Ensiling Properties of Wet Sugarbeet Pulp and the Addition of Liquid Feedstuffs or Urea

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ABSTRACT

Feed costs, a major expense in animal production, may be reduced by including locally and regionally grown crops and local crop processing byproducts in animal diets. About half of the U.S. sugarbeet crop is produced and processed in North Dakota and Minnesota. Therefore, sugarbeet byproducts are readily available to the region's livestock producers. Two experiments were conducted to characterize the ensiling properties of wet sugarbeet pulp (WBP; 25% DM). In Experiment 1, a 4 x 3 factorial treatment arrangement was used to define responses of ensiling WBP based on 1) formulated silage dry matter (DM) concentrations of 25, 30, 35, and 40%, and 2) inclusion of liquid feedstuffs (molasses, concentrated separator byproduct, and corn steep liquor). Experiment 2 was designed to evaluate the addition of 0.41% urea to WBP silage. In Experiment 1, lactic acid production increased (linear, *P* < 0.01) with the addition of all liquid feedstuffs. Though volatile fatty acid concentration was greatest (quadratic, *P* < 0.01) at 30% DM for molasses and concentrated separator byproduct, total organic acid production was enhanced with increasing silage DM only for the molasses treatment (linear, *P* = 0.002). As expected, in Experiment 2, ensiled products which included urea had greater crude protein

(P < 0.01) and soluble crude protein concentrations (P < 0.01) than those without urea. Added urea however, did not influence in vitro DM disappearance (P = 0.15). Lactate, acetate, total volatile fatty acids, and total organic acids ($P \leq$ 0.02) were increased with added urea. The results of these experiments indicate that the addition of liquid feedstuffs and urea would enhance the nutrient quality of ensiled WBP.

Additional key words: concentrated separator byproduct, corn steep liquor, fermentation, molasses, silage

Ensiling is a conservation method for moist crops such as whole crop corn silage, high moisture cereal grains, and forages. Preserving the nutritional value of feedstuffs is a major goal in producing high quality silages (Muck, 1988; Oude Elferink *et al.,* 2000). In order for such preservation to occur, one must balance proteolytic activity, pH, lactic acid fermentation, and aerobic microbial growth (Weinberg *et al.,* 2001).

Proteolysis occurs during the ensiling process and decreases during fermentation (Messman *et al.,* 1994). The degree of proteolysis is reflected in the crude protein (CP) to non-protein nitrogen (NPN) ratio. The degree to which fermentation has progressed is reflected in the concentration of lactic acid. Lactic acid producing bacteria play a key role in the conservation process of ensiled feedstuffs by converting water-soluble carbohydrates into lactic acid (Weinberg *et al.,* 2001). Due to the production of lactic and other acids, pH decreases and consequently inhibits microorganisms which may cause spoilage (Muck, 1988; Oude Elferink *et al.,* 2000).

To sustain nutritional quality and enhance the fermentation process during ensiling, various additives (feedstuffs, nutrients, absorbents, microbial innocculants) have been used (Oude Elferink *et al.,* 2000; Charmley, 2001). Liquid feedstuffs, most commonly molasses, have been added to improve fermentation and retention of nutritional value (Umana *et al.,* 1991; Martinez-Avalos *et al.,* 1998). Karalazos and Giouzeljannis (1988) evaluated diets consisting of either maize (*Zea maize*) silage or sugarbeet (*Beta vulgaris* L.) pulp silage with molasses. Beet pulp silage with molasses achieved a lower pH and a higher lactic acid concentration, as a % of DM, than the maize silage.

Urea is a common additive that provides both NPN and the ammonia needed for optimal ruminal fermentation (Erfle *et al.,* 1986). Nutrients, such as ammonia, and minerals, have also been used as additives during ensiling (Oude Elferink *et al.,* 2000). Non-protein nitrogen sources, such as urea and anhydrous ammonia, not only increase the nutritive value, but also improve aerobic stability during the ensiling process (Keller *et al.,* 1994). Furthermore, providing supplemental urea in beet pulp based rations has increased weight gains in cattle (Théwis *et al.,* 1985).

Therefore, two experiments were conducted to determine ensiling properties for wet sugarbeet pulp using readily available plant-derived liquid byproduct feeds or urea to achieve desired DM composition and enhance the nutrient value of the ensiled product.

