Blood gases and metabolite content and ruminal fermentation in response to diets with different fermentability in Holstein dairy cows

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Abstract   The objective of this study was to determine the effects of diets having different fermentability on blood gases, blood metabolites and ruminal fermentation parameters in Holstein dairy cows. Four multiparous Holstein dairy cows (665 ± 25 kg BW, 170 ± 7.0 DIM and 15 ± 1.5 kg of milk yield), fitted with rumen cannulae, were used in a 4×4 Latin Square design with 28-d periods. Corn starch and sucrose were added to diets and corn starch was replaced with sucrose at 0 (diet 1), 25 (diet 2), 50 (diet 3) and 75 g (diet 4) per kg diet dry matter in diets containing 600g concentrate and 400g forage. Dry matter intake (DMI), body weight changes (BWC) and milk yield were not affected by the diets ($P > 0.05$). Milk fat content increased by replacing starch with sucrose ($P \leq 0.05$). Milk protein concentration (%) tended to increase by replacing starch with sucrose ($P = 0.06$). Inclusion of sucrose in the diet did not affect ruminal pH (averaged 6.41) but reduced ($P \leq 0.05$) ruminal NH_3-N concentration. Total volatile fatty acids (VFA) and molar proportion of most of the individual VFA were unaffected by diets except for the molar proportion of butyrate that was increased with increasing levels of sucrose ($P \leq 0.05$). Total branched chain VFA also tended ($P = 0.06$) to increase with sugar levels. Blood gases and metabolites were not affected but blood urea N which was decreased ($P \leq 0.05$) by increasing the level of sucrose in the diets. In conclusion, dairy cows fed diets containing sucrose had lower ruminal NH_3 and BUN concentrations without any adverse effects on rumen fermentation characteristics, and blood gases and metabolites. This indirectly shows reduced nitrogen excretion to the environment which is critical for decreasing environmental pollution.

Keywords: diet fermentability, gases, metabolites, fermentation, dairy cows

Introduction

Carbohydrates are the major source of energy for dairy cows and contribute more than 700 g/kg dry matter (DM) of the total diet. Sugars, starches and other carbohydrates such as galactans and pectin constitute the highly digestible nonfiber carbohydrates (NFC) fraction of the dairy diets. Although these carbohydrates have similar fermentation characteristics, they greatly vary in their digestion rate and fermentation end products. Therefore, they have different effects on ruminal pH (Strobel and Russell, 1986; Khalili and Huhtanen, 1991), nitrogen metabolism (Khezri et al., 2009; Sannes et al., 2002) and fiber digestion (Heldt et al., 1999; Miron et al., 2002).

Rumen ammonia concentration is inversely related to the rate of energy fermentation and loss of ammonia in the rumen is the main reason for low efficiency of N utilization for milk protein synthesis in high producing dairy cows (Tamminga, 1992). The efficiency of dietary N utilization may be improved with synchronization of carbohydrate and protein fermentation in the rumen (Hristov and Jouany, 2005; Khezri et al., 2009). According to Cornell Net Carbohydrate and Protein (CNCPS) system, sugars have a fast degradation rate, and starch an intermediate rate (Sniffen et al., 1992). Rapid fermentation of sugars relative to the other carbohydrate fractions seems to be effective in reducing loss of $NH_3 - N$ in the rumen through providing proper rate of energy fermentation. Furthermore, ruminal pH and blood gases of dairy cows fed diets containing sugars should be considered to prevent ruminal acidosis. There are few reports (Ordway et al., 2002) studying the response of rumen N metabolism and blood gases to different levels of sucrose and starch in the dairy cow diets. Thus, the objective of this study was to determine the effects of dietary sucrose and starch on blood gases, blood metabolites and ruminal fermentation parameters in Holstein dairy cows.

Materials and methods

Cows and experimental design

Four multiparous lactating Holstein cows (665 ± 25 kg BW) previously fitted with rumen cannulae (10 cm i.d.; Bar-Diamond Inc., Parma, ID) and averaging 15 ± 1.5 kg in milk and 170 ± 7.0 days in milk were used in this experiment. Cows were housed in individual stanchions equipped with water troughs and bedded with rubber mats and straw. Cows had free access to salt stone. With the exception of the last days of each period, cows were allowed to exercise in a dry lot from 1200 to 1300 h. Diets were fed at 0800 and 1900 h for ad libitum intake to allow 10% orts with half of the daily feed being offered at each feeding. The cows were milked twice daily at the same time.

