FINAL REPORT

EFFECT OF SILAFERM TREATMENT OF CORN SILAGE ON MILK PRODUCTION, MILK COMPOSITION, AND LACTATION PERFORMANCE OF DAIRY COWS

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INTRODUCTION

Silaferm is a high crude protein silage preservative aid that has been demonstrated to improve nutritional value and stability of corn silage. Silaferm is manufactured as a coproduct to production of food grade amino acids and contains over 98% crude protein (DM basis) of which about 78% is nonprotein nitrogen equivalent with the majority of the balance as free amino acids. Silaferm also contains about 12% sugar. Thus it is an excellent source of readily degradable and soluble proteins as well as rapidly degraded carbohydrate in the form of sugar, making it complementary to corn silage as the primary ingredient in dairy cow diets.

When applied to corn silage upon ensiling, Silaferm has been demonstrated to improve dry matter recovery and decrease ethanol production, a byproduct of the presence of yeasts in silage. Silaferm has also been demonstrated to decrease the concentration of acid detergent fiber (ADF) in silage while increasing the crude protein content. Decreases in ADF generally indicate improved digestibility as ADF represents the least digestible portion of a forage. In accordance with the nutrient profiles observed with Silaferm treatment of corn silages, beef steers consuming Silaferm-treated corn silage had improved rate of gain and feed efficiency.

The majority of dairy cattle in the US are fed diets containing between 20 to 50% of DM as corn silage, representing a tremendous market potential for products that may improve efficiencies of production as feed costs have increased rapidly during the last 2 years. Research feeding Silaferm-treated corn silage to dairy cows, however, has not been conducted. Therefore, an experiment was designed to test the hypothesis, cows fed corn silage treated with Silaferm will demonstrate improved feed efficiency through increased fiber digestibility and improved protein utilization of corn silage. Our research objective was to quantify the effects of feeding Silaferm-treated corn silage to dairy cows on feed intake, milk production, milk composition, and feeding efficiency.

MATERIALS AND METHODS

Corn silage for the experiment was harvested at the South Dakota State University (SDSU) farms on September 20, 2007. Silage was kernel processed by the harvester and delivered to the SDSU Dairy Research and Training Facility (DRTF) in self-unloading silage wagons. Upon delivery at the dairy, silage was compressed into one of two 9’ × 100’ Ag Bags. The storage bags were filled sequentially, with silage in the first bag stored without any treatment. Silage placed into the second bag was treated with application of with amino acid fermentation coproducts (Silaferm, Ajinomoto USA, Inc., Eddyville, IA) via a prepared manifold attached to the bagger that distributed material evenly across the surface of the silage as it entered the bagger. An application rate of 5 gal/T was targeted, however, after completion of the application, inventory of remaining Silaferm, and estimation of the weight of silage, it was determined that the application rate was 3 gal of Silaferm/Ton of fresh silage. All silage was harvested on a single day from a single field planted to a single variety of corn. Harvest moisture averaged 60 ± 2%.

The production experiment was conducted from November 28, 2007 to February 13, 2008. For the experiment, twenty Holstein cows, 10 primiparous and 10 multiparous, that averaged 91 ± 56 DIM were used in randomized complete block design to evaluate effects of Silaferm-treated corn silage on milk production. All procedures in this study were carried out under approval of the South Dakota State University Animal Care and Use Committee. All cows were treated with bovine somatotropin (Posilac, Monsanto, Saint Louis, MO) at the same 14-d interval throughout the experiment. Cows were assigned to blocks based upon parity, DIM, and milk production before the start of the experiment and treatments were randomly assigned to cows within blocks. The experiment was conducted as a switchback with the last week before the start of the experiment for collection of covariate measures followed by two 28-d periods. Treatment diets contained either the control corn silage with no additives or the Silaferm-treated corn silage. Prior to the experiment, and during the covariate data collection, all cows were fed a common diet (Table 1, Covariate). Experimental diets (Table 1) were formulated with identical ingredient composition and consisted of either control or Silaferm –treated corn silage (48.7% of diet DM), alfalfa hay (12.2%), and a concentrate mix (39.1%). Diets were formulated to meet or exceed NRC requirements (NRC, 2001).

