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Evaluation of Stockpiled Perennial Forage Compared to Grass-legume Hay for Chemical Composition and Rumen Degradation Kinetics

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Abstract

The objective of this study was to determine the chemical composition and in situ degradability of dry matter (DM), crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) of stockpiled perennial forage (SPF) or sun-cured hay (HAY) when collected at the start or end (October vs. December) of fall grazing. Selected 6, 4-ha paddocks consisting of meadow bromegrass and alfalfa, were randomly assigned to 1 of 2 replicated (n = 3) winter feeding systems (SPF and HAY). Sampling was done twice per year at the beginning (October) and end (December) from (a) stockpiled perennial forage (SPF) in field paddocks and from (b) harvested round bale hay (HAY) over 2 consecutive years. Selected 6, 4-ha paddocks consisting of meadow bromegrass and alfalfa, were randomly assigned two winter feeding systems (SPF (n=3) and HAY (n=3)). Sampling were done twice per year at the beginning (October) and end (December) from (a) SPF (b) HAY over 2 consecutive years. To evaluate *in situ* degradability, duplicate nylon bags from each experimental unit were incubated for 0, 3, 6, 10, 13, 25, 48, 72, and 96 h in five Hereford heifers fitted with rumen cannula. Relative to HAY, SPF had greater (p = 0.01) OM (906 vs. 916 g/kg DM) and NDF (653 vs. 631 g/kg DM) concentrations. Sampling date had no effect ($p > 0.05$) on CP, OM, and ADF in both forages, whereas the NDF was greater (p = 0.01) in forages sampled in December. The *in situ* soluble fraction (S) of DM was greater (p = 0.01) for SPF collected in October, HAY collected in October, and HAY collected in December s (156, 138, and 152 g/kg DM, respectively) relative to SPF collected in December (106 g/kg DM). The potentially degradable fraction (D) of CP was less ($p < 0.05$) for HAY December samples compared to SPF December and HAY October samples (257 vs. 522 and 523 g/kg CP, respectively). The SPF had a greater ($p < 0.05$) potentially degradable ADF (749 vs. 587 g/kg ADF) and potentially degradable NDF (770 vs. 591 g/kg NDF) compared to HAY. The effect of forage type and sampling date did not affect ($p > 0.05$) effective degradability of NDF. Regardless of the forage type the potentially degradable fraction of NDF decreased from October to December (SPF: 770 to 730 g/kg NDF) (HAY: 680 g/kg to 491 g/kg NDF). These findings suggest SPF grazing is a robust substitute to hay feeding systems for beef cows.

Keywords: baled hay, rumen degradability, stockpiled forage

1. Introduction

In western Canada and many prairie regions the winter climate conditions can be challenging to cattle producers due to the end of the growing conditions of their feeding materials (McCartney, Okine, Baron, & Depalme, 2004; Kelln et al., 2011). Therefore, supplemental feed is required until the next growing season, and programs such as drylot feeding of stored hay is a common practice among Canadian cattle producers. However, there is an expense associated with this practice which has resulted in beef producers seeking alternate methods. Stockpiling forage (SPF) is the practice of accumulating forage biomass during the summer and fall; and then grazing that biomass after the growing season and usually mature and moderate to poor in nutritive value (Hitz & Russell, 1998). In SPF system, usually the grazing season is extended into the fall and winter (Johnson & Wand, 1999; Cherney & Kalenback, 2003; Kulathunga et al., 2016). However, stockpiled forages can potentially meet the nutrient requirements of dry cows in early to mid-gestation (Scarbroug et al., 2002; Poore & Drewnoski, 2010;

Kulathunga et al., 2016). The practice of extending the grazing season via stockpiled forage has exhibited an increase in economic profitability of cattle producer operations (Johnson & Wand, 1999). Additional benefits of stockpiled forage grazing include a replacement of nutrients into the soils due to the extended spread of manure and urine throughout the fields, which then improves the soil quality for the next growing season. This grazing system, can affect the feed consumption of beef cows and their performance based on the fiber content and the digestibility of the forage being consumed (Montgomery & Baumgardt, 1965). This is emphasizing the importance of investigating the ability of stockpiled forage to meet the nutrient requirements of beef cows managed in these fields.

