CP supply from OP would limit high animal performance. Poor soil N fertility is the most likely reason for the observed low CP values, particularly at the beginning of the grazing season. Immature forage usually has a high content of soluble protein (10 to 30%), mostly NPN (Beever, 1984; Van Vuuren *et al*., 1991; Elizalde and Santini, 1992). ARG values for NPN as a percentage of CP decreased with advancing maturity from 30 to 15%. However, the NPN values for PAS did not follow the same pattern as those for ARG, rather, these were around 25% with a peak of 36% on August 29th, decreasing from then on. The NPN concentration seems to behave independently of total CP content. Environmental factors associated with geographical location may play a critical role in total N content and the relationships between N fractions of nutritional interest.

The total cell wall content in OP increased with forage maturity towards the end of the grazing period at a rate similar to that reported by others (Cherney and Marten, 1982; Arelovich *et al*., 1996). As expected, the results for ADF paralleled those of NDF. The reported mean mineral contents for OP for March-September at Balcarce, Argentina, were 0.37, 0.17, 3.44 and 0.06% for Ca, Mg, K and Na respectively (Fay *et al*., 1991). These figures are similar to the values found in this study, which, averaged across locations are 0.40, 0.12, 2.11 and 0.06% for Ca, Mg, K and Na respectively. However, mineral concentration changed with sampling date and location. Ca was particularly low at ARG (0.17%) on August 1st, while Mg was lowest at PAS (0.09%) on July 16th. Grunes *et al*. (1984) indicated that autumn and winter wheat forage also showed variability for the same variables. According to the limiting values suggested by the NRC (1996), except for the Na content most mean mineral concentrations should support moderate to high growth rates. However, some changes in their relative proportion for a time during the grazing season may induce interactions that alter absorption.

The mean ratio K/(Ca + Mg) varied according to geographical location. Although it was lower at PAS (4.82) than at ARG (5.68) it exceeded 3.00 meq in both cases, indicating a high risk of a fall in blood Mg (Minson, 1990).

Animal performance

In the present study, hay supplementation improved ADG in cattle grazing OP, regardless of the nutritive value of the hay. However, the best quality hay induced the highest hay consumption and ADG. SH intake was 15 g kg^{-1} $W^{0.75}$ and AGH intake 17.5 g kg^{-1} $W^{0.75}$. In an attempt to protect the OP from trampling damage during night frosts, the animals were systematically removed at 17:00 h from the grazing paddocks. Therefore, grazing was restricted from 17:00 to 10:00 h the next day. In contrast, when grazing freely in lush pastures, the animals would eat small and erratic amounts of hay. Arzadún *et al.* (1989) showed that calves and steers grazing OP without restriction ate very little *Setaria italica* hay (0.41 and 0.78 g kg^{-1} $W^{0.75}$ respectively). The same report showed that ADG (948 g) was not affected by hay feeding and it was higher than the levels observed in our study. When the quality of offered hay is lower than the quality of the pasture, additional hay supply depresses rather than increases animal performance. Mader *et al*. (1983) showed that voluntary intake of low quality roughages was insignificant, and did not affect the live or carcass weight of steers grazing wheat pasture. Moreover, the same hays did not alter the ruminal turnover rate nor modify wheat forage use (Mader and Horn, 1986).

Grazing management, OP quality and DM availability were about the same for both locations. The reason for higher hay intakes at PAS is therefore unclear. Nevertheless in PAS we found a very low initial DM content in the OP (perhaps related to greater precipitation), as well as a lower mean temperature, mainly due to a sharper decrease in night time temperatures. According to other authors (Vèrité and Journet, 1970; NRC, 1987), low DM content may partially explain the difference in hay intake at the two locations.

Since the ARG heifers consumed less hay, a larger energy and protein intake might be expected from the OP, which may have increased the ADG compared with that of the PAS heifers. The main advantage of hay supplementation in this study was probably compensation for the reduction in grazing hours.

The most significant changes in pH were related only to time of day. The pH was lower at 14:30 h than at 10:00 h. A higher pH early in the morning may indicate that animals have not consumed much hay before entering the grazing paddock, the buffering capacity increased by the salivary output. The pH decreased immediately after fresh forage was grazed, and this can be attributed to increased VFA production. Similar pH changes for oats and ryegrass diets were associated with high VFA production during the first hours after grazing (Weston and Hogan, 1968). A pH reduction from 6.8 to about 6.0 causes only a moderate depression in fermentation (Hoover and Miller, 1991). The mean pH at 14:30 h, across treatments and locations, was 6.7. Therefore, significant changes in digestibility or rumen fermentation patterns should not be thought due to a pH effect.