The experiment was designed as a 4×4 Latin Square with four periods of 28 days each. The first 21 days of each period were assigned for adaptation to the diet, and the remaining 7 days for data collection. Corn starch and sucrose were added to the diets, with corn starch being replaced by sucrose to prepare four experimental diets:

0.0 g sucrose + 75 g corn starch (0 SU + 75 CS), 25 g sucrose + 50 g corn starch (25 SU + 50 CS), 50 g sucrose + 25 g corn starch (50 SU + 25 CS), and 75 g sucrose + 0.0g corn starch (75 SU + 0 CS) per kg diet DM. Other dietary ingredients were alfalfa hay, corn silage, barley grain, soybean meal and mineral-vitamin premix (Table1).

Measurements and analytical methods

Dry matter intake (DMI) was measured daily, and samples of ingredients, diets and orts were collected for the last 5 days of each period. Body weight was measured at the beginning and at the end day of each period before feeding. Samples of individual feedstuffs, diets and orts were composited per cow and period, dried in a forced-air oven (60° C) and ground to pass a 1-mm screen in a Wiley Mill (Arthur H. Thomas, Philadelphia, PA). Ash content was determined by the method of AOAC, 2000 (ID 942.05). Nitrogen (N) content was measured by the Kjeldahl method (Kjeltec 2300 Autoanalyzer, Foss Tecator AB, Hogans, Sweden) and crude protein (CP) was calculated as N×6.25. Ash-free neutral detergent and

Table 1. Ingredients and chemical composition of the experimental diets (g/ kg DM)

	Diet			
	0 SU + 75 CS	25 SU + 50 CS	50 SU + 25 CS	75 SU+ 0 CS
Ingredients				
Alfalfa hay	300.0	300.0	300.0	300.0
Corn silage	100.0	100.0	100.0	100.0
Barley grain	250.0	250.0	250.0	250.0
Wheat bran	65.0	65.0	65.0	65.0
Soybean meal	192.0	192.0	192.0	192.0
Sodium bicarbonate	6.20	6.20	6.20	6.20
Calcium carbonate	3.30	3.30	3.30	3.30
Mineral-vitamin mixture [a]	8.50	8.50	8.50	8.50
Sucrose	0.00	25.0	50.0	75.0
Corn starch	75.0	50.0	25.0	0.00
Chemical composition				
Dry matter	702.4	703.1	706.3	701.9
Organic matter	921.3	927.5	928.8	924.7
Crude protein	170.1	171.9	173.6	172.8
Ether extract	21.5	21.8	20.1	21.7
Neutral detergent fiber[b]	329.2	330.6	322.8	324.6
Acid detergent fiber [c]	192.4	196.7	193.2	197.5
Starch	271.7	258.6	229.5	204.1
Sugar	33.0	60.2	81.3	110.9
Nonfiber carbohydrates[d]	400.5	403.2	412.3	405.6
NE_L[e] (MJ/kg)	6.89	6.93	6.90	6.97

0 SU + 75 CS= 0.0g sucrose + 75g corn starch, 25 SU + 50 CS= 25g sucrose + 50g corn starch, 50 SU + 25 CS= 50g sucrose + 25g corn starch, 75 SU+ 0 CS= 75g sucrose + 0.0g corn starch.

[a] Contained (DM basis) 65 mg of Zn, 51 mg of Mn, 22 mg of Fe, 15 mg of Cu, 0.9 mg of I, 0.5mg of Co, 0.4 mg of Se, 6640 IU of vitamin A, 2500 IU of vitamin D, and 17 IU of vitamin E.

[b] Ash-free neutral detergent fiber

[c] Ash-free acid detergent fiber

[d] Nonfiber carbohydrates calculated as (1000−(NDF, g/kg + CP, g/kg + ash, g/kg + fat, g/kg)).

[e] Estimated based on NRC (2001).

ash-free acid detergent fiber (NDF$_{om}$ and ADF$_{om}$) were determined without sodium sulfite and expressed exclusive of residual ash according to Van Soest et al. (1991). Starch and sugar contents of the total mixed ration (TMR) were analyzed by the methods of Hall et al. (1999).

Samples of ruminal fluid were collected from multiple sites in the rumen at 0, 1, 2, 4, 6, and 8 h after the morning feeding on the last two days of each experimental period. Samples of ruminal fluid were strained through two layers of cheesecloth and the pH was measured immediately, using a portable pH meter with a combination electrode. Ruminal fluid (8 mL) from each collection at 0, 2, 4, 6 and 8 h was mixed with 2 mL of 25% (wt/vol) metaphosphoric acid and frozen for VFA analysis and 20 mL was mixed with 20 mL 0.2 N HCl (Robles et al., 2007) and frozen for NH$_3$-N analysis. After thawing, ruminal fluid samples for VFA were centrifuged at 30,000 × g for 20 min. VFA concentrations were measured in the supernatant by gas chromatography (Model 5890, Hewlett-Packard, Avondale, PA) equipped with a 1.8m glass column packed with 10% SP 1200/1% H3PO4 on 80/100 chromosorb WAW (Supelco, 1975). Nitrogen was the carrier gas and the temperature of the injector port and column was 175 °C and 125°C, respectively. Ruminal NH$_3$-N was determined according to the procedures outlined by Crooke and Simpson (1971). Milk yield was recorded at the last week of each period. To determine milk composition, samples were collected at a.m. and p.m. milking on two consecutive days (days 25 and 26) of each period.

