Ensiling Properties of Wet Sugarbeet Pulp and the Addition of Dry Feedstuffs

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ABSTRACT

An experiment was conducted to characterize ensiling properties of wet sugarbeet pulp (WBP). A 6 x 4 x 2 factorial arrangement of treatments was used to determine the effects of 1) formulated silage dry matter concentrations (DM) of 25, 30, 35, 40, 45, and 50%, 2) inclusion of dry feedstuffs (dry pelleted beet pulp, dry rolled corn, wheat midds, and dry corn gluten feed), and 3) addition of wet sugarbeet tailings (WBT; to make up 25% DM of ensiled product) on ensiling characteristics of WBP. Pre-calculated amounts of each feedstuff were individually weighed in triplicate, thoroughly mixed, and transferred to sealed buckets to initiate an anaerobic, fermentation environment for 47 d. Nutritive value (crude protein, soluble crude protein, and in vitro DM disappearance) of ensiled WBP was influenced by the addition of dry feedstuffs. The most desirable fermentation (associated with increased acid production) of WBP-based silage occurred with inclusion of dry feedstuffs to achieve 35% DM. The results of our experiment indicate addition of dry feedstuffs can increase the DM and nutrient quality of WBP, while maintaining a quality fermentation environment.

Additional key words: dry corn gluten feed, dry pelleted beet pulp, dry rolled corn, fermentation, silage, wheat midds

The sugarbeet industry produces 1100 tonne of pulp annually. Drying of wet beet pulp takes energy; hence increasing utilization of wet pulp as a livestock feed would benefit the processing industry while providing livestock producers a low-cost feed source. Approximately 297,000 hectares of sugarbeet (*Beta vulgaris* L.) are planted annually in North Dakota and Minnesota (MNASS, 2005; NDASS, 2005). A byproduct of the sugar extraction process is pressed, wet sugarbeet pulp (WBP). In some regions of the U.S. which produce sugarbeet, WBP has been incorporated into diets for growing and finishing beef cattle (Schimek *et al.,* 1999) and dairy cows (Khalili and Sairanen, 2000). This feed byproduct, in a dry pelleted form, has also gained popularity outside of these regions (Voelker and Allen, 2003). However, drying capacity and associated costs currently limit production of pelleted, sugarbeet pulp. Due to its high moisture content, shipping WBP is not economically advantageous. Therefore, partial drying or ensiling of WBP may provide a cost-effective option.

Ensiling of WBP has been a common practice in areas of Europe (Karalazos and Giouzeljannis, 1988; Leterme *et al.,* 1992; Deniz *et al.,* 2001). Wet sugarbeet pulp silages have a relatively high feedout value for livestock (Bell *et al.,* 2001), which may be attributed to the highly digestible fiber fraction of WBP (Tatlli *et al.,* 2001).

Preserving the nutritional value of feedstuffs is a major goal in producing silages (Muck, 1988; Oude Elferink *et al.,* 2000). Various additives (feedstuffs, non-protein nitrogen (NPN), and microbial inoculants) have been used to enhance the fermentation environment and sustain nutritional quality during the ensiling process (Charmley, 2001). In addition to sugarbeet pulp, other plant-derived feed byproducts, such as wheat middlings and dry corn gluten feed have been considered for inclusion in ruminant diets (Loe, 2002). The nutritive value of these and other plant-derived byproduct feeds and seasonal low costs, have made them attractive to livestock producers (Weiss *et al.,* 1997).

Due to local availability of potential ensiling additives, we hypothesized that readily available plant-derived feeds may increase the nutritive value of WBP-based silages and provide livestock producers an option that efficiently utilizes plant-derived byproduct feeds, such as WBP.

MATERIALS AND METHODS

Feedstuff source

Wet sugarbeet pulp, wet beet tailings, and dry pelleted pulp were obtained from American Crystal Sugar Company processing facility in Moorhead, MN. Dry pelleted corn gluten feed was obtained from the Cargill Corn Processing facility near Wahpeton, ND. Wheat midds were purchased from a local commercial feed processor (Zip Feeds, Grandin, ND). Whole corn was delivered from Northern Crops Institute Feed Mill (Fargo, ND, USA). Prior to ensiling, corn was dry rolled on site.