Cows were housed in a curtained free-stall barn and fed individually using Calan Broadbent feeder doors (American Calan, Inc., Northwood, N. H.). Cows were placed in the free-stall area and assigned to Calan feeding doors 2 wk before the start of collection of covariate data. Cows were individually fed the respective diets once daily (0800 h) for ad libitum consumption with continuous access to feed except during milking. Amounts fed and refused were recorded daily.

Samples of alfalfa hay, the high moisture corn grain, the concentrate mix, and complete diets were collected on alternate days during the last week of each period (4 samples/wk) made into composites by period and diet and stored at -20°C until analyses. Composites of samples were analyzed for DM (105ºC for 24 h), CP (AOAC, 1997) using a LECO-428 combustion analyzer (LECO Corp., St. Joseph, MI), and ether extract with petroleum ether (AOAC, 1997). Neutral detergent fiber (NDF) and ADF were measured using the ANKOM A200 (ANKOM Technology Corp., Fairport, NY) filter bag technique. Determinations of ADF were according to AOAC (973.18 C, 1997) whereas NDF was according to Van Soest et al. (1991) with the addition of 4 mL of α-amylase and 20 g of sodium sulfite. Starch was measured as dextrose after treating samples with glucoamylase using a YSI 2700 SELECT Biochemistry Analyzer (Yellow Springs, OH; Holm et al., 1986). Minerals were quantified according to AOAC methods (985.01, 1997) using an inductively coupled plasma spectrometer (Thermo Garrell Ash, Franklin, MA). Body weights and BCS (3 independent recorders; Wildman et al., 1982) were recorded at the beginning of the experiment and at the end of each period and weekly throughout the trial.

Samples of each corn silage, Silaferm-treated and control, were collected at 60 d after ensiling, at the end of the covariate feeding period (start of the 1st experimental period) and at the end of each experimental period. Corn silage samples were submitted to Dairyland labs in triplicate by each sampling date and analyzed as described above for other feedstuffs. Additional analysis for corn silage samples collected during the feeding periods included digestibilities of fiber and DM and ruminal starch accessibility (degree of starch access, DSA, Table 2), fermentation analysis (Table 3), and mold and yeast counts (Table 3). Data from six silage samples collected at the end of the feeding periods are reported as these collections corresponded to data collection for production and milk composition at these same days, though analysis of samples collected at the beginning of the experiment showed similar values.

Cows were milked daily at 0600, 1400, and 2100 h. Milk was sampled from all three milkings during three consecutive days at the end of each period. Daily composites of the milk samples were analyzed for fat, protein, and MUN (AOAC, 1997) by midinfrared spectrophotometry (Multispec; Foss Food Technology Corp., Eden Prairie, MN); SCC (AOAC, 1997) was determined using a Fossomatic 90 (Foss Food Technology Corp).

Data were analyzed using the mixed procedures of SAS (1996). Fixed effects were Silaferm-treated or control silage, parity, and experimental period. Random effects were cow within experimental group. Group was defined by whether cows received the Silaferm-treated or control silages during the first or second experimental period. Corresponding measures collected during the covariate period for each experimental variable were included in the model. Interactions of all effects were examined and removed from model as deemed nonsignificant. One cow was removed from analysis during period 2 because of severely declining milk production as lactation progressed. Model effects were considered significant at $P < 0.05$ with trends noted at $P < 0.10$.

RESULTS AND DISCUSSION

Nutrient Analysis of Silages

Initial analysis of samples of Silaferm-treated corn silage and the control silage collected at 60 d after ensiling indicated similar concentrations of crude protein for the silages (7.3 vs. 8.5% CP for Silaferm-treated and control silage, respectively). Concentrations of ADF (17.9 vs. 19.6%) and NDF (35.6 vs. 39.2%) were decreased for Silaferm treatment while starch (35.5 vs. 30.0) was increased by addition of Silaferm. Because of the inexplicably similar concentrations of CP, though other parameters responded as expected, the experimental diets were formulated identically so the nutrient profile of either corn silage would meet the nutrient requirements of the experimental cows (Table 1).

