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ARTICULO ORIGINAL

Effect of source of carbohydrate in concentrate on the performance of high producing dairy cows during spring grazing#

Efecto del tipo de carbohidrato en el concentrado sobre la respuesta productiva de vacas lecheras de alta producción en pastoreo primaveral

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RESUMEN

Efecto del tipo de carbohidratos en el concentrado, sobre la respuesta productiva de vacas lecheras de alta producción en pastoreo primaveral. Dos experimentos se implementaron para evaluar dos fuentes de carbohidratos (almidón y fibra digestible) en el suplemento concentrado, sobre parámetros productivos y metabólicos en vacas lecheras de alta producción en pastoreo primaveral con una generosa oferta de pradera. En el experimento 1, 12 vacas produciendo 33 kg/leche por día fueron asignadas a un cuadrado latino con periodos de 21 días cada uno. En el experimento 2, 27 vacas produciendo 29/kg de leche por día fueron asignadas a un diseño completamente al azar por 45 días. Para ambos experimentos los tratamientos fueron: Tratamiento 1: sólo pastoreo (GO), Tratamiento 2: pastoreo + 6 kg de un concentrado basado en pulpa de remolacha (beet pulp) y Tratamiento 3: pastoreo + 6 kg de un concentrado basado en cereal (barley). Las vacas fueron suplementadas dos veces al día y manejadas en pastoreo rotativo en franjas sobre una pradera consistente principalmente en gramíneas. El porcentaje promedio de proteína cruda en la materia seca del concentrado fue de un 17% y un 11,9%, para el experimento 1 y 2, respectivamente. En el primer experimento, la producción y la composición de leche fueron similares para ambos tipos de concentrado. En el segundo experimento, la producción y la concentración grasa de la leche fueron similares en los tratamientos suplementados. El tipo de concentrado no afectó el peso vivo, la ganancia de peso vivo ni la condición corporal de las vacas. La suplementación con concentrado aumentó la producción de leche (5,0 y 6,0 kg/día en el experimento 1 y 2, respectivamente) y la concentración de la proteína (0,12 y 0,15 unidades de porcentaje en los experimentos 1 y 2, respectivamente), siendo sólo significante en el primer experimento, comparado al tratamiento sólo pradera. En el segundo experimento, el concentrado basado en cereal, produjo un aumento de las concentraciones de glucosa en plasma y una disminución de las concentraciones de BHBA y de nitrógeno ureico en plasma (P<0,05). Bajo estas condiciones, los resultados sugieren que la fuente de carbohidratos no afecta la productividad animal, pero mejora la condición metabólica de las vacas.

Palabras clave: vacas, concentrado, pastoreo, leche.

Key words: cows, concentrate, grazing, milk.

INTRODUCTION

In temperate regions, milk production is often based on pastures due to the lower cost compared with indoor feeding systems. However, by providing pasture as the only source of nutrients it is often impossible to meet the energy requirements of high producing cows (Kolver and Muller 1998; Pulido and Leaver 2001; Pulido and Leaver, 2003). It is generally accepted that under pasture based systems the main factors limiting milk production are low herbage DMI, low energy intake, and lack of synchrony in the release of nutrients in the rumen between the energy and degradable CP supply of herbage (Peyraud and Delaby 2001; Stockdale 2000), therefore energy supplementation is needed in order to improve production. It has been reported that the energy source in the concentrate has little effect on milk output and composition when moderate levels of concentrate (less than 6 kg/d) are fed (Peyraud and Delaby 2001). However, few studies have examined the effect of starch or digestible fiber-based concentrates on milk production and composition of high producing dairy cows fed on pasture with high pasture allowance (Bargo *et al* 2003), and provided reliable conclusions about the relationship between milk production and energy source. Some of those studies were conducted in confinement with cows fed fresh-cut forage (Spörndly 1991; Schwarz *et al* 1995), while others were grazing studies (Meijs 1986; Delahoy *et al* 2003; Sayers *et al* 2003) in which sources of variation in animal responses can be attributed to the source of carbohydrate in the concentrate, the level of concentrate

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supplementation, type of pasture and pasture allowance, milk production level, and days in milk (Bargo *et al* 2003).

