Digestibility of Undegradable Intake Protein of Feedstuffs

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Summary

Digestibility of undegradable intake protein of subirrigated meadows, upland native range, smooth bromegrass, and other feedstuffs used in several growing trials was measured using the mobile nylon bag technique. In general, as the grazing season progressed, undegradable intake protein (UIP) digestibility of grazed forages decreased. Also, UIP digestibility was highly variable among feedstuffs. Compared to the constant 80% digestibility of UIP used by the 1996 Beef NRC, grazed and harvested forages tend to have much lower UIP digestibility values while the supplemental protein sources evaluated tend to have higher UIP digestibility values.

Introduction

The amount of protein available for absorption in the small intestine of cattle depends on the amount of microbial protein and ruminally undegradable intake protein (UIP) flowing to the small intestine as well as the digestibility of these protein sources in the small intestine. Current protein evaluation systems acknowledge that intestinal digestibility of proteins may differ between feedstuffs, but the NRC (1996) model for beef cattle still uses a constant, true digestibility of 80% for UIP, due to a lack of available data on UIP digestibility (UIPDIG). Research conducted at the University of Nebraska (*2005 Nebraska Beef Report,* pp. 25-27) showed UIP content and UIPDIG of forages is low which suggests the values used by the NRC (1996) model for the UIP content and UIPDIG of feedstuffs may be overestimated. The objectives of our study were: 1) to determine effects of season on UIP content and UIPDIG of forage samples collected from subirrigated meadow or upland native range during a grazing trial and 2) to evaluate protein characteristics of feedstuffs used in four growing trials.

Procedure

In the first experiment, meadow and range samples from a previous study (*2002 Nebraska Beef Report*, pp. 7-9) were further analyzed to determine the UIP content, UIPDIG, and total tract indigestible dietary protein (TTIDP). In the previous study, forage samples were collected from two subirrigated meadow sites and two upland native range sites at the Gudmunsen Sandhills Laboratory near Whitman, Neb. Subirrigated meadow samples consisted of warm and cool-season grasses and upland native range samples consisted of warm season grasses. Collections were made using esophageally-fistulated cows in May, June, July, August, and September of 2000. Forage samples were freeze-dried and later analyzed for IVDMD. The IVDMD was used to estimate the rate of passage (kp) using the following equation: *kp = 0.07 * IVDMD (%) - 0.20.* The kp was then used to determine the mean retention time (MRT = 1/kp) and a 10-hour passage lag was added to the MRT to yield the total mean retention time (TMRT).

In the present experiment, two ruminally and duodenally cannulated steers were used to incubate 5 x 10 cm dacron bags with 50 μm pore size. Bags contained 1.25 g of forage ground through a 2 mm screen. A mixed ration of 70% smooth bromegrass hay and 30% concentrate was fed twice daily for a total intake of 1.8% BW. Four bags per steer were ruminally incubated for 75% of the TMRT determined using the IVDMD. The 75% TMRT incubation time points of the meadow and range samples are shown in Table 1. After ruminal incubation, all bags were frozen. Two bags per sample were later thawed and prepared for duodenal insertion. Bags were first pre-incubated in a pepsin and HCl solution at 37°C for 3 hours to simulate abomasal digestion. Bags were inserted into the duodenum 2 hours post-feeding at a rate of 1 bag every 0.1 hour for a total of 12 to 13 bags/steer/day. Bags were recovered in the feces beginning 12 hours after insertion and frozen until all bags had been collected. After all bags had been intestinally incubated, the ruminally incubated bags and intestinally incubated bags were thawed and washed in a washing machine for 0.25 hours. This was done using five rinse cycles consisting of a 1 minute agitation and a 2-minute spin per cycle. Bags were subsequently bulk refluxed in neutral detergent solution to remove microbial contamination of the residue. Residues were then analyzed for NDIN using a combustion method.

In the second experiment, feed ingredients and forage diet samples from four previous growing trials were analyzed for UIP, TTIDP, and UIPDIG. Three of these previous trials were grazing studies from 2002, 2003, and 2004 where animals rotationally grazed smooth bromegrass pastures. In each of these three studies, two ruminally cannulated heifers per pasture were used to collect forage diet samples of the grazed forage throughout the grazing season, but collection strategies differed each year. In 2002, all pastures in the rotation were sampled at two time points and samples were composited by time. In 2003, diet samples were collected at three times during the trial from the pasture where cattle were grazing at that time. In 2004, cattle grazed each pasture for one day. Two pastures were sampled at the start of each rotation, one was a pasture the cattle had grazed the previous day and the other was the pasture they would graze that

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Table 1. Protein characteristics of subirrigated meadows and upland native range from May to September.

	May		June		July		August		September		
Item	M[a]	R	M	R	M	R	M	R	M	R	SEM[b]
CP, %DM[c]	14.1[h]	12.2[i]	11.9[i]	9.4[j]	12.3[i]	9.6[j]	11.8i	9.0[j]	8.5[j]	9.4[j]	0.6
IVDMD, %[d]	70.2[h]	67.7[h]	67.3[h]	63.6[i]	59.0[jk]	61.6[ik]	57.2[jl]	55.8[l]	50.4[m]	52.5[m]	1.2
UIP, %DM[e]	1.65[hj]	1.88[hj]	1.87[hj]	1.87[hj]	1.60[hi]	1.48[hi]	1.44[hi]	2.05[j]	1.26[i]	2.44[k]	0.29
TTIDP, %DM[f]	0.91[h]	1.08[hi]	1.06[hi]	1.19[i]	1.09[hi]	1.20[i]	1.14[hi]	1.70[j]	1.11[hi]	2.18[k]	0.15
UIPDIG, %UIP[g]	43.3[h]	40.2[hi]	43.0[hi]	36.1[hi]	30.1[ij]	21.2[jk]	16.1[jkl]	10.9[kl]	6.5[l]	13.1[kl]	6.3