MATERIALS AND METHODS

Feedstuff origin

Wet sugarbeet pulp, molasses, and concentrated separator byproduct (de-sugared molasses) were obtained from the American Crystal Sugar Company sugarbeet processing facility in Moorhead, MN. Corn steep liquor was delivered from the Cargill Corn Processing Plant in Wahpeton, ND. Corn steep liquor, a byproduct of high fructose corn syrup production, contains soluble corn proteins, steep water, and sulfurous acid (Lardy and Anderson, 2003).

Ensiling procedures

Pre-calculated amounts of each feedstuff were weighed individually to achieve desired proportion for each silage product and a final weight of 33.9 kg. Feedstuffs were thoroughly mixed in a small capacity, horizontal mixer (Crown Portable Cement Mixer; Model: 6SR; Crown Construction Equipment, Winnipeg, Canada) for approximately 5 minutes. After mixing, the silage product was immediately transferred into two 19.3 L- buckets lined with heavy-duty plastic and sealed to initiate an anaerobic fermentation environment. Each silage product was prepared in triplicate. Samples were fermented for 47 d.

Silage analyses

Following the fermentation period, a sample was collected from each bucket. Five grams of each sample was submersed into 100 mL of water and refrigerated (4°C) for 12 h. The pH of the liquid was measured using a combination electrode (Model 2000pH/temperature meter, VWR Scientific Products, West Chester, PA). Composited samples were analyzed for dry matter (DM) and CP (Procedure numbers: 930.15, and 984.13, respectively; AOAC 1990). Soluble nitrogen was determined using 0.9% saline incubations according to procedures of Waldo and Goering (1979). In vitro DM disappearance (IVDMD) of silage samples were measured using procedures of Tilley and Terry

(1963). Determination of volatile fatty acids (VFA) were conducted with a Supelco (10% SP1200; 80/100 Chromosorb) column (Goetsch and Galyean, 1983). Methods outlined by Barker and Summerson (1941) were used to quantify lactate concentrations.

Experimental design and statistics

Experiment 1. Effects of added liquid feedstuffs to WBP were evaluated in a 47-d fermentation study arranged in a triplicate 4 x 3 factorial experimental design. This study was designed to evaluate effects of 1) silage DM and 2) liquid feedstuff addition to WBP-based silage. Wet sugarbeet pulp silage was evaluated at four formulated DM concentrations, 25, 30, 35, or 40%. Liquid feedstuffs used were sugarbeet molasses (MOL; 0, 10, 20, and 30% added; DM basis), concentrated separator byproduct (CSB; 0, 12.2, 24.4, and 36.6%; DM basis), and corn steep liquor (CSL; 0, 20.0, 40.0, and 60.6%; DM basis). Formulated silage mixtures are presented in Table 1.

Data were analyzed using the GLM procedures of SAS (SAS Inst. Inc., Cary, NC) as a 4 x 3 factorial arrangement of treatments. Effects accounted for in the model included formulated silage DM, particular liquid feedstuff addition, and the associated two-way interaction. Level of significance was determined at a probability of 95% (P = 0.05). Linear, quadratic, and cubic contrasts were used to characterize the effects of increasing silage DM.

Table 1. Silage mixtures with a WBP-base and added liquid feeds to achieve desired silage dry matter[†].

	Silage DM[‡]			
Item	**25**	**30**	**35**	**40**
	---------% DM basis---------			
WBP	100	89.98	80.00	69.98
MOL	0	10.02	20.00	30.02
WBP	100	87.81	75.62	63.43
CSB	0	12.19	24.38	36.57
WBP	100	80.00	60.00	39.42
CSL	0	20.00	40.00	60.58

[†]Feed codings are: wet sugarbeet pulp = WBP, sugarbeet molasses = MOL, concentrated separator by-product (de-sugared molasses) = CSB, and corn steep liquor = CSL

[‡]Wet sugarbeet pulp without added feedstuffs was used to produce the 25% DM silage

Experiment 2. An experiment was designed to evaluate the impact of added urea on the ensiling characteristics of WBP. Wet beet pulp ensiled alone or WBP ensiled with urea (WBP+U) was prepared in triplicate as described in Experiment 1. Urea concentration was 0.41% of total silage mixture.

