Impact of Corn Silage Inclusion on Nutrient Digestion and Rumen Fermentation in Finishing Cattle

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Summary with Implications

A digestion study was conducted comparing different inclusions of corn silage used as a roughage source on digestibility, feeding behavior and rumen environment. Treatments consisted of 3 inclusions of corn silage at 0, 7.5 and 15% of the diet DM, and a control treatment with 7.5% alfalfa. As expected, increasing available energy and decreasing roughage (either silage or alfalfa) showed an increase in diet digestibility and ruminal propionate concentrations. However, average ruminal pH was least, with more time spent in subacute acidosis (pH < 5.3) when cattle were fed no roughage. These data suggest that feeding cattle increasing silage inclusions as a roughage source prevented ruminal conditions from entering and remaining in subacute acidosis. Feeding corn silage at 15% gave similar digestibility responses compared to 7.5% alfalfa. Including silage as a roughage source at 15% could help prevent acidosis and digestive upset in feedlot cattle.

Introduction

Feeding a high grain diet increases the risk for acidosis and liver abscesses in feedlot cattle. Roughages are included in feedlot rations to help minimize the risk for digestive upset caused by highly fermentable carbohydrate by buffering rumen pH. Corn silage is fed as a roughage source in many feedlots. However, it is necessary to consider the grain portion of corn silage when deciding inclusion levels in a feedlot diet. Because corn silage is approximately 50% corn grain and 50% roughage, greater inclusions may be required to achieve the same buffering capacity as a traditional forage.

The objective of this study was to determine the effects of feeding no roughage, 7.5% or 15% corn silage, compared to feeding alfalfa hay at 7.5% of diet DM, on ruminal pH, VFA concentrations, and digestibility.

Procedure

A digestion study was conducted using 4 ruminally cannulated steers (948 lbs ± 0.04 lbs) in a row-column design. Steers were assigned randomly to the same 4 treatments as described in the performance study (*2019 Nebraska Beef Cattle Report*, pp. 63–65); 3 inclusions of corn silage at 0 (CS0), 7.5 (CS7.5) or 15% (CS15) of the diet DM and a control treatment with 7.5% alfalfa (Alf). The study consisted of 8 periods, 21 days long with 17 days of adaptation and 4 days of collection. One steer was removed from study due to the steer removing the rumen canula during multiple periods.

Steers were fed once daily at 0800 h. Feed refusals were removed daily prior to feeding. Refusals were collected on d 17 to 21. Each pen was fitted with a feed bunk that was suspended from a load cell to determine the eating behavior of each animal and weight measurements were recorded every 5 seconds. These measurements were averaged by minute and analyzed for number of meals, length of meal, and average amount eaten at each meal. A meal was considered the change in weight, greater than or equal to 0.15 lbs, before or after a 10-minute period of inactivity (rest period).

Steers were dosed 2 times, daily, on days 10–20, intraruminally, with titanium dioxide (10 g/d) to determine fecal output. Fecal grab samples were taken at 0800, 1200, 1600, and 2000 h and composited wet on days 17–20. The lyophilized and ground daily composites were then composited on a dry weight basis by steer within collection period. Fecal samples were analyzed for titanium dioxide concentration and used to determine total tract digestibility. Feed and fecal samples were also analyzed for gross energy content (calories/g) using a bomb calorimeter. Digestible energy was calculated by subtracting the fecal energy from the total gross energy intake. Wireless pH loggers were submerged into the rumen on day 14. Ruminal pH was measured every 5 seconds and averaged per minute on days 17–21. Dry bran (0.5 g) was placed in 5 × 10 cm in situ bags. In situ bags (6) were submerged into the rumen for 24 h on day 20. NDF disappearance was determined using the Ankom Fiber Analyzer. Samples of individual ingredients were taken prior to mixing diets, composited by period, lyophilized and ground through a 1-mm screen using a Wiley mill. Feed and fecal samples were analyzed for nutrient composition.

Rumen fluid was analyzed for VFA concentration following collections on day 20 at 0800, 1000, 1200, and 1400 h using a vacuum hand pump. Once samples thawed, they were analyzed for VFA concentration using gas chromatography.