Maintenance and pregnancy energy requirements of beef cattle increase in response to colder temperatures, as well as advancing gestation, and therefore information on the nutritional quality of the stockpiled forage is vital to ensure proper dietary requirements for the cattle. Intercropping is the practice of growing two or more crop types in one field location simultaneously. Benefits of intercropping can include an increase in soil fertility due to nitrogen-fixing legumes, which in turn promote grass growth (Hauggaard-Nielsen, Ambus, & Jensen, 2001); and furthermore, it provides an increase in the quality of the forage through complementary effects of the multiple crops being grown (Ross, King, O'Donovan, & Spaner, 2004). Grass-legume is an example of an intercropped field, that would provide adequate biomass for stockpiled grazing. The digestibility of grass-legume hay may change during the storage. Therefore, the nutritive value of grass-legume hay and stockpiled forage needs to be evaluated before using these forages in winter feeding systems for beef cattle (Aasen, Baron, Clayton, Dick, & McCartney, 2004). At present there are limited studies available describing ruminal degradability kinetics of stockpiled perennial forages during fall months in western Canada. Rumen degradability is described as one of the most important variables in modern protein evaluation systems for ruminant animals (Weisbjerg, Hvelplund, Hellberg, Olsson, & Sanne, 1996). Crude protein degradation kinetics is an appropriate estimate to predict the supply of amino acids to the small intestine and therefore overall nutrients being received by the ruminant (Miranda, Passarinho, & Gouveia, 2012). The objectives of this study were to compare stockpiled and baled grass-legume hay harvested forages collected at the start and end of fall in terms of (i) nutritive value and (ii) *in situ* rumen degradation kinetics.

2. Materials and Methods

2.1 Forage Sample Collection

The forages were derived from a companion field grazing study evaluating 2 perennial forage systems (Kulathunga et al., 2016) conducted at the Western Beef Development Centre's Termuende Research Ranch (currently Livestock and Forage Centre of Excellence of University of Saskatchewan) located at Lanigan, Saskatchewan, Canada (51 ℉1′N; 105°02′W). A detailed description of the experimental site is presented in Kulathunga et al. (2016). The field is located in the Black Soil Zone of Saskatchewan and the soil is Chernozemic Black Oxbow soil (Saskatchewan Soil Survey 1992). Over 2 yr, a 24-ha field of meadow bromegrass (*Bromus riparius* Rehm.;'Paddock') - alfalfa (*Medicago sativa* L.; 'Algonquin') (80:20 blend) mixture was subdivided into six, 4-ha paddocks and each paddock was randomly assigned to either stockpiled perennial forage (SPF) or harvested as sun-cured hay (HAY (n=3)) (Kulathunga et al., 2016). The perennial forages were allowed to grow in all paddocks during spring, summer and early fall, and then were swathed into windrows mid September each year. The SPF grazing treatment was used for grazing in early October in each yr, while the HAY treatment was harvested mid-September as large round hay bales (598 ± 48 kg) using a New Holland BR780 round baler. The HAY bales were then hauled and stored at a centralized yard site and fed to cattle in drylot pens. Forage samples were collected from both feeding systems in October and December of each yr of the field grazing study (Kulathunga et al., 2016). Based on previous research, it was reported that the botanical composition of the grass and legume components did not differ significantly (p = 0.52) between forage systems (Kulathunga et al., 2016). Each sampling time, five grab samples were taken randomly from swath forages to analyze chemical composition and *in situ* analyses from each replicate (n = 3) paddock in SPF system. For HAY sampling, five bales were sampled using a coring device (Penn State Forage Sampler, Modesto CA, USA) from each replicate (n = 3) group of round bales.

2.2 Experimental Animals

Five Hereford heifers (398 ± 14 kg) fitted with rumen cannulae (13 cm i.d.; Bar Diamond Inc., Parma, ID, USA) and were housed in a 10 × 10 m pen at the Beef Cattle Research Unit, Department of Animal and Poultry Science, University of Saskatchewan. The cannulated heifers were fed a grass hay (TDN 50.8%, CP 9.8%, NDF 66.2%) and adapted to the diet for 21 d prior to the *in situ* rumen incubation study. All animals were supplied adequate water. The Animal Care Committee of the University of Saskatchewan (Protocol Number 20100021)

approved the animal trial and animals were managed according to the Canadian Council of Animal Care Guidelines (2009).