The NH_3-N concentration of ruminal fluid indicates N availability to rumen microorganisms. A universal constant of 5 mg dl^{-1} of NH_3-N for this fluid (Satter and Slyter, 1974) is widely accepted as the minimum concentration at which maximum microbial growth and activity can take place. The NH_3-N concentration was below the critical value of 5 mg dl^{-1} before grazing (10:00 h), and four times higher after grazing (14:30 h). Since NH_3-N concentration showed large variation among determinations, statistical differences were not detected for treatments and location. NH_3-N levels of ARG cattle were numerically higher than those of PAS cows, which can be attributed to a greater consumption of OP (there was 5.4 % more protein in the OP across the whole grazing period for the ARG location). In any case, mean rumen NH_3-N largely exceeded 5 mg dl^{-1}.

Despite the high variability in rumen N availability, the higher quality hay supplement numerically increased NH_3-N values, as shown by a non-significant trend with AGH. Although the CP level of the OP was often limiting for high animal performance, hay supplementation improved not only total CP but also energy supply. When grazing restrictions are imposed, producers usually supplement with hay. Therefore, depending on the quality of that hay, the N supply may be marginal for several hours - as occurred in the experiment with morning sampling. Arelovich *et al*. (2003) reported a dramatic response in productivity to supplemented escape protein in young cattle grazing OP of similar composition to that of this trial.

The differences in blood mineral levels detected in these studies should have no biological or practical significance. Normal plasma levels are 10.0 and 1.8 to 2.0 mg dl^{-1} for Ca and Mg respectively (NRC, 1996), and 250.0 and 14.0-18.0 mg dl^{-1} for Na and K respectively (Fontenot and Church, 1979). Most of the observations made indicate variable but normal blood levels for these minerals. This is in agreement with the data discussed above on OP mineral concentration.

For cattle grazing OP, weight gain can be affected by restricted grazing as well as by the type of supplementation program. Wheeler (1981) stated that ADG might vary between 700 and 1000 g in ruminants grazing small grain forages. Other authors also report a similar range of ADG values for cattle grazing winter annuals (Wagner *et al*., 1984; Arzadún *et al*., 1989; Arelovich *et al*., 2003). This expected variability in ADG could make it very difficult to predict animal performance, even when they consume the same type of forage year after year.

In this study, total ADG was closer to 600 g when the highest quality hay was provided. However, ADG could be further improved and variability in performance reduced by feeding concentrates rather than hay to OP cattle grazing. Utley and McCormick (1976) reported higher daily weight gains of 1,340 and 1,357 g when yearling steers were supplemented with whole-shelled corn and rolled sorghum grain respectively. The controls gained only 1,058 g per day. It would also seem that the common practice of enclosing cattle at night to protect pastures from trampling substantially affects performance, although this is partially offset by hay supply.

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References

AOAC, 1990. Official methods of analysis. Association of Official Analytical Chemists. 15th ed. Washington, D.C.

ALLISON C.D., 1985. Factors affecting forage intake by range ruminants: A review. J Range Manage 38, 305-311.

ARELOVICH H.M., ARZADÚN M.J., LABORDE H.E., VASQUEZ M.G., 2003. Performance of beef cattle grazing oats supplemented with energy, escape protein or high quality hay. Anim Feed Sci Technol 105, 29-42.

ARELOVICH H.M., MIRANDA R., HORN G.W., MEILLER C., TORREA M.B. 1996. Oats varieties: forage production, nutritive value and grain yield. Animal Sci Res Rep Okla Agr Exp Sta P-951, 104-108.

ARZADÚN M.J., ARELOVICH H.M., LABORDE H.E., VILLALBA J.J., TORREA M.B., 1989. Oats grazing with low quality hay supplement. Rev Arg Prod Anim 9 (Sup 1), 13.

BEEVER D.E., 1984. Utilization of the energy and protein components of forages by ruminants - A United Kingdom Perspective. In: National Wheat Pasture Symposium Proceedings (Horn, G.W., ed.). Okla Agr Exp Sta Pub, MP-115, 65-97.

BEEVER D.E., TERRY R.A, CAMMELL S.B., WALLACE A.S., 1978. The digestion of spring and autumn harvested perennial ryegrass by sheep. J Agr Sci 90, 463-470.

BRODERICK G.A., KANG J.H., 1980. Automated simultaneous determination of ammonia and total amino acids in ruminal fluid and in vitro media. J Dairy Sci 63, 64-75.

CHERNEY J.H., MARTEN G.C., 1982. Small grain crop forage potential: I. Biological and chemical determinants of quality and yield. Crop Sci 22, 227-231.

CROY L.I., 1983. Variety and species effects on forage quantity, forage quality and animal performance. In: National Wheat Pasture Symposium Proceedings (Horn, G.W., ed.) Okla Agr Exp Sta Pub, MP-115, 23-33.

ELIZALDE J.C., SANTINI F.J., 1992. Nutritional factors that constrain the body weight gains in beef cattle in autumn-winter period. INTA Balcarce, Argentina, Agr Exp Sta Tech Bull 104, 3- 27.