Blood was collected before morning feeding from the coccygeal vein into 10-ml heparinized, evacuated glass tubes and placed on crushed ice. A 1-mL syringe was filled with whole blood from the heparinized blood tube, capped to prevent air invasion, and immediately analyzed for blood gases and pH (System 1304 pH/blood gas analyzer; Instrumentation Laboratory, Lexington, MA). The blood in the 10-ml heparinized tube was centrifuged at 3,000 × g for 20 min at 4°C , and plasma stored at −20°C until further analysis.

Plasma samples were analyzed for glucose (Sigma Glucose Kit 510-A), blood urea nitrogen (BUN; Stanbio Urea N Kit 580), β-hydroxybutyric acid (BHBA; Ranbut kit, Randox, Rukkwamsuk et al., 1998) and NEFA (Wako NEFA C Kit No. 990-75401) as modified by Johnson and Peters (1993). Blood insulin concentration was determined by using a radioimmunoassay kit (Coat-A-Count, Insulin Kit No. TK1NX; Diagnostic Products, Los Angeles, CA).

Statistical analysis

The experiment was designed as a 4 ×4 Latin square with four periods of 28 days each, in which cows were randomly assigned to one of the four treatments. Lactation performance, body weight changes (BWC), DMI, concentrations of blood gases and metabolites were all analyzed using the MIXED procedure of SAS (2001) with a model that included treatment effect, period effect, random effect of cows and experimental error. Ruminal variables with repeated measurements over time (Littell et al., 2002), including ruminal pH, NH$_3$-N and VFA, were analyzed using the MIXED procedure of SAS (2001) with a model that included treatment effect, time effect, interaction between treatment and time, period effect, random effect of cows and experimental error. For ruminal fermentation parameters, a compound symmetric covariance structure was selected based on the Akaike Information Criterion (AIC) and orthogonal contrasts were used to test for linear and quadratic effects. Treatment differences with $P \leq 0.05$ were considered significant, whereas tendencies to differences were accepted if $0.05 < P < 0.10$.

Table 2. Effects of replacing dietary corn starch with sucrose on DM intake, milk yield, milk components and BWC in dairy cows

	Diets				SEM	Contrasts[d]	
	0 SU + 75 CS	25 SU + 50 CS	50 SU + 25 CS	75 SU + 0 CS		Linear	Quadratic
Dry matter intake (kg/d)	14.11	14.50	14.73	15.12	0.53	0.11	0.42
Milk (kg/d)	15.86	16.45	16.68	15.96	0.73	0.79	0.68
Fat (%)	3.47[b]	3.51[b]	3.75[a]	3.88[a]	0.06	0.04	0.56
Protein (%)	3.05	3.11	3.28	3.17	0.05	0.06	0.72
Lactose (%)	4.88	5.03	5.00	4.92	0.07	0.23	0.61
3.5 FCM[c] (kg/d)	16.39	16.25	17.45	17.24	0.59	0.16	0.46
Body weight change (kg/d)	0.57	0.47	0.44	0.50	0.07	0.51	0.59

[a, b] Means in the same row with different superscripts differ significantly ($P \leq 0.05$).

0 SU + 75 CS= 0.0g sucrose + 75g corn starch, 25 SU + 50 CS= 25g sucrose + 50g corn starch, 50 SU + 25 CS= 50g sucrose + 25g corn starch, 75 SU+ 0 CS= 75g sucrose + 0.0g corn starch.

[c] 3.5% Fat corrected milk, calculated as 3.5% FCM = (Milk kg × .432) + (Fat kg × 16.216).

[d] Probability of linear and quadratic orthogonal contrasts for the effects of dietary treatments.

Results

DMI, milk yield, milk compositions and BWC

Inclusion of sucrose into diets did not affect DMI, BWC and milk yield of dairy cows. A linear increase ($P \leq$ 0.05) was observed for milk fat content in response to NFC (replacing corn starch with sucrose) in diets (Table 2). Furthermore, milk protein concentration (%) tended to increase ($P = 0.06$) with sucrose inclusion.

Ruminal fermentation

Although the mean ruminal pH for diet 4 (75 SU+ 0 CS) was numerically lower compared with other diets (Table 3), there was no treatment effect for this variable ($P >$ 0.05). Increasing the level of sucrose in the diets linearly affected ($P \leq 0.05$) the ruminal NH_3 - N concentrations (Table 3). Total VFA (averaged 110.54 mmol/L) and molar proportion of most VFA were unaffected by the diet except for the molar proportion of butyrate that increased linearly with increasing levels of sucrose ($P \leq$ 0.05). Total branched chain VFA tended ($P = 0.06$, Table 3) to decrease with sucrose supplementation.