Digestibility, in situ DM disappearance, gas production and gas production rate data were analyzed with 3 steers using the MIXED procedure of SAS with treatment and period as fixed effects and steer as random. Orthogonal contrasts were used to determine linear and quadratic relationships between CS0, CS7.5 and CS15. PROC MIXED was also used for VFA data where period, treatment, hour and the interaction between hour and treatment were included in the model with steer as random. Intake parameters were analyzed using PROC GLIMMIX with treatment as fixed effects and steer and period as random. The pH data were averaged over day and analyzed using the MIXED procedure of SAS with treatment, day and day by treatment interaction included in the model and day being considered a repeated measure with period as random. The pH data were also averaged over hour to analyze daily variation. Hourly pH data were analyzed the same as day but using hour as the repeated measure. Treatment differences were declared significant for all statistical analysis at $P \leq 0.10$.

Table 1. Diet intake and digestibility for steers fed corn silage at two levels as a roughage source compared to no roughage or an alfalfa control

	Treatment[1]					P–value[3]		
Item[2]	Alf	CS0	CS7.5	CS15	SEM	F-test	Linear	Quadratic
DM								
intake, lb	26.4	25.5	28.4	26.8	0.97	0.18	0.27	0.07
digestibility, %	74.2[b]	82.0[a]	76.6[b]	73.0[b]	1.26	< 0.01	<0.01	0.40
OM								
intake, lb	24.4	23.8	26.4	24.6	0.90	0.23	0.50	0.06
digestibility, %	75.2[bc]	82.8[a]	77.7[b]	73.5[c]	1.34	<0.01	<0.01	0.72
NDF								
intake, lb	6.25[a]	5.06[b]	6.34[a]	6.69[a]	0.22	<0.01	<0.01	0.11
digestibility, %	61.3[b]	72.5[a]	62.0[b]	56.9[b]	2.42	<0.01	<0.01	0.38
ADF								
intake, lb	2.86[ab]	1.84[c]	2.64[b]	3.10[a]	0.09	<0.01	<0.01	0.18
digestibility, %	55.5[b]	73.5[a]	58.0[b]	54.4[b]	2.46	<0.01	<0.01	0.03
DE, Mcal/lb	7.57[b]	8.40[a]	7.77[b]	7.52[b]	0.11	<0.01	<0.01	0.15
DE, Mcal/d	41.3	44.0	45.8	41.7	1.44	0.15	0.28	0.13
Bran in situ NDF digestibility, %[4]	20.9	20.1	21.1	20.3	1.34	0.94	0.90	0.60

[a-c]Means in a row with different superscripts are different (*P* < 0.10)

[1]Treatments included Alf: Alfalfa included at 7.5% of diet DM; CS0: contained no corn silage or alfalfa; CS7.5: corn silage included at 7.5% of diet DM; CS15: corn silage included at 15% of diet DM.

[2]DM: Dry matter; OM: Organic matter; NDF: Neutral detergent fiber; ADF: Acid detergent fiber; DE: Digestible energy;

[3]F-test comparing all 4 treatments, linear and quadratic effects of silage inclusion

[4]Incubated for 24 hours inside steers fed treatment diets

Table 2. Eating behavior of steers fed corn silage at two levels as a roughage source compared to no roughage or an alfalfa control

	Treatment[1]					P–value[2]		
Item	Alf	CS0	CS7.5	CS15	SEM	F-test	Linear	Quadratic
Meals, n	14.3	13.7	13.9	15.3	1.1	0.60	0.20	0.60
Time per meal, min	15.1[a]	15.3[a]	13.7[ab]	12.5[b]	1.3	0.10	0.10	0.90
Meal size, lb DM	1.96	1.90	2.14	1.99	0.08	0.80	0.72	0.38
Meal size/ total DMI, %	7.64	7.79	7.67	7.17	0.06	0.75	0.33	0.73
rate, lb DM/hr	8.12[bc]	7.68[c]	9.44[ab]	9.55[a]	0.31	0.09	0.04	0.22

[a-c]Means in a row with different superscripts are different (P < 0.10)

[1]Treatments included Alf: Alfalfa included at 7.5% of diet DM; CS0: contained no corn silage or alfalfa; CS7.5: corn silage included at 7.5% of diet DM; CS15: corn silage included at 15% of diet DM.