Ensiling procedures

Pre-calculated amounts of each feedstuff were weighed individually to achieve desired proportion for each silage product and a final weight of approximately 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 to two 19.3 L buckets lined with heavy-duty plastic and sealed to initiate an anaerobic environment for fermentation. Each silage product was prepared in triplicate. After the mixing process, products were allowed to ferment for 47 d.

Silage analyses

Following the fermentation period, a representative 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). Dry matter (DM) and crude protein (CP) were determined on composite samples (Procedure numbers: 930.15, and 984.13, respectively; AOAC 1990; Table 1). Soluble nitrogen was determined 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). Volatile fatty acids (VFA) were determined 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

Determination of optimal conditions for wet pressed sugarbeet pulp (WBP) ensiled with dry feedstuffs (>85% DM) was evaluated in a 47-d

Table 1. Laboratory analysis of feedstuff nutrient composition.

	Feedstuff[†]					
Item	**WBP**	**DBP**	**WBT**	**DCGF**	**DRC**	**WM**
DM, %[‡]	25.7	90.7	21.0	87.5	87.8	87.9
	----% DM basis----					
CP	8.55	8.06	7.54	22.63	10.20	19.40
Soluble CP	3.13	0.69	2.22	15.00	2.25	7.06
OM	92.7	93.3	83.8	92.2	98.0	93.5
IVDMD[§]	82.8	84.9	76.3	85.0	91.7	80.5
ADF	32.2	31.2	24.0	11.6	4.0	10.1

[†]Feedstuff codings are pressed wet beet pulp = WBP, pelleted dry beet pulp = DBP, wet beet tailings = WBT, pelleted dry corn gluten feed = DCGF, dry rolled corn = DRC, and wheat midds = WM.
[‡]As-is basis
[§]In vitro dry matter disappearance

study. Treatments were arranged in a 6 x 4 x 2 factorial design. The study was designed to determine the effects of 1) formulated silage DM, 2) dry feedstuff type, and 3) addition of wet sugarbeet tailings (WBT) on ensiling characteristics of WBP. Levels of silage DM tested were 25, 30, 35, 40, 45, and 50%. Wet sugarbeet pulp was ensiled alone for the 25% DM treatment and used as a control. To evaluate the effect of dry feedstuff type on WBP silage, the following feedstuffs were added: dry pelleted beet pulp (DBP), dry pelleted corn gluten feed (DCGF), dry rolled corn (DRC), or wheat midds (WM). The third factor in the design was addition of WBT to make up 25% DM of the ensiled product. Wet beet tailings are readily available at sugarbeet processing plants and represent a potential source of readily fermentable carbohydrate since they contain root material and other substances not suitable for sugar extraction (Lardy and Anderson, 2003).

Data were analyzed using the GLM procedures of SAS (SAS Inst. Inc., Cary, NC) for a 6 x 4 x 2 factorial arrangement of treatments. The model contained effects for formulated silage DM, dry feedstuff type, and WBT. The model accounted for all two- and three-way interactions. Level of significance was set at $P = 0.05$. Linear, quadratic, and cubic contrasts were used to characterize the effects of increasing silage DM.