Blood gases and metabolites

Data on blood metabolites, pH, HCO_3, O_2 saturation and partial pressure of O_2 (pO_2) and CO_2 (pCO_2) are presented in Table 4. Replacing corn starch with sucrose in the diets did not affect blood gases, glucose, insulin, BHBA and NEFA concentrations, but BUN was decreased linearly ($P \leq 0.05$) with increasing levels of sucrose in the diet.

Discussion

Milk yield, DMI and BWC were similar among diets in this study. These results were consistent with some rese-

arches (McCormick et al., 2001; Penner et al., 2009) but not with others (Broderick, 2008; Penner and Oba, 2009). Penner et al. (2009) reported that feeding sucrose at 57 g/kg of diet DM did not affect DMI, milk production and BWC but Broderick (2008) showed a linear increase in DMI of lactating cows in response to sucrose supplementation. The concomitant effect of reduction in starch concentration with sucrose inclusion in the diet seems to be through the rate of energy supply for rumen microbial growth and in turn the fermentation process. According to some reports (Khalili and Huhtanen, 1991; Plaizier et al., 1999) sucrose improves the palatability of the diet or increases the rate of passage in the rumen. This might explain the numerical increase in DMI observed in our study (Table 2). Moreover, although the effects of sucrose supplementation were not consistent among reportedstudies, to our knowledge, there is no report showing any negative effect of feeding sugars on DMI. In our study, increasing levels of sucrose in increased the mik fat percentage. Ordway et al. (2002) reported a numerical increase in milk fat percentage (3.76 vs. 3.54%) when sucrose was substituted for 2.7% ground corn in theprepartum diet. It seems that high starch diets affect biohydrogenation of fatty acids via their effects on rumen microbial population (Jenkins et al., 2008), resulting in milk fat depression as observed for diet 1 in our study. Butyrate is a substrate in *de novo* fatty acid synthesis (Van Soest, 1994), and the increased butyrate content in the diet 4 (Table 3), might explain the increased milk fat percentage in cows supplemented with sucrose. In our study, sucrose tended to increase milk protein percentage. Rapid fermentation of sucrose in comparison to corn starch is expected to increase ruminal microbial protein production and in turn milk protein content (Khezri et

Table 3. Effects of replacing dietary corn starch with sucrose on ruminal fermentation parameters in dairy cows

	Diets				SEM	Contrasts [e]	
	0 SU + 75 CS	25 SU + 50 CS	50 SU + 25 CS	75 SU + 0 CS		Linear	Quadratic
pH	6.46	6.49	6.38	6.31	0.09	0.52	0.64
NH_3- N (mg/dl)	17.09 [a]	16.37 [a]	13.90 [b]	14.36 [b]	0.37	0.05	0.49
Total VFA[c] (mmol/L)	105.38	112.35	113.24	111.17	3.89	0.43	0.37
VFA (mol/100 mol)							
Acetate (A)	61.01	61.15	62.11	61.28	1.41	0.26	0.28
Propionate (P)	23.38	23.22	22.44	21.86	0.44	0.19	0.23
Butyrate	11.76 [b]	11.94 [b]	12.35 [ab]	13.57 [a]	0.31	0.04	0.11
BCVFA[d]	3.85	3.69	3.10	3.29	0.17	0.06	0.17
A:P ratio	2.62	2.65	2.79	2.83	0.07	0.10	0.25

[a, b] Means in the same row with different superscripts differ significantly ($P < 0.05$).
0 SU + 75 CS= 0.0g sucrose + 75g corn starch, 25 SU + 50 CS= 25g sucrose + 50g corn starch, 50 SU + 25 CS= 50g sucrose + 25g corn starch, 75 SU+ 0 CS= 75g sucrose + 0.0g corn starch.
[c]Volatile fatty acids.
[d] Branched chain volatile fatty acids.
[e] Probability of linear and quadratic orthogonal contrasts for the effects of dietary treatments.

al., 2009). These responses are consistent with lower ruminal NH_3 - N concentrations caused by sucrose (Table 3) and suggest a potential for improving the efficiency of dietary N utilization.