[2]F-test comparing all 4 treatments, linear and quadratic effects of silage inclusion

Results

There was a quadratic effect for DM intake from silage inclusion ($P = 0.07$; Table 1). These results were expected but differed from the performance study where no differences in intake or performance were observed (*2019 Nebraska Beef Cattle Report*, pp. 63–65). Steers fed Alf had similar intakes to all silage treatments ($P = 0.18$). Dry matter digestibility decreased linearly from CS0 to CS15 ($P < 0.01$). Steers fed Alf had similar DMD to both CS7.5 and CS15. Organic matter intake was not different for Alf and all silage treatments ($P = 0.23$) but showed a significant quadratic response to increasing inclusion of silage with CS7.5 having the greatest OMI ($P = 0.06$). There was a significant difference among all treatments ($P < 0.01$) for OMD where Alf was similar to both CS7.5 and CS15 but all lesser than CS0. There was a linear decrease in OMD with increasing silage inclusion ($P < 0.01$). There was a significant difference ($P < 0.01$) for NDF and ADF intake with CS0 having the least NDF and ADF intake followed by the other three treatments which were similar ($P < 0.01$). Digestibility of both NDF and ADF was greatest for CS0, followed by the other three treatments which were similar ($P < 0.01$). There was a linear decrease in digestibility as silage level increased ($P < 0.01$). Digestible energy (Mcal/lb) was greatest for CS0 ($P < 0.01$) and lesser but not different between Alf, CS7.5 and CS15. There was a tendency ($P = 0.15$) for DE intake (Mcal/d) to be greatest in cattle fed CS7.5 followed by CS0, CS15 and Alf treatments. There was no difference for *in situ* NDF digestibility on bran incubated for 24 hours across diet treatments ($P = 0.94$).

Cattle on all treatments consumed the same amount of meals, with the same meal size, and ate the same proportion as a total of their daily DMI at each meal (Table 2; $P = 0.60$). However, cattle fed CS0 and Alf spent the most time eating, and linearly decreased time spent eating when corn silage inclusion increased to 15% ($P = 0.10$). Similarly, cattle fed CS0 had a slower rate of intake per hour of time spent eating and linearly increased as silage inclusion increased ($P = 0.04$).

Average daily pH, minimum, and maximum pH linearly increased with increasing silage inclusion ($P < 0.01$; Table 3). Steers fed Alf had similar average, minimum, and maximum pH to steers fed CS15. There was a quadratic increase in magnitude and linear increase in variation of pH with increasing inclusions of silage ($P < 0.05$). Steers fed Alf had similar magnitude and variation as both CS7.5 and CS15. Maximum and minimum pH was least, but magnitude was also less for CS0 compared to CS7.5, CS15 or Alf.

Steers that received the CS0 treatment had increased time with ruminal pH below 5.6 and 5.3 and greater area below the curve for both 5.6 and 5.3 ($P < 0.01$). Animals fed CS0 spent over 19.7 hours in subacute acidosis (pH < 5.6) and 13.7 hours in acute acidosis (pH < 5.3). This is compared to 6.7 for both subacute and acute acidosis for animals fed the CS15 treatment. There was a linear decrease in time spent below 5.6

Table 3. Ruminal pH characteristics for steers fed corn silage at two levels as a roughage source compared to no roughage or an alfalfa control.

	Treatment[1]					*P*–value[3]		
Item[2]	Alf	CS0	CS7.5	CS15	SEM	F-test	Linear	Quadratic
Minimum	4.96[ab]	4.78[c]	4.86[bc]	4.98[a]	0.04	< 0.01	< 0.01	0.81
Maximum	6.47[a]	6.09[b]	6.39[a]	6.48[a]	0.06	< 0.01	< 0.01	0.15
Average	5.52[ab]	5.29[c]	5.42[b]	5.58[a]	0.05	< 0.01	< 0.01	0.83
Magnitude	1.51[a]	1.32[b]	1.53[a]	1.50[a]	0.06	0.03	0.02	0.09
Variation	0.124[a]	0.087[b]	0.125[a]	0.127[a]	0.014	0.16	0.05	0.31
Time < 5.6, min/d	911[bc]	1184[a]	1030[ab]	814[c]	67	< 0.01	< 0.01	0.71
Area < 5.6	296[bc]	505[a]	399[ab]	255[c]	52.1	< 0.01	< 0.01	0.77
Time < 5.3, min/d	480[bc]	821[a]	658[ab]	407[c]	90.7	< 0.01	< 0.01	0.60
Area < 5.3	83[b]	200[a]	141[ab]	73[b]	31.1	0.01	< 0.01	0.90