RESULTS

Three way interactions (formulated silage DM x dry feedstuff x sugarbeet tailings) were encountered for all nutrients ($P \leq 0.02$) and fermen-

Table 2. Formulated silage mixtures with a WBP-base and added dry feeds to achieve varying silage dry matter[†]

	Formulated Silage DM[‡], %					
Item	**25**	**30**	**35**	**40**	**45**	**50**
	% DM basis					
Without WBT						
WBP	100	92.07	84.14	75.94	68.55	60.33
Dry feeds	0	7.93	15.86	24.06	31.45	39.67
With WBT						
WBP	75.01	69.05	63.10	57.16	51.24	45.24
WBT	24.99	24.99	24.99	25.00	25.01	24.99
Dry feeds	0	5.95	11.91	17.84	23.75	29.77

[†]In experiment one silages dry feeds were mixed in proportions to achieve a final weight of 33.9 kg. Feed codings are: wet sugarbeet tailings = WBT, wet sugarbeet pulp = WBP, dry pelleted beet pulp = DBP, dry pelleted corn gluten feed = DCGF, dry rolled corn = DRC, and wheat midds = WM

[‡]Wet sugarbeet pulp (25% DM) was used as a control

tation characteristics ($P \leq 0.001$); therefore, data are presented as interactive means. Formulated silage mixtures are presented in Table 2. Analyzed nutrient values are displayed in Table 3 for WBP and WBP with 25% WBT silages. The 25% DM silage for the DBP treatment was not prepared and ensiled; therefore, no values are reported in Tables 3 and 4 for these silage mixtures.

Increasing silage DM resulted in a linear increase ($P < 0.001$) in silage DM with inclusion of all feedstuffs (data not shown). As expected, inclusion of dry feeds influenced ($P < 0.001$) the CP content of WBP-based silages (Table 3). Increasing DM resulted in a quadratic effect ($P < 0.001$) in CP for DRC and WM inclusions into WBP-based silages, while DBP inclusion resulted in a linear decrease ($P < 0.001$). Moreover, soluble CP fraction responded quadratically ($P \leq 0.001$) in response to increasing silage DM for DBP and WM inclusions. Increasing silage DM resulted in a cubic effect for soluble CP ($P = 0.03$) with DRC inclusions. Inclusion of DBP increased (linear; $P < 0.001$) IVDMD, while WM inclusion decreased (linear, $P < 0.001$) IVDMD as silage DM increased to 50%. Additionally, a cubic ($P \leq 0.05$) response was observed for IVDMD with DRC inclusion.

With respect to CP, a cubic effect ($P \leq 0.05$) was observed with increasing silage DM when DBP and WM were included with WBT. Crude protein of WBT ensiled with DCGF or DRC responded quadrat-

Table 3. Analyzed nutritional composition of wet sugarbeet pulp ensiled for 47 d with inclusion of dry feedstuffs to achieve varying levels of dry matter[†].

	Formulated Silage DM[‡], %								Contrasts[§]		
Item	**25**	**30**	**35**	**40**	**45**	**50**	**SEM[¶]**	**P-Value[††]**	**L**	**Q**	**C**
CP, % DM											
DBP	—	8.94	8.86	8.77	8.56	8.51	0.03	<0.0001	<0.0001	0.71	0.06
DBP plus WBT	9.81	8.75	8.84	8.75	8.64	8.52	0.04	<0.0001	<0.0001	<0.0001	<0.0001
DCGF[‡‡]	9.53	13.15	15.14	17.47	17.55	18.83	—	—	—	—	—
DCGF plus WBT	9.35	12.26	14.79	15.74	17.10	17.92	0.29	<0.0001	<0.0001	0.0001	0.21
DRC	9.05	9.80	10.54	10.73	10.69	10.29	0.07	<0.0001	<0.0001	<0.0001	0.38
DRC plus WBT	9.07	9.53	9.79	9.94	10.08	10.23	0.10	<0.0001	<0.0001	0.03	0.31
WM	9.16	11.38	13.49	14.87	16.06	16.87	0.09	<0.0001	<0.0001	<0.0001	0.83
WM plus WBT	9.21	11.53	12.99	14.49	15.35	16.60	0.14	<0.0001	<0.0001	<0.0001	0.05
Soluble CP, % DM											
DBP	—	2.75	2.13	1.81	1.31	1.16	0.04	<0.0001	<0.0001	0.001	0.87
DBP plus WBT	4.56	2.06	2.63	2.38	1.81	1.31	0.06	<0.0001	<0.0001	<0.0001	<0.0001
DCGF[‡‡]	4.50	7.50	8.81	10.75	10.38	11.56	—	—	—	—	—
DCGF plus WBT	3.19	5.67	7.56	8.50	9.56	9.81	0.33	<0.0001	<0.0001	0.0004	0.65
DRC	3.00	3.31	5.13	5.00	4.44	3.88	0.06	<0.0001	<0.0001	<0.0001	0.03
DRC plus WBT	2.88	3.46	3.48	3.48	3.58	3.69	0.09	<0.0001	<0.0001	0.05	0.02
WM	3.50	5.63	7.50	9.00	9.56	10.38	0.13	<0.0001	<0.0001	<0.0001	0.80
WM plus WBT	3.13	5.35	6.75	8.19	8.60	9.77	0.12	<0.0001	<0.0001	<0.0001	0.01