2.3 In-Situ Rumen Incubation

The *in-situ* procedure described in this study followed the previous literatures, Ørskov and MacDonald (1979) and Damiran and Yu (2010). All forage samples (October and December) were ground to pass through a 2-mm screen using a Thomas-Wiley Laboratory Mill (Model 4, Thomas Scientific, Swedesboro, NJ, USA). Seven grams of sample was weighed into numbered nylon numbered (5 × 10 cm, #BG510, Bar Diamond Inc., Parma, Idaho, USA) bags with 40 μm pores and bags were then sealed. In each sample the weight and the type of the forage sample was recorded. The nylon bags were randomly allocated to the five cannulated heifers and packed into laundry bags and inserted into the rumen (30 to 40 bags/laundry bag). Each bag was connected to 80 cm cord, which extended outside of the cannulae plug. Samples were incubated for 0, 2, 4, 8, 12, 24, 48, 72, and 96 h according to the gradual addition/all out procedure (Damiran & Yu, 2010). In this technique, the bags assigned for the longest incubation time (96 h) are put in the rumen first, then at 24 h since the first bags were incubated in the rumen, the next bags with the next longest incubation time (72 h) are added and so on; in this way the bags are added into the rumen gradually in a descending order of their assigned incubation time until the 0 h bags and then all bags are removed from the rumen at the same time or at 96 h of the first and 0 h of the last bags, because each bag is supposed to have been incubated for the designated time (Damiran & Yu, 2010). All samples of residue were weighed after drying, removed from the bags, and pooled according to forage, sampling date, and incubation duration. All pooled residues were ground to pass through a 1-mm screen with a Wiley mill grinder (Model #2, Arthur H. Thomas Co., Philadelphia, PA, USA).

2.4 Analysis

To determine chemical composition, original forage samples and residues from in situ incubation were analyzed for DM, OM, CP, NDF, and ADF. Dry matter (method #930.15; AOAC 2000) and ash (AOAC method # 942.05) were determined according to the procedures outlined by the Association of Official Analytical Chemists (AOAC 2000). Crude protein (N × 6.25) concentration was determined using the Kjeldahl procedure (method #984.13; AOAC 2000, model 2400 53 Kjeltec Analyzer Unit, FOSS Tecator, Hoganas, Sweden). The ground samples (1 mm, 0.45 - 0.55 g) were placed inside Ankom filter bags and sealed to measure the ADF and NDF content following the method # 973.18, AOAC (2000). Heat stable α-amylase and sodium sulfite were included in the NDF procedure.

2.5 Rumen Degradation Kinetics

In-situ data were fitted to the first-order kinetic degradation model (Orskov & McDonald, 1979):

$$R\,(t) = U + D \times exp\,(-K_d \times (t - T_0)) \quad (1)$$

where, R (t) is the amount of residue at t h of incubation (g/kg), U is the undegradable fraction (g/kg), D is the potentially degradable fraction (g/kg), T_0 is the lag time (h) and K_d is the degradation rate (%/h). This model described the rumen degradation of DM, CP, NDF, and ADF and was solved with the use of the NLIN procedure of SAS with iterative least-square regression (Gauss-Newton method) (Version 9.3, SAS Institute, Cary, NC). Effectively degradability (ED) of each nutrient component was determined using the nonlinear (NLIN) parameters calculated by the Equation (S, U, D, and K_d) (Orskov & McDonald, 1979) as:

$$ED\,(g/kg) = S + D \times K_d / (K_p + K_d) \quad (2)$$

where, S is the soluble fraction (g/kg) and A K_p value of 4%/h was used to represent the rumen turnover rate.

2.6 Statistical Analysis

Data were analyzed using the MIXED procedure of SAS 9.3 (SAS, 2013) for a completely randomized design (CRD) with subsampling and with a 2 × 2 factorial arrangement of treatments.