Supplementation with cereal-based concentrates, high in starch, are characterized by modifying molar proportions of volatile fatty acid, enhancing propionate concentration, which is the most relevant precursor of glucose in ruminants, and therefore positively influencing the energetic metabolism status of the cow (Knowlton 1998, Bargo *et al* 2003). Sugar beet pulp is degraded more slowly than starch in the rumen, therefore a decrease in the rumen degradation rate and an increase in the acetate/propionate ratio may be expected (Webster 1993).

The measurement of purine derivatives (PD) as specific markers for rumen microbial biomass has been suggested (Topps and Elliot 1965). Purines present in digesta entering the small intestine are mostly of microbial origin. Purines are then metabolized by the ruminant to form PD such as allantoin, uric acids, xanthine, and hypoxanthine which are mainly excreted in the urine (Chen *et al* 1992). Among the purine derivatives, allantoin is the most important in cattle (Chen *et al* 1995) and is excreted in a constant proportion to the other derivative purines, therefore, it can be used to estimate rumen microbial protein (Gonda *et al* 1996; Orellana-Boero *et al* 2001). Urinary excretion of creatinine is not affected by feed intake and is excreted in proportion to body weight (Gonda *et al* 1996). The allantoin/creatinine ratio in spot urine samples was constant during the day and followed the same trend as allantoin excretion in urine, supporting the idea that allantoin/creatinine ratio could be used as an index of total allantoin excretion in urine, and, therefore, avoiding the total collection of urine (Gonda, 1995). This methodology has been used to compare diets of dairy cows (Bargo *et al* 2002; Orellana *et al* 2004). Production efficiency of lactating dairy cows is optimal when the synthesis of microbial protein in the rumen is maximized (Bargo *et al* 2003). Little research has been conducted to evaluate the effect of the diet on rumen microbial synthesis in high producing grazing dairy cows (Bargo *et al* 2002; Delahoy *et al* 2003), and only one has evaluated the effect of the carbohydrate source in the concentrate on early calving cows under grazing conditions (Sayers *et al* 2003).

The objective of this study was to evaluate the effect of the carbohydrate source in the concentrate (high digestible fiber vs. high starch) at a moderate level of supplementation, on milk production and composition, blood and urinary metabolites and rumen microbial protein synthesis in early spring calving high producing dairy cows offered a high pasture allowance.

MATERIAL AND METHODS

Experiment 1. The experiment was conducted at the Vista Alegre Experimental Research Station of the Universidad Austral de Chile, Chile (latitude 39º 47' 46" and longitude 73º 13' 13") from September 26th to December 1rt, 2002. The sward was a 7 yr-old permanent pasture that had been subjected to rotational grazing management in previous years. The soil type was classified as a medial, mesic, typic Hapludand (Soil Survery Staff 1992). Fertilizer was applied at a rate of 40 kg/ha of N in mid-September followed by 25 kg/ha of N during the first week of October and 25 kg N/ha in the last week of October. In all cases the source of N was ammonium nitrate.

Twelve Friesian dairy cows (milk yield, 33.2 ± 2.39 kg/d; parity 3.8 ± 1.49; DIM, 53.3 ± 7.03; BW, 527 ± 38.0) were blocked according to milk yield, DIM and BW and were randomly assigned to three dietary treatments: grazing only (GO), grazing plus 6 kg/d of a sugar beet pulp-based concentrate (beet pulp) and grazing plus 6 kg/d of a cereal-based concentrate (barley), in a 3x3 Latin Square design (4 replicates) with 21 d periods. The amount of supplementation used was calculated considering the pasture offered and the supply of ME for an approximate milk production of 30 kg/d (NRC 2001).

All cows grazed 3.4 ha consisting of mainly perennial ryegrass (*Lolium perenne*) as one group and were rotated to a new paddock twice daily after each milking. Throughout the experiment and in order to maximize pasture DMI the target amount of daily herbage DM offered per cow or pasture allowance (PA) was 35 kg DM. Herbage mass (kg/ha of DM) was measured weekly by cutting three quadrants to ground level and drying for 48 h at 60 ºC in a forced air oven. The grazing areas were estimated daily prior to grazing using a rising plate meter (RPM, Ashgrove Plate Meter, Hamilton, New Zealand) and walking the paddocks in "W" pattern. Pre and post grazing sward height was recorded daily based on 80 measurements per paddock. A topping machine was used to provide a homogenous sward height, following each of the three grazing rotations. Supplements and a vitamin-mineral mix were individually fed in two equal meals after each milking and refusals were weighed daily. The mineral mix[1] was also available to all cows in the paddocks. Composition of the supplement is shown in table 1. Cows were milked at 06:30 and 14:30 h, yield was measured at each milking and averaged per week. Representative subsamples of milk were collected two days during the last week of each period at a.m. and p.m. milking and analyzed for milk fat, milk total protein and milk urea-N (MUN) by infrared spectrophotometer (Foss 4300 Milko-scan; Foss Electric, Denmark). Throughout the experiment, cows were weighed once a week after morning milking and BCS was recorded by two experienced observers using the five-point scale.