Table 3 continued.

	Formulated Silage DM[‡], %								Contrasts[§]		
Item	**25**	**30**	**35**	**40**	**45**	**50**	**SEM[¶]**	**P-Value[††]**	**L**	**Q**	**C**
IVDMD[§§], % DM											
DBP	—	83.5	84.0	84.6	84.8	86.2	0.16	<0.0001	<0.0001	0.06	0.08
DBP plus WBT	81.9	82.3	84.0	81.6	81.6	82.5	0.5	0.05	0.69	0.40	0.03
DCGF[‡‡]	81.2	82.9	83.8	84.5	85.3	84.6	—	—	—	—	—
DCGF plus WBT	81.2	83.5	83.4	85.4	86.1	83.0	0.7	0.01	0.01	0.005	0.12
DRC	82.6	86.3	89.6	88.8	90.3	92.1	0.75	<0.0001	<0.0001	0.03	0.05
DRC plus WBT	85.0	83.2	86.5	87.7	89.4	90.9	0.9	0.001	<0.0001	0.24	0.14
WM	84.7	84.6	83.1	82.0	80.5	80.0	0.42	<0.0001	<0.0001	0.58	0.11
WM plus WBT	83.5	82.6	82.2	81.5	80.9	78.8	0.69	0.006	0.0002	0.28	0.38

[†]Dry feedstuff codings are dry pelleted beet pulp = DBP, dry pelleted corn gluten feed = DCGF, dry rolled corn = DRC, and wheat midds = WM

[‡]Wet sugarbeet pulp was used without any other added feedstuffs 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

[‡‡]Descriptive only; treatment not replicated therefore, data could not be analyzed

[§§]In vitro dry matter disappearance

ically ($P \leq 0.03$) with increasing DM. There was a cubic effect ($P \leq 0.02$) for soluble CP with the addition of WBT to DBP, DRC, and WM and a quadratic effect ($P = 0.001$) for DCGF as silage DM increased. Dry beet pulp plus WBT responded in a cubic manner ($P = 0.03$) to increasing DM up to 50% for IVDMD. On the other hand, DCGF plus WBT inclusion responded with a quadratic effect ($P = 0.005$) for IVDMD with increasing silage DM. Inclusion of DRC plus WBT resulted in a linear increase ($P < 0.001$) in IVDMD and WM plus WBT inclusion decreased linearly ($P \leq 0.001$) as silage DM increased.

Fermentation characteristics are presented in Table 4. Inclusion of dry feeds to obtain a 50% DM influenced pH (linear, $P < 0.001$). Our data demonstrates some variability in pH of WBP when ensiled with dry feedstuffs. Inclusion of DRC and DCGF to WBP resulted in pH values of 6.2 and 6.6, respectively. However, inclusion of WM and DBP resulted in pH of 4.2 and 4.3, respectively. Quadratic effects ($P \leq 0.001$) for pH were present with inclusion of DBP and DRC with increasing DM. As DM increased, a linear increase ($P < 0.001$) in pH was observed with WM inclusion. Greatest measured lactate (% DM) was at 30, 30, 35, and 50% DM for DBP, DCGF, DRC, and WM inclusion, respectively. No effects for lactate production were observed with the addition of DBP. In contrast, a quadratic effect ($P < 0.001$) for lactate production was noted for DRC inclusion and a cubic effect ($P = 0.05$) for WM inclusion was noted as DM increased.