Data were analyzed using a 1-way analysis of variance using the GLM procedures of SAS. The model contained effects for WBP and urea. Level of significance chosen for all experiments was 95% ($P = 0.05$).

RESULTS

Experiment 1. Liquid feedstuff x silage DM interactions were significant ($P < 0.0001$) for all silage nutrients and fermentation variables examined, therefore data are presented as interactive means. A linear increase ($P < 0.0001$) in DM was associated with increasing inclusion levels of MOL, CSB, and CSL (data not shown). As expected, inclusion of MOL, CSB, and CSL to increase silage DM also increased (cubic, $P \leq 0.03$) silage CP concentrations (Table 2). Similarly, soluble CP of silage increased (cubic, $P \leq 0.02$) for CSB and CSL inclusion while MOL inclusion increased linearly ($P < 0.0001$) with increasing DM. In vitro DM disappearance increased cubically for MOL, CSB, and CSL inclusion as silage DM increased up to 40% DM ($P = 0.02$; $P = 0.004$; $P = 0.01$, respectively). Increasing silage DM resulted in a cubic increase ($P \leq 0.02$) in IVDMD with inclusions of MOL, CSB, and CSL. Addition of CSB enhanced IVDMD (11.8%) more than MOL (6.4%) or CSL (5.1%) inclusion.

Fermentation characteristics are displayed in Table 3. Increasing silage DM resulted in a cubic increase ($P \leq 0.02$) in pH with the inclusion of MOL and CSB, but the inclusion of CSL had no affect ($P = 0.63$) on silage pH. Lactate production was greatest (cubic, $P = 0.01$) in silages containing CSB (10.94 % DM) as DM increased. Lactate production responded quadratically ($P = 0.002$) with MOL addition as silage DM increased. Addition of CSL resulted in a linear increase ($P = 0.01$) in lactate production as DM increased. With increasing DM, inclusion of MOL increased (cubic, $P = 0.01$) VFA production, whereas both CSB and CSL decreased (quadratic, $P = 0.0002$; cubic, $P = 0.01$, respectively) VFA in silages. Increasing DM in WBP silages with MOL, CSB, and CSL resulted in acetate comprising 99, 90, and 73% of the total VFA, respectively. Inclusion of liquid feedstuffs to achieve 40% DM resulted in lactate accounting for 65.5% of total organic acid production while total VFA accounted for only 34.4% of total organic acid production.

Table 2. Analyzed nutritional composition of wet sugarbeet pulp ensiled for 47 d with inclusion of liquid feedstuffs to achieve varying levels of dry matter[†].

	Formulated Silage DM[‡], %						Contrasts[§]		
Item	**25**	**30**	**35**	**40**	**SEM[¶]**	**P-Value[††]**	**L**	**Q**	**C**
CP, % DM									
MOL	8.49	10.02	10.68	9.89	0.11	<0.0001	<0.0001	<0.0001	0.03
CSB	8.94	12.77	17.01	19.37	0.11	<0.0001	<0.0001	0.001	0.01
CSL	8.68	14.11	18.22	22.56	0.13	<0.0001	<0.0001	0.003	0.02
Soluble CP, % DM									
MOL	2.25	4.38	5.88	6.00	0.11	<0.0001	<0.0001	<0.0001	0.19
CSB	3.06	7.69	13.44	16.50	0.13	<0.0001	<0.0001	0.001	0.001
CSL	2.50	8.31	12.63	17.56	0.17	<0.0001	<0.0001	0.46	0.02
IVDMD[‡‡], % DM									
MOL	85.4	87.1	87.8	90.9	0.40	<0.0001	<0.0001	0.03	0.02
CSB	82.3	84.0	89.7	92.0	0.40	<0.0001	<0.0001	0.43	0.004
CSL	85.1	85.6	89.4	90.3	0.40	<0.0001	<0.0001	0.66	0.01

[†]Liquid feedstuff codings are sugarbeet molasses = MOL, concentrated separator byproduct = CSB, and corn steep liquor = CSL
[‡]Wet sugarbeet pulp without added feedstuffs was used to produce the 25% DM silage
[§]Contrasts: L = linear; Q = quadratic; C = cubic
[¶]Standard error of the mean; n = 3
[††]Probability of statistic greater than F for treatment.
[‡‡]In vitro dry matter disappearance