Analysis of samples of silage collected during the experiment though validated the inclusion of Silaferm to the treated silage (Table 2). Crude protein content of the Silaferm-treated silage was determined to be 9.4% for silage DM compared with 7.7% for the control silage. Soluble protein was increased slightly though not substantially in the Silaferm-treated silage. As previously tested, samples collected during the feeding period indicated concentrations of ADF and NDF were decreased in the Silaferm-treated silage. Contrary to initial determinations, analyzed concentrations of starch were not changed by addition of Silaferm (29.8 vs. 30.2 for Silaferm and control, respectively), though samples of complete diets indicated that starch concentrations were greater in Silaferm-treated corn silage (Table 4). Lastly, the increased concentration of sulfur in silaferm-treated silage is likely a result of contribution of sulfur from the Silaferm. Nutrient profiles of the two silages indicated that DM losses during storage were likely diminished by Silaferm.

To provide indication of the feeding value of the two silages, in vitro digestibility of fiber and dry matter were conducted. Silaferm treatment of the corn silage improved digestibilities of both NDF and total DM by two percentage units. Degree of starch access (DSA), a measure of ruminal availability of the grains in silages was also improved about two percentage units by Silaferm treatments. Because of all of the above, the total digestible nutrients (TDN) and net energy of lactation (NE_L) of the Silaferm-treated silage was improved by 2.3% and 50 kcal/kg compared with the control silage.

Fermentation Characteristics of Silages

Fermentation parameters (Table 3) were not greatly different between the two silages. Notably, ethanol, acetate, lactate, and total acids appeared to be increased by Silaferm treatment. Because the experiment was not designed to test fermentation parameters of the silages, it is not known whether these differences would prove significant. Standard deviations indicate that these would not be significant differences. Preservation of the silage appeared to be greatly improved however by Silaferm treatment. Though silages had similar yeast counts, the numbers of mold colonies were decreased greatly in Silaferm-treated corn silage. Control silage had a 5-fold greater content of molds. Differences were visibly detectable.

Nutrient Composition of Diets

Analysis of samples of diets collected during the experimental periods (Table 4), reflect the differences in nutrient content of the silages. Protein content of both diets was less than formulated while concentrations of ADF and NDF were greater than predicted. These differences from original formulation were attributed to decreased quality of the alfalfa hay and haylage that were included in the diet compared with pre-experiment determinations of the nutrient value of the stored feedstuffs. Differences between the Silaferm treatment diet and the control diet are entirely attributable to, and reflect, differences in nutrient profiles of the silages discussed above. Predicted NE_L and amount of milk production supported (NRC, 2001 model, data not shown) based upon nutrient profiles were similar for the two diets.

Production Performance of Cows

Dry matter intakes (Table 5) were not affected by the corn silages. This was somewhat surprising as the greater content of molds in the control silage was expected to cause a decrease in feed intake. Milk yields were increased by Silaferm treatments though, indicating greater nutrient utilization of the corn silage. Concentrations of fat, protein, lactose, and solids-not-fat (SNF) were not changed by treatment of the corn silage with Silaferm, but as milk yields increased with Silaferm treatment, yields of all milk components were increased. Lack of changes in milk urea nitrogen (MUN) indicate that protein utilization was similar between the two silages. The additional protein from Silaferm was well utilized by ruminal microbes and subsequently supported additional milk protein production. All of the above reflect significant increases in both fat- and energy-corrected milk yields by feeding cows corn silage treated with Silaferm. Feed efficiency (kg ECM/kg DMI) was numerically greater for the cows fed Silaferm-treated silage. here was an interaction between parity and treatment on feed efficiency, however. Primiparous cows demonstrated increased feed efficiency when provided diets containing the Silaferm-treated corn silage (1.48, 1.69, 1.46, and 1.43 for primiparous cows fed control, primiparous fed Silaferm, multiparous fed control, and multiparous fed Silaferm, respectively).