Rumen pH is expected to be lower for diets containing sugars, due to the rapid fermentation of sugars relative to the other carbohydrate fractions. In the current study, mean rumen pH was not affected when corn starch was replaced by sucrose (Table 3). These results are in agreement with some studies (Broderick et al., 2000; Sannes et al., 2002), but not others (Khalili and Huhtanen, 1991; Lee et al., 2003) who reported significant effect of sucrose on ruminal pH. Differences between some studies and our study could be attributed to the fact that for example in the study of Lee et al. (2003), sucrose inclusion increased linearly the total content of dietary NFC, whereas in our study, replacing sucrose for starch did not affect the NFC content of diets (Table 1). Feeding rapidly fermentable carbohydrates has been reported to capture more ruminally degradable nitrogen (Sniffen et al., 1992), and there are some reports that dietary inclusion of sucrose decreased NH_3- N concentration in rumen fluid (Chamberlain et al., 1993; Sannes et al., 2002; Broderick et al., 2008) which are consistent with our results. In another study (Vallimont et al., 2004), NH_3 - N concentration was not affected by inclusion of sucrose in the diets and averaged 9.22 mg/dL. In the present study, the mean rumen NH_3 - N concentrations for all diets remained above the value of 5 mg/dl suggested (Satter and Slyter, 1974) as the minimum necessary for maintenance of ruminal bacterial growth. The reduction in ruminal NH_3 - N for high-sucrose diets may suggest a more efficient utilization of the rapidly

rapidly available N components in the diet and a concomitant increase in microbial growth and metabolism. The effects of feeding sugar on rumen fermentation have been considerably variable (Sannes et al., 2002; McCormick et al., 2001; Lee et al., 2003). In the current study, total VFA were not affected by sucrose supplementation. Sannes et al. (2002) also reported no effect of including 32 g sucrose/kg of diet on total VFA concentration (127.1 mmol/L), but Lee et al. (2003) reported a linear increase in total VFA concentration from 133.3 to 143.1 mmol/L as the amount of infusion of sucrose into the rumen increased linearly. Concentrations of VFA represent a balance between production and disappearance, and differences in production rate may not be apparent from VFA concentrations (Leng, 1970). Among individual VFA, molar proportion of butyrate was increased with increasing levels of sucrose in the current study. These findings agree with some researches (Vallimont et al., 2004; Ribeiro et al., 2005) but not others (Broderick et al., 2008; Penner and Oba, 2009). In our study, supplementation of the diets with sucrose tended to reduce total branched chain VFA concentrations. Sannes et al. (2002) also reported a decrease in total branched-chain VFA when a portion of corn was replaced by sucrose in the diets fed to lactating cows. Branched chain VFA are produced in the rumen from deamination and decarboxylation of branch-chained amino acids (Allison, 1970). Ruminal branched-chain amino acids may arise from feed protein or microbial protein, and differences in branched chain VFA concentrations probably reflect differences in one or both of these components. Furthermore, replacing corn starch with sucrose might reduce proteolysis through supply-

Table 4. Effects of replacing dietary corn starch with sucrose on blood gases and metabolites in dairy cows

| | Diets | | | | | Contrasts[f] | |
	0SU + 75CS	25SU + 50CS	50SU + 25CS	75SU + 0CS	SEM	Linear	Quadratic
pH	7.46	7.41	7.43	7.44	0.02	0.61	0.92
pO_2 (mm Hg)	84.75	80.74	82.41	81.86	3.77	0.79	0.85
pCO_2 (mm Hg)	36.98	38.42	37.65	37.25	0.94	0.75	0.86
O_2 saturation (%)	96.32	95.36	94.99	97.13	1.39	0.73	0.91
HCO_3 (mmol/L)	28.51	26.10	27.58	26.41	1.35	0.39	0.73
Glucose (mg/dl)	63.12	65.94	63.33	62.70	4.26	0.31	0.57
NEFA[c] (mM/L)	0.29	0.21	0.28	0.32	0.04	0.24	0.36
BHBA[d] (mM/L)	0.35	0.30	0.38	0.41	0.08	0.42	0.49
Insulin (ng/ml)	0.66	0.69	0.62	0.60	0.07	0.39	0.53
BUN[e] (mg/dl)	16.05[a]	15.53[ab]	13.28[b]	14.17[b]	0.63	0.04	0.65

[a, b] Means in the same row with different superscripts differ significantly ($P < 0.05$).

0 SU + 75 CS= 0.0 g sucrose + 75 g corn starch, 25 SU + 50 CS= 25 g sucrose + 50 g corn starch, 50 SU + 25 CS= 50 g sucrose + 25 g corn starch, 75 SU+ 0 CS= 75 g sucrose + 0.0 g corn starch.

[c] NEFA: nonesterified fatty acids.

[d] BHBA: β-hydroxybutyric acid.

[e] BUN: Blood urea nitrogen.

[f] Probability of linear and quadratic orthogonal contrasts for the effects of dietary treatments.

ing a faster source of ATP to the rumen, which caused lower ruminal NH_3 concentration (Table 3).