[a-c]Means in a row with different superscripts are different (*P* < 0.10)

[1]Treatments included Alf: Alfalfa included at 7.5% of diet DM; CS0: contained no corn silage or alfalfa; CS7.5: corn silage included at 7.5% of diet DM; CS15: corn silage included at 15% of diet DM.

[2]Average pH over 4 days; Time × Day was not significant (*P* > 0.58)

[3]F-test comparing all 4 treatments, linear and quadratic effects of silage inclusion

Table 4. Concentration of VFA for ruminal fluid collected from steers fed corn silage at two levels as a roughage source compared to no roughage or an alfalfa control.

	Treatment[1]					*P*–value[3]		
Item[2]	Alf	CS0	CS7.5	CS15	SEM	F-test	Linear	Quadratic
Propionate, %[4]	36.0[c]	44.2[a]	39.6[b]	37.2[c]	3.04	<0.01	0.02	<0.01
Acetate, %	47.3	40.8	46.6	48.8	4.87	0.12	0.6	0.02
Butyrate, %	10.1	7.80	7.72	8.70	1.1	0.1	0.36	0.11
Total VFA, mM	98[bc]	119[a]	108[ab]	86[c]	7.8	<0.01	0.15	<0.01
A:P ratio[5]	1.38[a]	0.84[c]	1.18[b]	1.31[ab]	0.18	<0.01	<0.01	<0.01

[a-c]Means in a row with different superscripts are different (*P* < 0.10

[1]Treatments included Alf: Alfalfa included at 7.5% of diet DM; CS0: contained no corn silage or alfalfa; CS7.5: corn silage included at 7.5% of diet DM; CS15: corn silage included at 15% of diet DM.

[2]Average concentration over 4 time points (0800 h, 1000 h, 1200 h, 1400 h); Time x Trt was not significant (*P* > 0.34)

[3]F-test comparing all 4 treatments, linear and quadratic effects of silage inclusion

[4]Percent of total VFA

[5]Acetate to propionate ratio

and 5.3 with an increase in silage inclusion (*P* < 0.01). The area under 5.6 and 5.3 also linearly decreased with increasing silage inclusion. Steers fed Alf had parameters, time and area below 5.6 and 5.3, which were more similar to CS15 than CS7.5.

Collected from rumen fluid (Table 4), molar concentrations of total VFA were greatest for CS0, followed by CS7.5 and Alf, and CS15 having the lowest concentration of total VFA (*P* < 0.01). Propionate concentration was greatest for CS0 (44.2%), followed by Sil 7.5 (39.6%), and least for Alf (36.0%) and CS15 (37.2%; *P* < 0.01). Acetate and butyrate concentrations were not significantly different among treatments (*P* ≥ 0.10). The A:P ratio was greatest for Alf (1.38) and CS15 (1.31) followed by CS7.5 (1.18) and least for CS0 (0.84; *P* <0.01). Steers fed Alf had similar propionate and total VFA concentrations to CS15 compared to CS7.5.

Conclusion

Results suggest that decreasing inclusion of silage increased the concentration of VFA and lowered ruminal pH, increasing potential risk for acidosis. Animals fed 15% corn silage had similar ruminal pH to animals fed 7.5% alfalfa and spent less time in subacute and acute acidotic conditions. Feeding 15% corn silage also yielded similar VFA concentrations to feeding alfalfa hay. Therefore, potential for acidosis is significantly decreased with increased pH, mitigating risk for digestive upset or death when steers are fed 15% corn silage.

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