Data on body condition and weight changes are typically not observed to be different, or meaningful, when collected during short-term experiments such as this. During this experiment, however, body condition scores (BCS) and body weights (BW) were increased for cows fed the Silaferm-treated silage while they were decreased for cows fed control corn silage. These differences indicated that cows fed the control silage were not able to support the amount of milk produced without mobilization of body stores. These changes were also reflected by greater BW losses for cows fed the control silage compared with cows fed Silaferm-treated silage. Though cows fed the Silaferm silage paradoxically gained BCS while losing BW, the values of the gain or loss are not likely different than 0 (no change) demonstrating energy balance for these cows as opposed to a negative energy balance for the cows fed the control cows.

CONCLUSION

Treatment of corn silage at harvest with Silaferm increased the feeding value of the corn silage for dairy cattle. Cows fed corn silage treated with Silaferm demonstrated improved milk and component yields as well as improved energy balance, indication greater nutrient utilization from corn silage treated with Silaferm.

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Table 1. Ingredient and estimated nutrient composition of diets containing a control corn silage or Silaferm-treated corn silage based upon pre-experiment analysis and Dairy NRC (2001).

	Diets		
	Covariate	**Control**	**Silaferm**
Ingredients	---------------------------- % of DM -----------------------		
Control corn silage	20.3	48.7	
Silaferm treated corn silage			48.7
Alfalfa haylage	18.6		
Alfalfa hay	10.2	12.2	12.2
High moisture ground corn	22.0	10.7	10.7
Cottonseed, whole	7.78	7.78	7.78
SoyPlus[1]	4.23	6.76	6.76
Soybean meal, 48 %	4.23	5.24	5.24
Flaxseed	4.52		
QLF 4/19[2]	4.15		
Dried distillers grains with solubles		4.64	4.64
Meat-bone meal	0.85	0.79	0.79
Fishmeal	0.39	0.39	0.39
Limestone	0.76	1.00	1.00
Sodium bicarbonate	0.55	0.55	0.55
Salt-white	0.67	0.50	0.50
Dairy Micro Premix[3]	0.24	0.24	0.24
Diamond V XP[4]	0.19	0.19	0.19
Magnesium oxide	0.17	0.17	0.17
MTB 100[5]	0.06	0.06	0.06
Zinpro 4-Plex[6]	0.05	0.05	0.05
Vitamin E[7]	0.02	0.02	0.02
Estimated nutrient composition prior to experiment[8]			
DM, %	67.5	53.8	56.0
	---------------------------- % of DM -----------------------		
CP	17.3	17.4	16.9
Rumen Degradable Protein (RDP)[8]	65.8	59.9	59.5
Rumen Undegradable Protein (RUP)[8]	34.2	40.1	40.5
NDF	27.0	31.9	30.1
Forage NDF	20.0	24.1	22.9
ADF	18.9	18.2	17.4
NFC,[9]	40.4	38.7	40.6
Starch	19.1	22.6	25.1
Fat	6.49	4.42	4.75
Calcium	0.96	0.83	0.81
Phosphorus	0.45	0.42	0.42
Magnesium	0.4	0.40	0.40
Chloride	0.61	0.48	0.44
Potassium	1.32	1.01	1.05
Sodium	0.48	0.40	0.38
Sulfur	0.22	0.21	0.19
Net energy lactation[10]	1.72	1.63	1.67