We were not able to find any report on the effect of the source of non-fiber carbohydrates on blood gases in dairy cows. In our study, lack of significant difference among blood parameters might be due to low DMI of experimental animals. Furthermore, no effect of replacing corn starch with sucrose on blood pH was expected, because the acid-base balance in blood is highly regulated, and blood is saturated with bicarbonate. Thus, blood pH rarely fluctuates (Owens et al., 1998). During metabolic acidosis, the concentration of blood CO_2 increases due to the reduction of the blood bicarbonate ion (Owens et al., 1998). Considering the results of ruminal fermentation characteristics and blood gases in the our study, it appears that rapid disappearance of sugar in comparison to starch per se does not necessarily mean extensive fermentation acid production and low rumen pH.

Among the blood metabolites data, BUN was affected by inclusion of sucrose in the diets (Table 4). Sannes et al. (2002) reported that inclusion of sucrose in the diet of dairy cows reduced the milk urea N concentration. Urea, being a small neutral molecule, readily diffuses across cell membranes. As milk is secreted in the mammary gland, urea diffuses into and out of the mammary gland, equilibrating with urea in the blood. Because of this process, milk urea nitrogen (MUN) equilibrates with BUN (Roseler et al., 1993). The results of low BUN in dairy cows fed high sucrose diet are consistent with the lower ruminal NH_3 - N caused by sucrose (Table 3) and the reports by others (Sannes et al., 2002; Broderick et al., 2008), suggesting a positive effect of sucrose on ruminal NH_3 metabolism and dietary rumen degradable protein utilization in dairy cows (Khezri et al., 2009).

Conclusions

Replacing corn starch with sucrose, decreased ruminal NH_3 and BUN concentrations which is an indication of enhanced N utilization efficiency. The lack of an adverse effect of sucrose inclusion on blood gases, blood metabolites and rumen fermentation characteristics implies that rapid disappearance of sugar in comparison to starch per se does not necessarily mean extensive fermentation and acid production, and low rumen pH and may be a good nutritional strategy for dairy cows especially during early lactation.

Acknowledgments

References

Allison, M.J., 1970. Nitrogen metabolism of ruminal microorganisms. In: Phillipson, A.T. (Eds.) Physiology of Digestion and Metabolism in the Ruminant. Oriel Press, Newcastle Upon Tyne, UK. pp. 456.

AOAC, 2000. Official Methods of Analysis, 17th ed. Official Methods of Analysis of AOAC International, Gaithersburg, MD, USA.

Broderick, G.A., Luchini, N.D., Reynal, S.M., Varga, G.A., Ishler, V.A., 2008. Effect on production of replacing dietary starch with sucrose in lactating dairy cows. *Journal of Dairy Science* 91, 4801-4810.

Broderick, G.A., Luchini, N.D., Smith, W.J., Reynal, S., Varga, G.A., Ishler, V.A., 2000. Effect of replacing dietary starch with sucrose on milk production in lactating dairy cows. *Journal of Dairy Science* 83(Suppl. 1), 248.

Chamberlain, D.G., Robertson, S., Choung, J.J., 1993. Sugars versus starch as supplements to grass silage: effects on ruminal fermentation and the supply of microbial protein to the small intestine, estimated from the urinary excretion of purine derivatives, in sheep. *Journal of the Science of Food and Agriculture* 63, 189-194.

Crook, W.M., Simpson, W.E., 1971. Determination of ammonium in Kjeldahl digest of crops by an automated procedure. *Journal of the Science of Food and Agriculture* 22, 9-11.

Hall, M.B., Hoover, W.H., Jennings, J.P., Webster, T.K.M., 1999. A method for partitioning neutral detergent-soluble carbohydrates. *Journal of the Science of Food and Agriculture* 79, 2079-2086.

Heldt, J.S., Cochran, R.C., Mathis, C.P., Woods, B.C., Olson, K.C., Titgemeyer, E.C., Nagaraja, T.G., Vanzant, E.S., Johnson, D.E., 1999. Effects of level and source of carbohydrate and level of degradable protein on intake and digestion of low-quality tallgrass-prairie hay by beef steers. *Journal of Animal Science* 77, 2846-2854.

Hristov, A.N., Jouany, J.P, 2005. Factors affecting the efficiency of nitrogen utilization in the rumen. In: Pfeffer, E ., Hristov, A.N. (Eds.) Nitrogen and phosphorus nutrition of cattle. CABI Publishing, Cambridge, USA. pp. 117-166.

Jenkins, T.C., Wallace, R.J., Moate, P.J., Mosley, E.E, 2008. Recent advances in biohydrogenation of unsaturated fatty acids within the rumen microbial ecosystem. *Journal of Animal Science* 86, 397-412.

Johnson, M.M., Peters, J.P., 1993. Technical note: An improved method to quantify nonesterified fatty acids in bovine plasma. *Journal of Animal Science* 71, 753-756.