The model used was $Yij = \mu + forage_i + date_j + (forage \times date)_{ij} + e_{ij}$

Where Y_{ij} = response variable; μ = mean; forage system (forage; SPF vs. HAY) and sampling date (date; October vs. December) were both fixed effects, and e_{ij} was the error. Each paddock (SPF) or pen (HAY) (n = 3) was considered an experimental unit for a total of 12 experimental units over the 2 yr study. Year was treated as a random variable in all analyses and differences between treatment means were determined using Tukey's multiple range test and were considered significant when $p < 0.05$. For the chemical composition variables, the forage × date interaction was not affected ($p > 0.05$) and removed from the model.

3. Results

3.1 Chemical Composition

The chemical composition of SPF and HAY sampled at the October and December time points are presented in Table 1. There were no interactions between forage type and sampling date ($p > 0.05$) for the chemical composition. Relative to HAY, SPF had greater ($p = 0.01$) OM (906 vs. 916 g/kg DM) and NDF (653 vs. 631 g/kg DM) concentrations. Sampling date had no effect ($p > 0.05$) on the CP, OM, and ADF; whereas, NDF was greater ($p = 0.01$) for forages sampled in December than in October (654 vs. 630 g/kg DM).

Table 1. Chemical composition of stockpiled perennial forages (SPF) and baled hay (HAY) sampled in October or December on 2 consecutive years

	Forage		Date			*p*-value	
Item	SPF	HAY	October	December	SEM	Forage	Date
Crude protein (g/kg DM)	99	90	97	91	10.2	0.08	0.23
Organic matter (g/kg DM)	916	906	912	910	2.4	0.01	0.52
Neutral detergent fiber (g/kg DM)	653	631	630	654	5.3	0.01	<0.01
Acid detergent fiber (g/kg DM)	449	446	445	451	5.9	0.68	0.48

Note. SPF = stockpiled perennial grass–legume forage grazed in field paddocks; HAY = round bale grass–legume hay fed in drylot pens. Differences between of treatment means were determined using Tukey's multiple range test and were considered significant when $p < 0.05$. Forage × Date interaction was not detected ($p > 0.05$).

3.2 Rumen Degradation Kinetics of DM, CP, ADF, and NDF

The effect of forage type on DM and CP degradation kinetics are presented in Table 2 and 3. The Forage × date interaction was not observed for lag time for both DM and CP. The forage × date interaction was observed in the the S and the D fractions of DM and CP. The S was greater ($p = 0.01$) for SPF sampled in October, HAY sampled in October, and HAY sampled in December (156, 138, and 152 g/kg DM respectively) relative to SPF sampled in December (106 g/kg DM). Further, a forage × date interaction was not observed for U of DM while interaction was found in U of CP.

No forage × date interaction was observed in K_d, or EDDM for both DM and CP. A forage × date interaction ($p < 0.05$) was also observed for the D of dry matter and CP and U of CP. The dry matter soluble fraction (S) was (Table 2) highest ($p = 0.01$) in SPF October, HAY October, and HAY December samples (156, 138, and 152 g/kg DM, respectively) and lowest for SPF December (106 g/kg DM) forage samples. Differences were detected for the potentially degradable fraction (D) and undegradable fraction (U) ($p < 0.05$) of CP among stockpiled and baled forages collected at two different sampling dates. The potentially degradable fraction of CP was less ($p = 0.04$) in HAY December samples compared to SPF December and HAY October samples (257 vs. 522 and 523 g/kg CP, respectively) and the U fraction of CP was greater ($p < 0.05$) in December HAY compared to either October or December SPF and October HAY (549 vs. 367, 371 and 382 g/kg CP respectively). Further, the S fraction was greater ($p < 0.05$) for SPF October (261 g/kg CP) when compared to SPF December (108 g/kg CP), suggesting loss of soluble CP from swathed stockpiled forages due to leaching and weathering. A numerically greater EDCP fraction was observed in October (435 g/kg CP) samples compared to SPF December (335 g/kg CP), HAY October (352 g/kg CP) and HAY December (321 g/kg CP).