Table 3. Analyzed fermentation characteristics of wet sugarbeet pulp ensiled for 47 d with inclusion of liquid feedstuffs to achieve different of dry matter concentrations[†]

	Formulated Silage DM[‡], %						Contrasts[§]		
Item	**25**	**30**	**35**	**40**	**SEM[¶]**	**P-Value[††]**	**L**	**Q**	**C**
pH									
MOL	4.34	4.21	4.36	4.39	0.03	0.002	0.01	0.01	0.003
CSB	4.27	4.71	4.70	4.87	0.03	<0.0001	<0.0001	0.02	0.02
CSL	4.23	4.26	4.23	4.24	0.02	0.63	0.86	0.70	0.24
Lactate, % DM									
MOL	2.35	5.34	7.85	8.94	0.56	<0.0001	<0.0001	0.002	0.35
CSB	3.16	4.15	9.41	10.94	0.21	<0.0001	<0.0001	0.64	0.01
CSL	2.61	5.97	6.64	8.25	0.21	<0.0001	<0.0001	0.004	0.01
VFA, % DM									
MOL	4.96	8.10	7.21	7.24	0.45	0.001	0.002	0.001	0.01
CSB	7.55	10.42	7.47	4.48	0.30	0.0001	0.0003	0.0002	0.22
CSL	6.02	6.42	3.61	3.42	0.42	0.001	0.001	0.50	0.01
Acetate, % DM									
MOL	4.63	7.87	6.96	7.14	0.23	0.001	0.002	0.002	0.01
CSB	6.85	10.30	7.19	4.05	0.34	<0.0001	0.0004	<0.0001	0.01
CSL	5.55	5.71	3.03	2.48	0.42	0.001	0.0001	0.40	0.02
Total organic acid, % DM									
MOL	7.31	13.44	15.06	16.18	0.68	<0.0001	<0.0001	0.001	0.08
CSB	10.71	14.55	16.88	15.42	0.45	0.001	0.001	0.005	0.48
CSL	8.63	12.39	10.25	11.67	0.33	0.002	0.002	0.01	0.0002

[†]Liquid feedstuff codings are sugarbeet molasses = MOL, concentrated separator byproduct = CSB, and corn steep liquor = CSL
[‡]Wet sugarbeet pulp without added feedstuffs was used to produce the 25% DM silage
[§]Contrasts: L = linear; Q = quadratic; C = cubic
[¶]Standard error of the mean; n = 3
[††]Probability of statistic greater than F for treatment

Experiment 2. Nutritional composition of WBP silages in Experiment 2 are shown in Table 4. Dry matter of silage was elevated ($P = 0.03$) by 14.0% in WBP+U (31.8%) compared to WBP (27.9%). Added urea (to achieve 0.41% of the DM) did not affect pH (4.13 vs. 4.11; $P = 0.45$) after a 47-d fermentation. As expected both CP and soluble CP were elevated ($P < 0.001$) in WBP+U compared to WBP ensiled alone. A numerical increase ($P = 0.15$) was observed for IVDMD in WBP+U versus WBP. Lactate production increased ($P = 0.02$) in WBP+U versus WBP silage. Total VFA were 4.51 and 5.50% (DM) for WBP and WBP+U, respectively ($P = 0.03$). Similar to observations in Experiment 1, acetate production contributed a majority (84%) of total VFA. Wet sugarbeet pulp and WBP+U acetate concentrations were 3.71 and 4.71%, respectively ($P = 0.006$). Increased lactate and VFA concentrations resulted in increased ($P < 0.002$) total organic acid production in WBP+U.

DISCUSSION

Our objectives for Experiment 1 were to determine optimal ensiling conditions for WBP by altering the DM composition using readily available liquid feedstuffs. The addition of increasing levels of CSB

Table 4. Effect of added urea on nutrient value of ensiled wet beet pulp following a 47-d fermentation.