Khalili, H., Huhtanen, P., 1991. Sucrose supplements in cattle given grass silage-based diet. Digestion of cell wall carbohydrates. *Animal Feed Science and Technology* 33, 263-273.

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Khezri, A., Rezayadi, K., Danesh- Mesgaran, M., Moradi Shahrbabak, M., 2009. Effect of different rumen-degradable carbohydrates on rumen fermentation, nitrogen metabolism and lactation performance of Holstein dairy cows. *Asian- Australian Journal of Animal Sciences* 5, 651- 658.

Lee, M.R.F., Merry, R.J., Davies, D.R., Moorby, J.M., Humphreys, M.O., Theodorou, M.K., MacRae, J.C., Scollan, N.D., 2003. Effect of increasing availability of water-soluble carbohydrates on in vitro rumen fermentation. *Animal Feed Science and Technology* 104, 59-70.

Leek, B.F., 1993. Digestion in the ruminant stomach. In: Swenson, M.J., Reece, W.O. (Eds.) Dukes' physiology of domestic animals. 11th ed. Cornell University Press, Ithaca, NY, pp. 387-416.

Leng, R.A., 1970. Formation and production of VFA in the rumen. In: Phillipson, A.T. (Eds.) Physiology of Digestion and Metabolism in the Ruminant. Oriel Press, Newcastle upon Tyne, UK. pp. 406-421.

Littell, R.C., Stroup,W.W., Freund, R.J., 2002. SAS for Linear Models, 4th Ed. SAS Institute Inc, NC, USA.

McCormick, M.E., Redfearn, D.D., Ward, J.D., Blouin, D.C., 2001. Effect of protein source and soluble carbohydrate addition on rumen fermentation and lactation performance of Holstein cows. *Journal of Dairy Science* 84, 1686-1697.

Miron, J., Yosef, E., Ben-Ghedalia, D., Chase, L.E., Bauman, D.E., Solomon, R., 2002. Digestibility by dairy cows of monosaccharide constituents in total mixed ration containing citrus pulp. *Journal of Dairy Science* 85, 89-94.

NRC., 2001. Nutrient Requirements of Dairy Cattle, 7th Ed. National Academy Press, Washington, DC.

Ordway, R.S., V.A. Ishler, and G.A. Varga. 2002. Effects of sucrose supplementation on dry matter intake, milk yield, and blood metabolites of periparturient Holstein dairy cows. *Journal of Dairy Science* 85, 879-888.

Owens, F.N., Secrist, D.S., Hill, W.J., Gill, D.R., 1998. Acidosis in cattle: A review. *Journal of Animal Science* 76, 276-286.

Penner, G.B., Guan, L.L., Oba, M., 2009. Effect of feeding Fermenten on ruminal fermentation in lactating Holstein cows fed two dietary sugar concentrations. *Journal of Dairy Science* 92, 1725-1733.

Penner, G.B., Oba, M., 2009. Increasing dietary sugar concentration may improve dry matter intake, ruminal fermentation, and productivity of dairy cows in the postpartum phase of the transition period. *Journal of Dairy Science* 92, 3341-3353.

Plaizier, J.C.B., Nkya, R., Shem, M.N., Urio, N.A., McBride, B.W., 1999. Supplementation of dairy cows with nitrogen molasses mineral blocks and molasses urea mix during the dry season. *Journal of Animal Science* 5, 735-741.

Ribeiro, C.V.D.M., Karnati, S.K.R., Eastridge, M.L., 2005. Biohydrogenation of fatty acids and digestibility of fresh alfalfa or alfalfa hay plus sucrose in continuous culture. *Journal of Dairy Science* 88, 4007-4017.

Robles,V., González, L.A., Ferret, A., Manteca, X., Calsamiglia, S., 2007. Effects of feeding frequency on intake, ruminal fermentation, and feeding behavior in heifers fed high-concentrate diets. *Journal of Animal Science* 85, 2538-2547.

Roseler, D.K., Ferguson, J.D., Sniffen, C.J., Herrema. J., 1993. Dietary protein degradability effects on plasma and milk urea nitrogen and milk nonprotein nitrogen in Holstein cows. *Journal of Dairy Science* 76, 525-534.

Rukkwamsuk, T., Wensing, T., Geelen. M.J., 1998. Effect of overfeeding during the dry period on regulation of adipose tissue metabolism in dairy cows during the periparturiant period. *Journal of Dairy Science* 81, 2904-2911.

Sannes, R.A., Messman, M.A., Vagnoni, D.B., 2002. Form of rumen-degradable carbohydrate and nitrogen on microbial protein synthesis and protein efficiency of dairy cows. *Journal of Dairy Science* 85, 900-908.

SAS, 2003. User's Guide: Statistics, Version 9.1 Edition. SAS Inst., Inc., Cary, NC, USA.