[1] High production dairy cow, Veterquimica S.A.

Table 1. Pasture management in experiments 1 and 2.
Manejo del pastoreo en los experimentos 1 y 2.

Pasture management	Experiment 1	Experiment 2
	X ± DE	X ± DE
Area, m^2/cow/day	134	129
Pasture allowance (kg DM/cow/day)	37.0 ± 2.8	36.6 ± 8.94
Pre-grazing herbage mass (kg DM/ha)	2759 ± 373.6	2749 ± 261.6
Sward height pre-grazing (cm) [1]	19.3 ± 2.67	26.4 ± 4.00
Post-grazing herbage mass (kg DM/ha)	1715 ± 87.4	1535 ± 204.3
Sward height post-grazing (cm)[1]	11.8 ± 0.60	11.7 ± 2.0

[1] = Using the Rising Plate Meter.

Experiment 2. Twenty-seven Friesian dairy cows (milk yield, 29.4 ± 0.71 kg/d; parity 3.7 ± 1.86; DIM, 54.9 ± 2.89; BW, 512 ± 50.9) were blocked into nine groups of three cows each according to milk yield, DIM, parity, and BW. Cows were randomly assigned within each group to three dietary treatments: grazing only (GO), grazing plus 6 kg/d of a sugar beet pulp-based concentrate (beet pulp) and grazing plus 6 kg/d of a cereal-based concentrate (barley), in a completely randomized design.

All cows grazed an 8.5 ha-pasture consisting of mainly perennial ryegrass (*Lolium perenne*). Herbage mass measurements and targeted PA were similar to experiment 1. Three treatment groups of nine cows each grazed together and were rotated to a new paddock as a group twice a day after each milking. Supplementation was offered in a similar way to experiment 1. Procedures for milking, milk sampling, BW and BCS were similar to those presented for experiment 1.

Experimental procedures and sampling. In each period of experiment 1, the first 14 d were used to adjust the cows to the dietary treatments and the last seven days were used for data collection. In experiment 2, data were obtained weekly.

Spot urine samples were taken by vulvae stimulation after each milking on three consecutive days of each period for experiment 1 and each week for experiment 2. Samples were acidified with sulphuric acid (10% v/v) to maintain pH below 3 and stored at -12 ºC. Urine samples were thawed and a composite sample per cow was obtained for each period in experiment 1 and for each week in experiment 2. Each sample was then analyzed for allantoin, uric acid and creatinine by liquid chromatography. Analytes were detected by an ultraviolet spectrophotometer at 205 nm (Ballcels *et al* 1991). Microbial protein synthesis (MP) was estimated by total PD/C ratio in urine samples, as described by Chen *et al* (2004), and by using cattle equations reported in the IAEA (1997) manual.

In experiment 2, six coccigeal blood samples were collected from each cow in vacuum tubes containing sodium heparin and sodium fluoride, for seven consecutive days following the morning milking. Plasma was separated after centrifugation, frozen at -25ºC and analyzed for Beta-hydroxybutyrate (BHBA), glucose, urea-N and albumin using a Cobas Mira Plus® autoanalyser.

Three days a week, samples of concentrates and pastures were collected in both experiments, composited, and then dried for 48 h at 60 ºC in a forced air oven. Once a week, samples of the pasture were obtained by hand-plucking at the approximate height the cows grazed. Pasture samples were stored in a freezer prior to freeze-drying. Supplements and pasture were ground through a 1 mm screen (Wiley Mill, 158 Arthur H. Thomas, Philadelphia, PA), and analyzed for dry matter (DM), crude protein (CP), ether extract (EE), acid detergent fiber (ADF), ash (AOAC 1990) and neutral detergent fiber (NDF) (Van Soest *et al* 1991). Metabolizable energy (ME) was estimated by regression using "D" value (digestible organic matter/ DM x 100) determined *in vitro,* according to Garrido and Mann (1981).