FAY J.P., CSEH S.B., ORBEA J., 1991. In vitro ruminal digestion of *Avena sativa* and *Paspalum dilatatum* in relation to hypomagnesemia in cattle. J Anim Phisiol An N 65, 1-10.

FONTENOT J.P., CHURCH D.C., 1979. The macro (major) minerals. In: Digestive physiology and nutrition of ruminants (Church, DC, ed.), Vol 2. O&B Books, Inc., OR. pp. 56-99.

GOERING H.K., VAN SOEST P.J., 1970. Forage fiber analysis (Apparatus, reagents, procedures and some applications). Agricultural Handbook, US Department of Agriculture, No. 379. ARS, USDA, Washington.

GRUNES D.L., HUTCHESON D.P., HORN F.P., STEWART B.A., UNDERSANDER D.J., 1984. Mineral composition of wheat forage as related to metabolic disorders of ruminants. In: National Wheat Pasture Symposium Proc (Horn, G.W., ed.). Okla Agr Exp Sta Pub, MP-115, 99-113.

HOGAN J.P., WESTON R.H., 1969. The digestion of pasture plants by sheep. III. The digestion of forage oats varying in maturity and in the content of protein and soluble carbohydrate. Aust J Agr Res 20, 347-363.

HOOVER W.H., MILLER, T.K., 1991. Rumen digestive physiology and microbial ecology. Vet Clin N Am-Food A 7, 311-325.

JOHNSON H.D., 1987. Bioclimate effects on growth, reproduction and milk production. In: Bioclimatology and the adaptation of livestock (Johnson H.D. ed.). World Animal Science, B5, Elsevier, Amsterdam, pp. 35-57.

KEMP A., HART M.L., 1957. Grass tetany in grazing milk cows. Neth J Agr Sci 5, 4-17.

MADER T.L., HORN G.W., 1986. Low quality roughages for steers grazing wheat pasture. II. Effect of wheat forage intake and utilization. J Anim Sci 62, 1113-1119.

MADER T.L., HORN G.W., PHILLIPS W.A., MCNEW R.W., 1983. Low-quality roughages for steers grazing wheat pasture. I. Effect on weight gains and bloat. J Anim Sci 56, 1021-1028.

MERCHEN N.R., FIRKINS J.L., BERGER L.L., 1986. Effect of intake and forage level on ruminal turnover rates, bacterial protein synthesis and duodenal amino acid flows in sheep. J Anim Sci 62, 216-225.

MINSON D.J., 1990. Forage in ruminant nutrition (Cunha T.J., ed.). Academic Press, Inc. 483 pp.

MOTT G.O., 1984. Relationship of available forage and animal performance in tropical grazing systems. Proc. Am. Forage Grassl. Counc., pp. 373-382.

NRC, 1987. Predicting feed intake of food-producing animals. National Academy Press, Washigton DC, USA.

NRC, 1996. Nutrient requirements of beef cattle (7th Ed.). National Academy Press, Washigton DC, USA.

ROSSO O.R., DE VERDE S.C., 1992. Oats: forage production and the utilization in cattle feeding. INTA Balcarce, Argentina, Agr Exp Sta Tech Bull 109, pp. 3-27.

SAS, 1985. SAS User's Guide: Statistics. SAS Inst. Inc., Cary, NC.

SATTER L.D., SLYTER L.L., 1974. Effect of ammonia concentration on rumen microbial protein in vitro. Brit J Nutr 32, 199-208.

UTLEY P.R., MCCORMICK W.C., 1976. Corn and grain sorghum for finishing steers in drylot or on rye pastures. J Anim Sci 43, 1141-1114.

VAN VUUREN A.M., TAMMINGA S., KETELAAR R.S., 1991. In sacco degradation of organic matter and crude protein of fresh grass (*Lolium perenne*) in the rumen of grazing dairy cows. J Agr Sci 116, 499-512.

VÈRITÉ R., JOURNET M., 1970. Influence de la teneur en eau et de la déshydratation de l'herbe sur sa valeur alimentaire pour les vaches laitières. Ann Zootech 10, 269-277.

WAGNER D.G, LOWREY R., GRIGSBY M., 1984. Supplemental feeding of grain and protein for stocker cattle on small grain pastures. In: National Wheat Pasture Symposium Proc (Horn, G.W., ed.) Okla Agr Exp Sta Pub, MP-115, 327-341.

WESTON R.H., HOGAN J.P., 1968. The digestion of pasture plants by sheep. 1. Ruminal production of volatile fatty acids by sheep offered diets of ryegrass and forage oats. Aust J Agr Res 19, 419-432.

WHEELER J.L., 1981. Complementing grassland with forage crops. In: Grazing animals (Morley F.H.W., ed.), World Anim. Sci. B1, Elsevier, NY, USA. pp. 239-260.