Satter, L.D., Slyter, L.L., 1974. Effect of ammonia concentration on rumen microbial protein production in vitro. *British Journal of Nutrition* 32,199-208.

Sniffen, C.J., O'Connor, J.D., Van Soest, P.J., Fox, D.G., Russell, J.B., 1992. A net carbohydrate and protein system for evaluating cattle diets. II. Carbohydrate and protein availability. *Journal of Animal Science* 70, 3562-3577.

Strobel, H.J., Russell, J.B., 1986. Effect of pH and energy spilling on bacterial protein synthesis by carbohydrate-limited cultures of mixed rumen bacteria. *Journal of Dairy Science* 69, 2941-2947.

Supelco, Inc., 1975. GC Separation of VFA C2-C5. Tech. Bull. 749D. Supelco, Inc., Bellefonte, PA.

Tamminga, S., 1992. Nutrition management of dairy cows as a contribution to pollution control. *Journal of Dairy Science* 75, 345-357.

Vallimont, J.E., Bargo, F., Cassidy, T.W., Luchini, N.D., Broderick, G.A., Varga, G.A. 2004. Effects of replacing dietary starch with sucrose on ruminalfermentation and nitrogen metabolism in continuous culture. *Journal of Dairy Science* 87, 4221-4229.

Van Soest, P.J., Roberson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* 74, 3583-3597.

Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant. 2th Ed. Cornell Univ. Press, Ithaca, NY.

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مطالعه گازها، متابولیت های خونی و تخمیر شکمبه ای در پاسخ به استفاده از جیره های با نرخ تخمیر متفاوت در گاوهای شیرده

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چکیده   هدف این مطالعه ارزیابی اثرات اســـتفاده از جیره های با نرخ تخمیر متفاوت بر گازها، متابولیت های خونی و فراســنجه های تخمیر شــکمبه ای در گاوهای شـیرده هلشتاین می باشد. چهار راس گاو شیرده چند شکم زایش هلشتاین (وزن بدنی ۶۶۵± ۲۵، روزهای شـیردهی ۷ ± ۱۷۰، تولید شـیر ۱/۵ ± ۱۵) دارای کانولای شکمبه ای در یک طرح مربع لاتین ۴×۴ با۴ دوره ۲۸ روزه اسـتفاده شـد. نشـاسـته ذرت و ساکارز به جیره ها اضافه شدند و نشاسته ذرت در سطوح صفر (جیره ۱)، ۲۵ (جیره ۲)، ۵۰ (جیره ۳) و ۷۵ (جیره ۴) گرم در کیلوگرم ماده خشک در جیره های دارای ۶۰۰ گرم کنسـانتره و ۴۰۰ گرم علوفه جایگزین گردید. در این مطالعه، ماده خشک مصرفی، تغییرات وزن بدن و تولید شیر گاوهای شـیرده تحت تاثیر جایگزینی نشـاسـته ذرت با سـاکارز قرار نگرفتند (0.05 < P). مقدار چربی شـیر گاوها تحت تاثیر جایگزینی نشاسته ذرت با ساکارز، افزایش یافت (0.05 ≥ P). علاوه براین با جایگزینی نشاسته ذرت با ساکارز ، درصد پروتئین شـیر تمایل به افزایش داشت(P = 0.06). اضافه کردن سـاکاز به جیره گاوها اثری بر pH شـکمبه نداشت (میانگین ۶/۴۱) اما غلظت نیتروژن آمونیاکی شکمبه را کاهش داد (0.05 ≥ P).کل غلظت اسیدهای چرب فرار و نسبت مولی اکثر اسـیدهای چرب فرار به اسـتثناء بوتیرات تحت تاثیر جیره های آزمایشـی قرار نگرفت. علاوه براین کل غلظت اسـیدهای چرب فرار شـاخه دار تمایل به افزایش با اضـافه کردن سـاکارز به جیره گاوها داشـت (P = 0.06). در این آزمایش اضافه کردن ساکارز در مقابل نشاسته ذرت به جیره گاوها، گازها و متابولیت های خون را تحت تثیر قرار نداد به اسـتثناء نیتروژن اوره ای خون که با افزایش سـطح سـاکارز در جیره ها، کاهش یافت (0.05 ≥ P). به طورکلی در این مطالعه، گاوهای تغذیه شـده با سـطوح بالای سـاکارز بدون داشـتن اثرات منفی بر خصوصیات تخمیری شکمبه، گازها و متـابولیت های خون دارای مقدار پایین تر غلظت نیتروژن آمونیاکی شـــکمبه و نیتروژن اوره ای خون بودند. این نتایج به طور غیر مستقیم نشان دهنده کاهش دفع نیتروژن به محیط و کاهش آلودگی زیست محیطی می باشد.