Statistical analysis. Milk yield and composition, and blood and urinary metabolites were analyzed in experiment 1 as a 3 x 3 Latin Square design, replicated four times, using the GLM procedure of SAS (1985). The model included, $Y_{ijkl} = \mu + T_i + S_j + P_k + C_m (S_j) + E_{ijkm}$

Where: Y_{ijkl} = dependent variable; μ = intercept; T_i = effect of treatment $_i$; S_j = effect of square $_j$; P_k = effect of period k; C_m (S_j) = effect of cow$_m$ within square $_j$; E = residual error.

For experiment 2, the animal performance and blood and urinary metabolites data were analyzed using Repeated Measures Analysis of Variance (ANOVA). The statistical model was: $Y_{ijkl} = \mu + T_i + C_{ij} + P_k + TP_{ij} + E_{ijkl}$

Where:
- Y_{ijkl} = observation on the jth cow of the ith treatment at the kth sampling time.
- μ = intercept
- T_i = fixed effect of the ith treatment.
- C_{ij} = effect of the jth cow nested within the ith treatment (This is equivalent to type **a** error)
- P_k = fixed effect of the kth sampling time.
- TP_{ik} = fixed effect of the interaction between the ith treatment and the kth sampling time.
- e_{ijkl} = residual random effect ~ $N(0,\sigma^2)$

The error term used as denominator for the F tests was the effect of the jth cow nested within the ith treatment.

This removes the correlation between observations done on the same animal. The analyses of variance were done using the PROC GLM procedure of SAS (1985).

RESULTS

Weather conditions. During experiment 1, the average maximum and minimum daily temperatures were 18.3 and 6.8 ºC, respectively. Mean daily rainfall was 12.8 mm, with precipitation higher than the previous 40-yr average. During experiment 2, mean maximum and minimum daily temperatures were 16.9 and 7.2 ºC, respectively. Mean daily rainfall was 5.8 mm.

Sward and concentrate characteristics. The results for pasture management variables for both experiments are shown in table 1. Actual daily pasture allowance per cow was 37.0 and 36.6 kg DM, and the efficiency of harvesting was 38 and 44.2 %, for experiment 1 and experiment 2, respectively. The chemical composition of herbage and concentrate supplements is shown in table 2.

Animal performance. The effect of concentrate type on milk production and composition for both experiments is shown in table 3. In both experiments, the results showed that the energy source in the concentrate had little effect on milk production, milk composition, and milk urea-N when moderate levels of concentrate were fed. In both experiments, concentrate supplementation increased milk yield and protein concentration in milk ($P<0.05$), but a significant increase in milk protein content was shown only for the high starch-based concentrate in experiment 2.

Body weight and blood and urine metabolites. Body weight and body condition score are reported in table 3.

The type of supplement had no significant effect on live weight, live weight gain, or BCS. Concentrate supplementation decreased the plasma urea-N concentration in experiment 2. In both experiments, the PD/C ratio was similar for all treatments. Rumen microbial protein synthesis (MP) increased by supplementation only in experiment 2, irrespective of the type of concentrate.

DISCUSSION

Sward and concentrate characteristics. Temperate pastures used for dairy cows are described as high quality or young and leafy pastures with—a composition similar to 18 to 24% DM, 18 to 25% CP, 40 to 50 % NDF, and 2.5 to 2.9 Mcal/kg DM of ME (Clark and Kanneganti 1998). In our studies (table 2), herbage nutritive value was high in both experiments, averaging 22.1% CP,

Table 2. Ingredients and chemical composition of the herbage and concentrates offered throughout experiments 1 and 2 (% of DM, unless otherwise stated).

Ingredientes y composición nutricional promedio de la pradera y de los concentrados para ambos experimentos (base seca, a menos que se señale de otra manera).