Production of VFA decreased (linear, $P = 0.001$) with inclusion of DBP through 50% DM, and increased (quadratic, $P \leq 0.03$) with DRC (maximum, 40% DM silage) and WM (quadratic, $P = 0.03$; maximum, 30% DM silage) inclusion. With increasing silage DM, acetate production responded quadratically ($P \leq 0.05$) with addition of DRC and WM, and decreased linearly ($P = 0.001$) with DBP inclusion. Increased lactate, VFA, and acetate in 25% DM silages, influenced total organic acid production (% DM) through 50% DM silages. This did not however, influence the general patterns of lactate, VFA, and acetate (%DM) observed in silages without 25% WBT.

The addition of WBT resulted in few differences in silage pH, with the exception of DCGF. The pH for DCGF inclusion ensiled with WBT averaged 4.3 compared to 6.6 for DCGF without tailings. Increasing silage DM resulted in a cubic effect ($P \leq 0.02$) on pH with addition of WBT to DBP, DRC, and WM. The pH of silages containing DCGF and tailings linearly ($P < 0.001$) increased with increasing DM. With respect to lactic acid production, the addition of WBT plus DBP, DCGF, and DRC resulted a cubic effect ($P \leq 0.02$). Wheat midds responded with a linear increase ($P < 0.001$) in lactic acid to increasing levels of DM.

Table 4. Analyzed fermentation characteristics of wet sugarbeet pulp ensiled for 47 d with inclusion of dry feedstuffs to achieve varying levels of dry matter[†]

	Formulated Silage DM[‡], %								Contrasts[§]		
Item	**25**	**30**	**35**	**40**	**45**	**50**	**SEM[¶]**	**P-Value[††]**	**L**	**Q**	**C**
pH											
DBP	—	4.20	4.33	4.33	4.43	4.40	0.01	<0.0001	<0.0001	0.0003	0.64
DBP plus WBT	3.96	4.22	4.14	4.19	4.29	4.37	0.02	<0.0001	<0.0001	0.30	0.0002
DCGF‡‡	7.11	6.23	6.41	6.50	6.77	6.65	—	—	—	—	—
DCGF plus WBT	4.18	4.21	4.22	4.24	4.32	4.34	0.01	<0.0001	<0.0001	0.11	0.87
DRC	6.68	6.46	5.71	5.86	6.10	6.39	0.04	<0.0001	<0.0001	<0.0001	0.44
DRC plus WBT	6.75	6.46	6.20	6.30	6.34	6.13	0.03	<0.0001	<0.0001	0.004	0.001
WM	4.15	4.12	4.18	4.20	4.27	4.32	0.03	0.002	<0.0001	0.09	0.57
WM plus WBT	4.10	4.19	4.24	4.24	4.28	4.33	0.02	<0.0001	<0.0001	0.16	0.02
Lactate, % DM											
DBP	—	3.76	2.85	3.47	2.89	2.87	0.27	0.11	0.07	0.58	0.28
DBP plus WBT	7.45	4.09	5.62	4.84	4.48	3.88	0.26	<0.0001	<0.0001	0.02	0.0003
DCGF‡‡	3.86	7.77	6.74	7.25	6.61	7.55	—	—	—	—	—
DCGF plus WBT	5.52	6.70	7.40	8.18	7.45	5.24	0.26	<0.0001	0.47	<0.0001	0.02
DRC	2.38	3.96	7.78	7.44	5.58	4.76	0.37	<0.0001	0.0002	<0.0001	0.71
DRC plus WBT	2.58	5.80	6.14	5.48	6.75	5.99	0.32	<0.0001	<0.0001	0.0001	0.01
WM	3.66	6.10	7.49	7.94	8.95	9.89	0.32	<0.0001	<0.0001	0.01	0.05
WM plus WBT	5.17	6.34	6.53	7.97	8.27	8.59	0.37	0.0001	<0.0001	0.28	0.67
VFA, % DM											
DBP	—	7.89	7.56	7.54	6.08	5.65	0.39	0.01	0.001	0.34	0.52
DBP plus WBT	11.27	7.92	10.60	10.61	9.52	8.61	0.40	0.001	0.03	0.45	0.001
DCGF‡‡	8.93	11.10	8.45	8.11	4.54	4.20	—	—	—	—	—
DCGF plus WBT	10.11	9.42	8.68	9.39	7.59	4.91	0.37	<0.0001	<0.0001	0.001	0.01
DRC	7.34	10.13	12.23	12.58	11.42	8.42	0.65	0.0004	0.10	<0.0001	0.57
DRC plus WBT	7.46	9.06	11.86	10.05	9.90	12.57	0.37	<0.0001	<0.0001	0.08	0.0001
WM	8.32	9.41	8.30	9.21	9.04	7.40	0.42	0.05	0.20	0.03	0.34
WM plus WBT	10.00	10.57	11.05	10.43	10.43	10.35	0.54	0.84	0.88	0.32	0.49