	Treatment			
Item	**-Urea**	**+Urea**	**SEM**[†]	**P-Value**[‡]
pH	4.11	4.13	0.02	0.45
	----------%	----------		
DM[§]	27.9	31.8	0.8	0.03
CP	9.50	12.12	0.06	<0.001
Soluble CP	3.63	6.19	0.06	<0.001
IVDMD[¶]	82.6	83.6	0.4	0.14
	---------- % DM ----------			
Lactate	4.20	5.21	0.20	0.02
VFA	4.51	5.50	0.29	0.03
Acetate	3.71	4.71	0.14	0.006
Total organic acid	8.71	10.71	0.32	0.002

[†]Standard error of the mean; n = 3

[‡]Probability of statistic greater than F for treatment

[§]As-is basis

[¶]In vitro dry matter disappearance

resulted in the largest increase in pH. This increase may have been due to increased buffering capacity resulting from a combination of high inorganic bases (potassium and sodium) and ammonia, subsequently elevating pH, whereas the highly fermentable components of molasses and steep liquor may have favored acid production. Leterme *et al.* (1992) reported silages with a molasses-urea mixture added had a lower pH than beet pulp ensiled alone or beet pulp ensiled with laying hen excreta. Similarly, Moore and Kennedy (1994) reported silages based on sugarbeet pulp ensiled with formic acid had a lower pH than silage with an additive based on sugarbeet pulp (Sweet 'n' Dry). Inclusion of CSB and CSL decreased VFA concentration in 35 and 40% DM silages. Similarly, Ferris and Mayne (1994) reported decreased VFA concentration with increasing levels of beet pulp (0, 40, 80, 120 kg/t) ensiled with perennial ryegrass. In contrast, Hameleers *et al.* (1999) reported no differences in VFA concentration when incorporating beet pulp at 0, 2, 7, 13, or 18 kg/ kg maize. Nutritive value (CP, soluble CP, and IVDMD) increased with increasing levels of liquid feedstuffs. This was due to increased nutritive values of the individual liquid feedstuffs compared to WBP. Addition of liquid byproducts increased lactate values through 40% DM. In order for fermentation to be successful, lactic acid bacteria need sufficient substrate (Muck, 1988). The amount of substrate necessary is partially dependent upon buffering capacity of the product being ensiled. The pH will remain higher with increased buffering capacity of the silage. Molasses and steep liquor may provide more fermentable sugars for lactate synthesis than CSB and thus have a lower buffering capacity. Though fermentation processes were acceptable for all additives, fermentation characteristics may have been more affected by inclusion of CSB than MOL and CSL. However, visual evaluation of ensiled products did not indicate any spoilage of CSB treated products. Our data suggests that ensiling characteristics and nutrient quality are primarily influenced by chemical composition of added feedstuffs. Molasses and CSL may be useful liquid additives when ensiling sugarbeet pulp.

The primary objective of Experiment 2 was to determine if added urea would enhance nutrient and ensiling characteristics of WBP. Non-protein nitrogen sources, such as urea, are most commonly used in silages as a mechanism to increase CP and, under certain conditions, improve aerobic stability. Interestingly, in this experiment, added urea did not influence pH. However, the CP of ensiled WBP was increased by added urea. Leterme *et al.* (1992) reported lower pH values than reported in this study, when molasses and urea were added to pressed sugarbeet pulp-based silage. Use of NPN in high moisture (>70%)

silages is often discouraged due to the inability to achieve a low enough pH (4.0) to minimize the microbial activity that causes nutrient loss (Valadares *et al.,* 1999). In contrast, our data suggests that addition of urea to WBP (pH = 4.1) may have lowered pH to a level which would minimize undesirable microbial activity (Oude Elferink *et al.,* 2000). Promoting a stable fermentation environment and increased efficiency of anaerobic bacteria, may have ultimately increased organic acid production (lactate and acetate). Leterme *et al.* (1992) observed a numerical increase in lactic acid concentration of beet silages with urea and molasses additions, when compared to silages with no additives.

Feed DM was increased with urea addition. Similary, others (O'Kiely, 1992; Hameleers *et al.,* 1999) have reported increased DM with increased levels of dry feedstuff additives to ensiled forage maize and ryegrass. As expected, CP and soluble CP were increased with inclusion of urea. In vitro DM disappearance was numerically increased with urea addition to WBP. O'Kiely (1992) reported increased IVDMD with increased levels of formic acid to ryegrass-based silage. They attributed this to an additive effect between the silage and dry feedstuff. Charmley and Veira (1990) reported ruminal ammonia concentrations increased after feeding alfalfa-based silages with high soluble CP content. They attributed this to the amount of soluble and total CP in the silage. These results indicate WBP may be ensiled with urea to increase DM content, enhance fermentation environment, and increase nutrient quality.

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