	Experiment 1				Experiment 2			
	Pasture		Concentrates*		Pasture		Concentrates*	
	X ±	DE	Barley	Beet pulp	X ±	DE	Barley	Beet pulp
N° samples	3		3	3	6		6	6
Barley			79.0	–			93.0	–
Sugar beet pulp			–	72.0			–	86.5
Soybean meal			19.0	26.0			5.0	11.5
Beet molasses			2.0	2.0			2.0	2.0
DM	18.9	2.04	87.8	87.8	15.6	1.4	88.1	88.9
CP	23.4	7.80	17.3	16.6	25.1	2.3	12.1	11.6
NDF	46.8	1.80	22.5	34.6	52.1	4.4	26.1	39.9
ADF	24.6	3.70	7.4	21.1	26.0	0.44	6.3	23.3
EE	–	–	2.28	0.98	–	–	1.8	1.6
Ash	10.5	0.9	62	86	9.3	1.74	2.5	6.9
ME (Mcal/kg DM)	2.7	0.1	3.02	3.03	2.7	0.08	3.12	3.13
Mineral mix								

Dry matter (DM), crude protein (CP), ether extract (EE), Acid detergent Fiber (ADF), Neutral detergent Fiber (NDF) and Metabolizable energy (ME).
Mineral mix; Na 7.5%, Cl 11.0%, Ca 15.6%%, P 9.56%, Mg 6.0%%, Zn 5750 mg/kg, Cu 545 mg/kg, Mn 2700 mg/kg, Co 71 mg/kg.
* Supplements prepared especially for these experiments by IANSAGRO S.A.

Table 3. Milk production and composition, body weight, body condition score and blood and urinary metabolites of the cows during experiments 1 and 2.

Producción y composición de leche, peso vivo y condición corporal, y metabolitos sanguíneos y urinarios de las vacas durante los experimentos 1 y 2.

	Experiment 1					Experiment 2				
	Treatments					Treatments				
	GO	Barley	Beet pulp	EE	P=	GO	Barley	Beet pulp	EE	P=
Milk production & composition										
Milk kg/day	24.2	29.6	28.5	0.72	0.00	25.0	31.1	30.7	1.11	0.03
Milk protein, %	2.88	3.01	2.99	0.03	0.00	3.07	3.30	3.14	0.06	0.00
Milk fat, %	3.65	3.40	3.44	0.11	0.04	3.59	3.58	3.73	0.10	0.28
MUN (mmol/L)	3.39	3.42	3.21	0.11	0.12	3.79	3.32	3.49	0.12	0.00
Body weight & body condition										
Body weight, kg	521	527	522	9.3	0.88	522	531	532	5.7	0.91
Body weight change, kg/day	–0.18	0.69	0.50	0.28	0.03	0.72	0.99	0.98	0.20	0.32
Body condition Score[2]	1.99	1.99	20.2	0.09	0.97	2.4	2.44	2.32	0.18	0.80
Plasma metabolites										
Glucose (mmol/L)	–	–	–	–	–	3.09	3.25	3.09	0.05	0.00
BHBA (mmol/L)	–	–	–	–	–	0.86	0.59	0.82	0.06	0.00
Urea –N (mmol/L)	–	–	–	–	–	3.82	3.09	3.39	0.24	0.00
Albumin (g/L)	–	–	–	–	–	38.6	38.4	38.4	0.46	0.93
Urinary metabolites										
PD/C ratio[3]	2.22	2.50	2.38	0.16	0.24	2.36	2.91	2.76	0.08	0.17
MP, g/day[4]	1182	1371	1296	98.3	0.16	1246	1576	1514	101.4	0.05

[1] MUN = Milk urea nitrogen, [2] Five point scale (1 = thin and 5 = fat), [3] Allantoin + uric acid (PD) / Creatinine (C) in urine, [4] Rumen microbial protein synthesis.

49.5% NDF and 2.7 Mcal/kg DM of ME. These values are representative of spring pastures in southern Chile (Teuber 1996). Neutral detergent fiber and ADF were lower for the high starch concentrate compared to the high fiber concentrate, however both concentrates were similar in CP and ME within each experiment (table 2).

Animal performance. In both experiments (table 3), the results show that the energy source in the concentrate had little effect on milk production, milk composition, and milk urea-N when moderate levels of concentrate were fed. However, a significant increase in milk protein content was shown for the high starch-based concentrate in experiment 2.