Table 4 continued.

	Formulated Silage DM[‡], %								Contrasts[§]		
Item	**25**	**30**	**35**	**40**	**45**	**50**	**SEM[¶]**	**P-Value[††]**	**L**	**Q**	**C**
Acetate, % DM											
DBP	—	6.87	6.46	6.63	5.95	4.70	0.33	0.01	0.001	0.07	0.30
DBP plus WBT	9.96	7.11	9.53	9.70	8.40	7.52	0.39	0.0007	0.03	0.18	0.001
DCGF‡‡	4.91	5.46	3.66	3.26	1.31	0.48	—	—	—	—	—
DCGF plus WBT	8.53	8.21	7.71	8.72	7.11	4.52	0.44	0.0002	<0.0001	0.002	0.02
DRC	6.13	8.84	11.42	11.14	9.95	7.34	0.58	0.0001	0.08	<0.0001	0.95
DRC plus WBT	6.54	8.23	11.40	9.10	9.11	11.48	0.35	<0.0001	<0.0001	0.01	<0.0001
WM	7.27	8.49	7.23	8.22	8.17	6.76	0.42	0.07	0.48	0.05	0.46
WM plus WBT	8.64	9.60	9.77	9.59	9.72	9.74	0.52	0.64	0.22	0.33	0.46
Total organic acid, % DM											
DBP	—	11.66	10.41	11.01	8.96	8.60	0.38	0.02	0.003	0.70	0.93
DBP plus WBT	18.72	12.01	16.22	15.46	13.99	12.49	0.43	<0.0001	<0.0001	0.41	<0.0001
DCGF‡‡	12.79	18.86	15.19	15.36	11.16	11.75	—	—	—	—	—
DCGF plus WBT	15.63	16.12	16.08	17.57	15.04	10.15	0.39	<0.0001	<0.0001	<0.0001	0.0003
DRC	9.72	14.09	19.99	20.02	17.00	13.18	0.62	<0.0001	0.0003	<0.0001	0.71
DRC plus WBT	10.04	14.85	18.00	15.53	16.66	18.56	0.47	<0.0001	<0.0001	0.0002	<0.0001
WM	11.98	15.51	15.79	17.14	17.99	17.28	0.68	0.001	<0.0001	0.01	0.69
WM plus WBT	15.17	16.91	17.58	18.40	18.70	18.95	0.33	<0.0001	<0.0001	0.01	0.50

[†]Dry feedstuff codings are dry pelleted beet pulp = DBP, dry pelleted corn gluten feed = DCGF, dry rolled corn = DRC, and wheat midds = WM.
[‡]Wet sugarbeet pulp (25% DM) was used as a control
[§]Contrasts: L = linear; Q = quadratic; C = cubic
[¶]Standard error of the mean; n = 3
[††]Probability of statistic greater than F for treatment
[‡‡]Descriptive only; treatment not replicated therefore, data could not be analyzed

Addition of WBT plus DBP, DCGF, and DRC on VFA concentration yielded cubic effects ($P \leq 0.01$) as DM increased. However, there were no significant effects ($P = 0.84$) for WM and tailings on VFA. Molar proportion of acetate and total organic acid followed trends observed for VFA concentrations.