The effect of forage type (or harvesting method) on *in situ* ADF and NDF rumen degradation kinetics are presented in Table 3. Forage × date interactions ($p > 0.05$) were not observed for ADF and NDF degradation kinetics with the exception of EDADF. The EDADF was not different ($p > 0.05$) due to sampling date for SPF (averaged 373 g/kg ADF); however, EDADF was greater ($p < 0.05$) in October (386 g/kg ADF) than December (287 g/kg ADF) for HAY.

Stockpiled perennial forage had a greater ($p < 0.05$) D of ADF (749 vs. 587 g/kg ADF), correspondingly, it had lower undegradable fraction (251 vs. 413 g/kg ADF) of ADF when compared to HAY. Regarding sampling date, the potentially degradable fraction of ADF was less ($p = 0.05$) in October relative to December.

Similar to the rumen degradation characteristics of ADF, the D of NDF was greater ($p < 0.01$) for SPF than HAY (770 vs. 591 g/kg NDF) and the U of NDF was less ($p < 0.01$) in SPF than HAY (230 vs. 409 g/ kg NDF). Differences due to forage type or sampling date were not detected ($p > 0.05$) in the EDNDF. However, the D of NDF in both SPF and HAY samples decreased ($p = 0.01$) from October to December (744 to 618 g/kg NDF); whereas the U of NDF increased ($p < 0.01$) from October to December (256 to 382 g/kg NDF).

Table 2. *In situ* rumen degradation kinetics of DM and CP of stockpiled perennial forages (SPF) and baled hay (HAY) sampled in October or December on 2 consecutive years

	SPF		HAY			*p*-value		
Item	October	December	October	December	SEM	Forage	Date	Forage × Date
Dry matter (g/kg DM)								
Lag time, (T_0; h)	0.7	0.2	0.5	0.8	0.47	0.58	0.73	0.12
Soluble fraction, (S; g/kg)	156	106	138	152	18.1	0.03	0.01	<0.01
Potentially degradable fraction, (D; g/kg)	562	583	536	391	30.2	<0.01	0.03	0.01
Undegradable fraction (U; g/kg)	282	312	327	457	44.0	<0.01	0.01	0.07
Rate of degradation (K_d; /h)	0.03	0.03	0.04	0.04	0.010	0.15	0.83	0.72
Effective degradability (EDDM; g/kg)	373	339	382	324	14.1	0.85	0.01	0.39
Crude protein (g/kg CP)								
Lag time, (T_0; h)	2.7	2.8	0.6	2.8	2.02	0.20	0.14	0.18
Soluble fraction, (S; g/kg)	261	107	95	195	45.6	0.41	0.56	0.02
Potentially degradable fraction, (D; g/kg)	372	522	523	257	45.5	0.23	0.23	<0.01
Undegradable fraction (U; g/kg)	367	371	382	548	31.8	<0.01	0.01	0.01
Rate of degradation (K_d; /h)	0.07	0.04	0.04	0.05	0.020	0.49	0.19	0.15
Effective degradability (EDCP; g/kg)	435	335	352	321	40.5	0.26	0.13	0.42

Note. SPF = stockpiled perennial grass–legume forage grazed in field paddocks; HAY = round bale grass–legume hay fed in drylot pens. Differences between treatment means were determined using Tukey's multiple range test and were considered significant when $p < 0.05$.

Table 3. *In situ* rumen degradation kinetics of NDF and ADF of stockpiled perennial forages (SPF) and baled hay (HAY) sampled in October or December on 2 consecutive years forages