These results are consistent with two recent studies conducted in the northern hemisphere (Sayers *et al* 2003; Delahoy *et al* 2003) and one in the southern hemisphere (Pulido *et al* 1999). In a review of grazing experiments designed to evaluate responses to concentrate in high yielding cows, Bargo *et al* (2003) reported that at this moment the number of studies is too small to draw strong conclusions, but differences in the source of starch or fiber used in the concentrate, the type of pasture and the other components of the diet, may affect the degradation of the concentrate and therefore produce inconsistent results. Peyraud and Delaby (2001) suggested that the differences between starchy and fibrous concentrates are minimal when using a concentrate rich in either sugar-beet or citrus pulp, both of which are sources of rapidly-fermentable pectins. This response could be explained because when the amount of concentrate eaten is less than 40% of the total DMI, the productivity of the cows will rely more on the intake and nutritive value of the pasture, than the effect of supplemented concentrate in the rumen. In our studies, concentrate represents in average 31.7 and 28.0% of the total DMI (Pulido *et al* 2006), for experiment 1 and 2, respectively. In addition, the average NDF concentration (50%) in the pasture of both experiments suggests that cows had an important NDF intake or effective fiber intake (Pulido *et al* 2006) in addition to the moderate level of supplementation used, thus allowing the cows to use the starchy concentrates without a detrimental effect on ruminal pH, pasture ruminal digestion, and pasture DMI (Bargo *et al* 2003).

In pasture-based production systems, it is generally assumed that energy is the first factor to limit animal performance (Kolver and Muller 1998). The lack of difference due to the type of supplements agrees with the results of Delahoy *et al* (2003) and Sayers *et al* (2003) and suggests that the energy rather than the protein intake was the first limiting factor for animal production.

Concentrate supplementation increased milk yield and protein concentration in milk (P<0.05), but significant increases in milk protein content were observed only for high starch-based concentrate in experiment 2. Milk production of cows receiving concentrates increased 0.83 and 0.98 kg of milk/kg of concentrate on average, over the non-supplemented cows for experiments 1 and 2, respectively. Bargo *et al* (2003) reported that milk production of high producing grazing dairy cows in early lactation increased linearly as the daily amount of concentrate increased from 1.8 to 10 kg DM with milk response changes ranging from 0.6 to 1.45 kg milk/kg of concentrate compared with pasture-only dietary treatments. The greater milk production and protein concentration in milk of the supplemented cows in this experiment appear to be due to a greater total DMI and energy intake and an average substitution rate, which agrees with data reported by Pulido and Leaver (2001).

Decreases in milk fat concentration and the acetate:propionate ratio in the rumen of grazing dairy cows are generally associated with the amount of concentrate rather than with the type of carbohydrate in the concentrate and with a low level of fiber in the ration (Sutton *et al* 1987) reflecting dietary ruminal fermentation changes. This is consistent with the lack of effect on milk fat content when starch was replaced by fiber-based supplements (Kibon and Holmes 1987), and with the higher fat content of the non-supplemented compared with the supplemented cows in our experiment 1 (P <0.05), but not with the results of experiment 2, where the supplemented treatments showed no effects (P >0.28) on milk fat content. It is possible that the high NDF concentration (52.1 %) in the pasture used in experiment 2 (table 2), allowed the cows to have a significant NDF intake, preventing a detrimental effect on ruminal digestion.

Body weight and blood and urine metabolites. It is generally accepted that the changes in body reserves are difficult to detect in short term experiments (Hoden *et al* 1991). The type of supplement had no significant effect on live weight, live weight gain, or BCS in our experiments (table 3). This lack of differences attributable to type of supplement supports the work of Delahoy *et al* (2003) where supplemented cows had a higher live weight gain (P<0.05) in experiment 1 and a higher BCS change (P<0.05) in experiment 2, compared to the non-supplemented cows.

In experiment 2 cows supplemented with the barley-based concentrate presented a lower plasma concentration of BHBA and a higher plasma concentration of glucose (table 3), possibly indicating a more efficient energy metabolism, related to the positive changes in the BCS. This treatment also had the lowest incidence of sub-clinical ketosis, 2 %, (concentrations of BHBA > 1.0 mmol/L) (Duffield 2000) during the 6 weeks of the experiment, compared to the beet pulp supplemented cows (30%) and the non-supplemente cows (41%). Hence, it is likely that in this experiment cows supplemented with barley-based concentrate had a better availability of glucose due to an increase in propionate absorption (Knowlton 1998).