[1]Heat treated soybean meal, West Central Soy, Ralston, IA
[2]Quality Liquid Feeds
[3]Contained 10.3 % Mg, 4,783 ppm Fe, 4,857 ppm Cu, 122 ppm Co, 17,793 ppm Mn, 26,556 ppm Zn, 408 ppm I, and 144 ppm Se, 2,640,000 IU/kg Vit. A, 528,000 IU/kg Vit D, and 10,560 IU/kg Vit E.
[4]Diamond V Mills, Inc., Cedar Rapids, IA
[5]Alltech, Inc., Lexington, KY
[6]Zinpro,
[7]Contained 20,000 IU vitamin E / lb

[8]Estimated based upon pretrial analysis of the forages (haylage, control corn silage, and Silaferm-treated corn silage) and the NRC Nutrient Requirements of Dairy Cattle (2001) for remaining ingredients.
[9]NFC (Nonfibrous carbohydrate) = 100 – (NDF % + CP % + Fat % + Ash %).

Table 2. Chemically determined nutrient composition of a control corn silage or Silaferm-treated corn silage as fed during the experimental periods (Dairyland Labs, Arcadia, WI).

	Diets			
	Control		**Silaferm**	
Nutrient	**Average**	**Std. Dev.**	**Average**	**Std. Dev.**
N	6		6	
DM, %	48.9	1.0	46.9	1.7
	------------------------------ % of DM ------------------------------			
CP	7.68	0.19	9.37	0.22
AD-ICP[1]	0.39	0.12	0.36	0.21
ND-ICP[2]	1.60	0.39	1.53	0.25
Soluble Protein	4.19	0.36	4.79	0.80
NDF	42.0	2.6	39.2	3.1
ADF	23.6	1.6	20.6	1.7
Lignin	2.58	0.26	2.41	0.38
NFC[3]	42.4	4.6	45.2	3.16
Starch	30.2	1.6	29.8	2.9
Fat	2.52	0.14	2.35	0.22
Calcium	0.25	0.08	0.20	0.01
Phosphorus	0.27	0.004	0.28	0.01
Magnesium	0.22	0.03	0.21	0.01
Potassium	0.79	0.05	0.78	0.05
Sulfur	0.10	0.01	0.19	0.02
Ruminal availability of carbohydrates				
NDFD, 24 h[4]	50.8	4.1	52.6	2.9
IVTDMD 24h[5]	79.4	1.7	81.5	0.9
DSA[6]	88.2	1.7	90.2	2.7
TDN	70.1	3.1	72.4	1.3
Net energy lactation, mcal/ kg[7]	1.60	7.48	1.65	3.08

[1]AD-ICP = Acid Detergent Insoluble Crude Protein
[2]ND-ICP = Neutral Detergent Insoluble Crude Protein
[3]NFC = Nonfibrous Carbohydrate (100 – (NDF % + CP % + Fat % + Ash %)).
[4]NDFD = Neutral Detergent Fiber Digestibility
[5]IVTDMD = Invitro Total Dry Matter Digestibility
[6]DSA = Degree of Starch Access
[7]Based upon OARDC calculations from Dairyland Labs, Arcadia, WI

Table 3. Fermentation characteristics of a control corn silage or Silaferm-treated corn silage as fed during the experimental periods (Dairyland Labs, Arcadia, WI).

	Control		Silaferm	
	Average	**Std. Dev.**	**Average**	**Std. Dev.**
N	6		6	
pH	3.95	0.12	3.93	0.05
NH_3-N, % of CP	7.8	0.91	15.6	1.6
Molds, colonies/gm DM	115,167	191,479	22,167	26,664
Log 10 of colonies/gm DM	4.51	0.89	3.80	0.89
Yeasts, colonies/gm DM	5,167	3,817	7,833	8,931
Log 10 of colonies/gm DM	3.56	0.45	3.60	0.57
	------------------------------ % of DM ------------------------------			
Ethanol	0.19	0.12	0.36	0.22
VFA				
Acetate	0.49	0.27	0.60	0.18
Propionate	< 0.01	< 0.00	< 0.01	0.00
Butyrate	< 0.01	< 0.00	< 0.01	0.00
Isobutyrate	< 0.01	< 0.00	< 0.01	0.00
Lactate	2.75	0.32	3.27	0.69
Total Acids	3.29	0.32	3.87	0.72
Lactate:Acetate	5.15	0.27	5.87	1.88
Lactate, % of total	83.7	0.7	84.4	4.6

Table 4. Chemically determined nutrient composition of diets containing a control corn silage or Silaferm-treated corn silage (Dairyland Labs, Arcadia, WI).