	SPF		HAY			*p* -value		
Item	October	December	October	December	SEM	Forage	Date	Forage × Date
Rumen degradation kinetics of ADF (g/kg ADF)								
Lag time, (T_0; h)	1.5	1.5	1.5	1.5	0.29	1.00	1.00	1.00
Soluble fraction, (S; g/kg)	13.6	17.6	11.3	20.6	4.80	0.94	0.19	0.59
Potentially degradable fraction, (D; g/kg)	765	733	684	491	83.0	0.01	0.05	0.14
Undegradable fraction (U; g/kg)	235	267	316	509	83.0	0.01	0.05	0.14
Rate of degradation (K_d; /h)	0.02	0.02	0.03	0.03	0.007	0.25	0.77	1.00
Effective degradability (EDADF; g/kg)	378	369	386	287	21.1	0.08	0.02	0.04
Rumen degradation kinetics of NDF (g/kg NDF)								
Lag time, (T_0; h)	1.5	1.5	1.5	1.5	0.29	1.00	1.00	1.00
Soluble fraction, (S; g/kg)	7.4	8.7	10.2	24.0	6.40	0.18	0.26	0.35
Potentially degradable fraction, (D; g/kg)	834	707	654	528	45.0	<0.01	0.01	1.00
Undegradable fraction (U; g/kg)	166	293	346	472	45.0	<0.01	0.01	1.00
Rate of degradation (K_d; /h)	0.02	0.03	0.03	0.03	0.010	0.23	0.80	0.39
Effective degradability (EDNDF; g/kg)	441	387	398	302	38.9	0.10	0.06	0.56

Note. SPF = stockpiled perennial grass–legume forage grazed in field paddocks; HAY = round bale grass–legume hay. Differences between treatment means were determined using Tukey's multiple range test and were considered significant when $p < 0.05$.

4. Discussion

4.1 Chemical Composition

The numerically greater CP content in SPF compared to of baled hay in samples collected in October can be explained by the harvesting leaf loss at baling. However, the NRC (2000) model predicts that a dry cow in early to mid-gestation requires 7 to 8% of CP in the diet for maintenance. The result of current study suggested that CP content in stockpiled perennial forage was adequate to marginal to meet the CP requirement of beef cow. Slightly lower organic matter in hay compared to stockpiled forages suggesting possible contamination of hay with dirt or sand at the time of harvesting, baling, and transportation.

The greater NDF concentration for SPF compared to HAY samples collected in December is n agreement with previous studies (Lux, Koch, Hess, & Held, 1999; Munson, Whittier, Schutz, & Anderson, 1999; Baron, Dick, Bjorge, & Lastiwka, 2004) reporting that the NDF content of stockpiled forage increases as leaves senesce, translocation of nutrients out of these senescing leaves, leaf-drop, decay and increase dead material which has more structural carbohydrate than non-structural carbohydrates. Further, the NDF concentration increased in both SPF and HAY over time may be also due to weathering, leaf loss, leaf dead, respiration process and leaching of cell solubles in both stockpiled forage and baled hay over time (Hoffman, Sievert, Shaver, Welch, & Combs, 1993; Scarbroug et al., 2002; Baron et al., 2004). Our results agree with the previous findings (Volesky, Adams, & Clark, 2002) that CP content of windrowed and baled forage was similar over all sampling months in

winter. The results of current study further agree with other's (Kelzera, Walkerb, Birdc, & Mathisonc, 2010) results which showed that fiber component of forage can increase due to wet and cold weather conditions in winter. Fiber composition of stockpiled forage can be affected by numerous factors such as weather, leaf senescence and presence of winter annual weeds (primarily at the pasture site) (Scarbrough et al., 2001).

4.2 Rumen Degradation Characteristics

The higher soluble DM fraction reflects the higher cell soluble content in SPF October, HAY October, and HAY December than that of SPF December sample. Leaching of cell soluble from swathed forage over time may have decreased the cell soluble content in yearend sample compared to samples, SPF October, HAY October and HAY December. The magnitude of rumen degradable fractions and degradation rate of perennial forages can be affected by plant species and maturity (Hoffman et al., 1993; Lardner, Kumar, Darambazar, Damiran, & McKinnon, 2016). In current study, the lag time, undegradable fraction, rate of degradation, as well as effective degradability values were not different between SPF and HAY at either sampling date (Table 2) since we used similar grass (*Bromus riparius* Rehm) and legume species (*Medicago sativa* L.) in both treatment and SPF and HY were harvested at similar stage of maturity. Further, relatively higher soluble fraction in SPF October samples (261 g/kg CP) compared to SPF December samples (108 g/kg CP) suggesting loss of soluble CP from swathed stockpiled forages due to leaching and weathering.