Energy supplementation (starch more than fiber) also produced a decrease in the plasma urea-N concentration (table 3). This is attributed to a better ratio between RDP and energy in the rumen, with a more efficient use of the N from the forage by the microorganisms of the rumen and consequently lower absorption of ammonia (Canfield *et al* 1990). Plasma urea-N concentration observed in the non-supplemented cows was also higher than the upper reference value (Wittwer *et al* 1999) in grazing cows (3.27 mmol/L) as a consequence to a shortage of energy intake in relation to the RDP content in the forage (Bargo *et al* 2003). Albumin concentrations were similar in the three treatments remaining within physiological range.

PD/C ratio in spot urine samples has been used to compare diets of dairy cows (Bargo *et al* 2002; Orellana *et al* 2004). In both of our experiments, the PD/C ratio was similar for all treatments, showing no difference among supplemented and non-supplemented cows. These results agree with Delahoy *et al* (2003) who found no differences on PD/C ratio (3.56 vs 3.47) in late lactation cows supplemented with 8.2 kg/d (DMI) either with ground corn or a non forage fiber-based supplement with a pasture DMI of 12 kg/d and a milk production, similar to the one reported in the present experiments. Sayers *et al* (2003) reported that high producing dairy cows in early lactation show an increase in the urinary excretion of purine derivatives (allantoin and uric acid), but since urinary creatinine excretion also increased, the PD/C ratio did not change with the level of supplementation (5 or 10 kg/d DM) or the type of concentrate (fibrous or starchy). The differences in the PD/C ratio observed among experiments in the literature can be attributed to the different methodologies used. While Bargo *et al* (2002) and Delahoy *et al* (2003) used a colorimetric technique to determine allantoin, uric acid and creatinine, in our experiments, as well as in Sayers *et al* (2003), a HPLC was used, so higher precision and accuracy (Chen *et al* 2004) could be expected. In addition, in these last two studies the differences in PD/C ratio observed agree with Chen *et al* (2004), who reported that spot urine samples do not allow to make comparisons between experiments due animal and dietary variations; therefore they are only useful to show differences between treatments within experiments.

Rumen microbial protein synthesis (MP) was increased by concentrate supplementation. This response was numerical in experiment 1, but significant (P<0.05) in experiment 2, although no effects of the type of carbohydrate in the concentrate were observed. The latter results agree with the increase in milk production and in milk protein concentration in experiment 2 (P<0.05) and with the decrease in milk urea-N concentration. Therefore, in experiment 2, it may be expected that cows supplemented with either concentrate had a better utilization of ruminal nitrogen to produce microbial protein.

These results suggest that when 6 kg/d of either a high fiber-based or high starch- based concentrate is fed to high producing dairy cows in early lactation, grazing *ad libitum* a high nutritive value pasture, the source of energy does not produce enough digestive modifications to affect animal performance, but starch supplementation reduces sub-clinical ketosis and improves ammonia utilization in the rumen more than fiber supplementation. Milk production was increased by concentrate supplementation.

SUMMARY

Two experiments were conducted to evaluate two different sources of carbohydrate (fibrous and starchy) in concentrate supplement for high producing dairy cows fed spring pasture. In experiment 1, 12 Friesian cows producing a daily milk yield of 33.0 kg were assigned to a 3x3 Latin Square design with 21 day periods each. In experiment 2, 27 Friesian cows yielding 29.3 kg/d were assigned to a completely randomized design for 45 days. In both experiments, the treatments included: grazing only (GO), grazing plus 6 kg/d of sugar beet pulp- based concentrate (beet pulp), and grazing plus 6 kg/d of cereal-based concentrate (barley). The cows were supplemented twice a day and managed under a strip grazing system on a pasture consisting mainly of perennial ryegrass. In experiment 1 and 2 the crude protein (CP) content of the concentrates was 17.0 and 11.9%, respectively. In experiment 1, average milk yield and milk composition were similar for the sugar beet pulp-based concentrate and the cereal-based concentrate. In experiment 2 average milk yield and milk fat were similar for the supplemented treatments. The type of concentrate did not affect body weight, body weight gain, or body condition score. Concentrate supplementation increased average milk yield (5.0 and 6.0 kg/d for experiments 1 and 2, respectively) and milk protein concentration (0.12 and 0.15 percent units for experiments 1 and 2, respectively).These results were only significant in experiment 1, when compared to grazing only. In experiment 2 the starchy concentrate produced an increase in plasma glucose concentration and a decrease in plasma BHBA and urea-N concentrations. Under these conditions, the results suggest that carbohydrate source did not affect the productive performance of dairy cows but it did improve the metabolic condition.

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