	Covariate	**Control**	**Silaferm**
N	1	2	2
DM, %	60.1	61.1	60.1
	--------------------------- % of DM ----------------------		
CP	16.0	15.5	16.4
AD-ICP[1]	0.60	0.80	0.98
ND-ICP[2]	3.14	4.19	4.29
Soluble Protein	5.49	4.98	5.53
NDF	28.1	37.0	36.2
ADF	18.2	22.8	21.3
Lignin	3.47	3.23	3.48
NFC[3]	43.2	38.0	37.5
Starch	27.2	21.6	24.0
Sugar	4.95	5.28	4.50
Fat	6.70	4.42	4.50
Calcium	0.79	0.68	0.69
Phosphorus	0.47	0.42	0.42
Magnesium	0.38	0.35	0.35
Chloride	0.55	0.33	0.46
Potassium	1.37	0.96	1.03
Sodium	0.47	0.39	0.29
Sulfur	0.55	0.17	0.21
Net energy lactation, mcal/ kg[4]	1.73	1.66	1.65

[1]AD-ICP = Acid Detergent Insoluble Crude Protein
[2]ND-ICP = Neutral Detergent Insoluble Crude Protein
[3]NFC = Nonfibrous carbohydrate (100 – (NDF % + CP % + Fat % + Ash %)).
[4]Based upon OARDC calculations from Dairyland Labs, Arcadia, WI

Table 5. Production data of cows fed diets containing a control corn silage or Silaferm-treated corn silage.

	Treatments			
Item, kg/d	Control	Silaferm	SEM	*P-value*
Dry matter intake, kg/d	23.5	23.2	0.6	0.68
Milk yield, kg/d	32.1	33.7	0.7	0.04
Fat				
Percentage	3.95	3.98	0.09	0.68
Yield, kg/d	1.25	1.33	0.04	0.02
Protein				
Percentage	3.09	3.14	0.04	0.17
Yield, kg/d	0.98	1.03	0.03	0.04
Lactose, %				
Percentage	4.91	4.94	0.03	0.16
Yield, kg/d	1.57	1.67	0.04	0.03
Solids not fat				
Percentage	8.97	9.07	0.06	0.31
Yield, kg/d	2.87	3.04	0.08	0.04
MUN, mg/dL	14.5	14.7	0.3	0.49
SCS, Log(SCC)	2.0	2.1	0.2	0.61
Fat-corrected milk,[1] kg/d	31.6	33.5	0.9	0.02
Energy-corrected milk,[2] kg/d	33.7	35.8	0.9	0.02
Feed efficiency[3]	1.47	1.56	0.06	0.14

[1]4% Fat-corrected milk = [(0.4 × milk yield (kg)) + (15 × fat yield (kg))] (NRC 2001).
[2]Energy-correct milk = [(0.3246 × milk yield (kg)) + (12.86 × fat yield (kg)) + (7.04 × protein yield (kg))].
[3]Feed efficiency = kg Energy-corrected milk / kg dry matter intake.

Table 6. Initial, final, and change of body weight (BW) and body condition score (BCS) of cows fed diets containing a control corn silage or Silaferm-treated corn silage.

	Treatment			*P-values*
Item	Control	Favored	SEM	Treatment
BCS^1_{final}	3.11	3.19	0.03	0.02
BCS_{change}	-0.11	0.04	0.03	< 0.01
BW_{final}, kg	595	604	4.7	0.05
BW_{change}, kg	-31.4	-18.5	4.6	0.06

[1] Numbers based on a scale of 1 to 5, with 1 being emaciated and 5 being obese (Wildman et al, 1982).