DISCUSSION

Ensiled products are produced through anaerobic fermentation. Anaerobic bacteria are critical for the production of organic acids (primarily lactic and acetic acid), which lower silage pH and create an efficient fermentation environment (Oude Elferink *et al.,* 2000). A lower pH (4.0 to 4.3) is desirable for high moisture (> 70% moisture) ensiled products, as it aids in reducing proteolysis and decreases undesirable microbial activity (clostridia), while preserving the nutritive value of the ensiled products (Muck, 1988). The silage fermentation period may last from 1 to 4 weeks; however, in high moisture (70%) ensiled products, most of the fermentation often occurs during the first week (Muck, 1988).

The objectives of this experiment were to determine optimal ensiling conditions for WBP by altering the DM composition using readily available dry feedstuffs in the Red River Valley. Our results indicate that WBP alone may heavily influence the conditions and quality of fermentation, as pH remained fairly constant from 25% DM (100% WBP) through 50% DM (45% WBP). High moisture ensiled products may require a pH as low as 4 to reduce unwanted microbial activity (Muck, 1988). Mean pH values of silages were 4.3, 6.6, 6.2, and 4.2 for DBP, DCGF, DRC, and WM, respectively. Addition of WBT decreased pH of silages containing DCGF, but not silages containing DRC. Mustafa *et al.* (2002) reported a rapid decline in pH of field pea silage 0 to 2 d post-ensiling, followed by a gradual decline to below a pH of 4 after 8 d. From day 8 to 70, the pH remained stable at approximately a pH of 4 (Mustafa *et al.,* 2002). Mustafa *et al.* (2002) attributed the rapid decline in pH to acetic and lactic acid producing bacteria. Ferris and Mayne (1994) ensiled ryegrass with 40, 80, or 120 kg/t of beet pulp. They observed a decrease in silage pH with increasing levels of beet pulp. Wet sugarbeet tailings, when added to DBP, elevated lactate. Ferris and Mayne (1994) reported increased inclusion of beet pulp decreased lactic acid concentration when compared to the control (no additives). However, when evaluating beet pulp ensiled with ryegrass, lactate concentration increased as the proportion of beet pulp increased. McDonald *et al.* (1991) suggested that increased lactic acid concentration was a reliable indicator of desirable fermentation.

Nutritive value (CP, soluble CP, and IVDMD) of the ensiled products appears to be representative of the added feedstuff. Our data suggests that inclusion of any dry feedstuffs used in this experiment can be used to partially dry and produce ensiled WBP products. However, for reasons that are not apparent, in some instances (DRC and DCGF) pH was not sufficiently reduced for long-term storage. Hameleers *et al.* (1999) reported no differences in pH when differing levels of sugarbeet pulp were ensiled with forage maize.

Results indicate that moisture content of WBP can be altered with addition of other drier, readily available feedstuffs. This experiment provides insight on moisture levels at which WBP can be partially dried and incorporated into a quality ensiled product. Based on this data, the most desirable fermentation (associated with pH and increased acid production) of WBP-based silage occurred at 25% DM for DBP plus WBT, 30% DM for DBP and DCGF, 35% DM for DRC and DRC plus WBT, 40% DM for DCGF plus WBT, and 50% for WM and WM plus WBT. However, it is important to note, corn products did not produce desirable fermentation characteristics. Further research is needed to determine nutrient retention after prolonged storage, palatability, and the conditions that will ensure a consistent quality ensiled WBP product for livestock consumption.

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