In a previous study (Hoffman et al., 1993) on rumen degradation characteristics of different perennial forages, a high correlation (r = 0.86) was observed for level of effective degradability of CP (EDCP) with magnitude of CP. Therefore, the numerically higher EDCP in SPF October samples compared to SPF December, HAY October and HAY December, in current study, was likely due to higher CP content in SPF October samples.

The greater degradable fraction of NDF and ADF in SPF than HAY was likely due to the leaf loss at baling of hay which can decrease the degradable fraction of fiber in hay compared to stockpiled forages. As Hoffman et al. (1993) reported, the maturity of forages can have a higher correlation (r = –0.65) with effective degradability of NDF (EDNDF). In this study forages were harvested at similar maturities and can explain the observed similar EDNDF values for SPF and HAY samples. The potential leaf loss in stockpiled forage over time can decrease the leaf: stem ratio and may have decreased the potentially degradable fraction and increased the undegradable fraction of NDF in samples collected in December compared to samples collected October. Further, weathering can affect the rumen degradation characteristics of NDF in stockpiled perennial forage and baled hay which were stored outside and have increased the lignin component and decreased the digestibility over time (Scarbrough et al., 2001).

When swathed forage is exposed to rain, soluble nutrients can be lost due to leaching which can decrease the DM and increases the proportion of fiber in tissue over time (Kormos & Chestnutt, 1968; Mark & Murray, 1994). The method of storing hay can contribute to decreases in grass-legume hay quality over time. Laflamme (1989) found that in large round hay bales DM content decreases and non-digestible fractions increase mainly as a result of precipitation. However, the deterioration of forage is mostly restricted to the first 15 cm layer of the bales. Therefore, in the current study weather deterioration may have contributed to the decrease in the quality of hay which was stored outside without cover. Previous literature described that when swathed forage is exposed to rain, soluble nutrients can be lost due to leaching which can decrease the DM and increases the proportion of fiber in tissue over time (Kormos & Chestnutt, 1968; Mark & Murray, 1994). Also, the method of storing hay can contribute to decreases in grass-legume hay quality over time. Laflamme (1989) described that in large round hay bales DM content can decreases and non-digestible fractions can increase due to precipitation. Usually, the deterioration of forage is mostly restricted to the first 15 cm layer of the bales and therefore, weather deterioration may have contributed to the decrease in the quality of hay which was stored outside without cover in this study. The rate of DM degradation obtained for stockpiled perennial forage (0.03 /h) were similar to that obtained for un-grazed (0.032 to 0.052 /h) and grazed (0.037 to 0.041 /h) fall-stockpiled bermudagrass by Scarbrough et al. (2001). Both NDF and ADF were degraded at the same rate (0.03 /h; p = 0.27) and no effect of treatment or sampling time were observed. The rate of degradation can be affected by cell wall physical characteristics like porosity, degree of polymerization and crystallinity and chemical factors like lignin (Cross, Smith, & DeBarth, 1974; Moore & Cherney, 1986; Scarbrough et al., 2001). According to Jung and Allen (1995) findings fiber digestibility was not affected by overall fiber content but it may affected by the undegradable fraction, rate of digestion, and rate of passage.

5. Conclusions

The HAY December sample had a lower potentially degradable fraction of CP and DM than SPF October, SPF December and HAY October samples suggesting that hay quality declined rapidly from October to December

compared to stockpiled perennial forage. The method of preservation (stockpiled vs. baled) may have affected the rate of change in rumen degradability kinetics during extended storage of hay. The potentially degradable fraction of ADF and NDF were greater in of stockpiled perennial forage than that of baled hay. However, potentially degradable fraction of NDF decreased from October to December in both stockpiled perennial forages and baled hay suggesting possible effects of weathering, leaf senescence, leaf dead, leaching of cell solubles, and leaf loss over time. Even though potentially degradable fraction of major nutrients declined rapidly from October to December, the result of current study suggested that SPF hold its CP values to maintain dry, pregnant cows in October to December. This suggests that winter grazing stockpiled perennial forage is a robust alternative to hay feeding systems; and may need additional supplementation when forage digestibility decreases over time and animal requirements increases due to very cold environmental temperatures.

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