[a]M = subirrigated meadow, R = upland native range.
[b]SEM = standard error of the mean.
[c]Forage x Month ($P < 0.01$).
[d]Forage x Month ($P = 0.02$).
[e]UIP = Undegradable intake protein, calculated as follows: UIP (% DM) = (NDIN at 75% total mean retention time * 6.25) / sample DM. Forage x Month ($P < 0.01$).
[f]TTIDP = total tract indigestible dietary protein, calculated as follows: TTIDP (% DM) = (fecal NDIN * 6.25) / sample DM. Forage x Month ($P < 0.01$).
[g]UIPDIG = UIP digestibility, calculated as follows: UIPDIG (% of UIP) = 1 - (TTIDP / UIP). Forage x Month ($P = 0.57$). Forage ($P = 0.24$). Month ($P < 0.01$).
[h, i, j, k, l, m]Means within a row with unlike superscripts differ ($P < 0.05$).

day. Those diet samples were averaged to obtain an average diet sample for that time. Samples were collected at eight times in 2004. The other non-grazed feed ingredients analyzed in Experiment 2 were: the commercially available methionine source Smartamine M™ (MET), corn cobs (COB), bloodmeal (BM), corn gluten meal (CGM), SoyPass™ (SP), feathermeal (FM), two sources of dry distillers grains (DDGA and DDGB), sorghum silage (SS) and corn bran ruminally incubated for 21 or 30 hours (BRAN21 or BRAN 30). The grazed forage samples and SS were freeze-dried and then all samples were ground through a 2 mm screen for the in situ incubations or a 1 mm screen for lab analysis. In vitro dry matter disappearance (IVDMD) was determined on the forage samples (COB, SS and grazed forage samples) and used to estimate TMRT as described in Experiment 1.

Two ruminally and duodenally cannulated steers were used to incubate 5 x 10 cm dacron bags with 50 μm pore size containing 1.25 g of sample. Steers were fed smooth bromegrass hay twice daily at ad libitum intake. Four bags per steer of each sample were ruminally incubated during one of two incubation periods. The forage samples (COB, SS and grazed forage diet samples) were ruminally incubated for 75% of their TMRT. All other feed ingredients were ruminally incubated for 16 hours except for the BRAN21 and BRAN30.

Table 2. Protein characteristics of smooth bromegrass diet samples collected in 2002 and 2003.

Year:	2002			2003			
Item	May 30	June 10	SEM[a]	May 14	June 4	July 1	SEM[a]
CP, %DM[bc]	19.9	15.1	0.50	25.3	13.3	20.4	0.82
IVDMD, %[bc]	61.5	51.9	0.81	69.5	51.3	53.9	0.41
UIP, %DM[bcd]	3.70	2.10	0.14	2.05	2.50	3.55	0.04
TTIDP, %DM[bef]	1.80	0.95	0.08	0.83	1.30	2.08	0.17
UIPDIG, %UIP[g]	49.0	54.3	1.82	58.1	48.3	41.3	5.40

[a]SEM = standard error of the mean.
[b]In 2002, collection times differ ($P < 0.05$).
[c]In 2003, quadratic effect of time ($P < 0.05$).
[d]UIP = Undegradable intake protein, calculated as follows: UIP (% DM) = (NDIN at 75% total mean retention time * 6.25) / sample DM.
[e]In 2003, linear effect of time ($P < 0.05$).
[f]TTIDP = total tract indigestible dietary protein, calculated as follows: TTIDP (% DM) = (fecal NDIN * 6.25) / sample DM.
[g]UIPDIG = UIP digestibility, calculated as follows: UIPDIG (% of UIP) = 1 - (TTIDP / UIP).

Two incubation times were used because it is unclear how long corn bran remains in the rumen. These two time points represent 75% of the expected total mean retention time (21 hours) and a hypothetical maximum retention time (30 hours). After ruminal incubations, all bags were frozen. Four bags per sample were later thawed and prepared for duodenal insertion. A total of 12 to 16 bags/steer were intestinally incubated each day. All bags were inserted, collected, and handled as in Experiment 1.

In Experiment 1, data were analyzed as repeated measures using the MIXED procedures of SAS. The UIP, TTIDP, and UIPDIG was analyzed with animal as a random effect. For Experiment 2, data were analyzed with the MIXED procedures of SAS. For grazed forage diet samples, the animal used to collect the diet sample was the experimental unit and repeated measures were used when samples were collected more than three times. For nongrazed samples, the animal in which the bags were inserted was the experimental unit. Means were separated using the pdiff option in SAS and contrasts were developed to make more precise comparisons for DDGA versus DDGB and BRAN21 versus BRAN30. Animal was considered to be random for both sample types.

Results

Protein characteristics and IVDMD of subirrigated meadows and upland native range are shown in Table 1. There was a forage x

Table 3. Protein characteristics of smooth bromegrass diet samples collected in 2004.

Item	1[a]	2	3	4	5	6	7	8	SEM[b]
CP, %DM[c]	21.2	21.9	19.7	20.4	20.1	19.5	22.5	21.4	0.63
IVDMD, %	68.7	67.7	62.9	67.5	63.6	62.6	69.1	63.5	2.08
UIP, %DM[d]	2.14	2.14	2.10	2.02	2.10	2.28	2.01	2.53	0.17
TTIDP, %CP[ef]	—	1.00	1.15	1.03	1.20	1.40	1.17	1.37	0.08
UIPDIG, %UIP[eg]	—	50.0	44.9	47.4	42.3	43.9	42.1	45.7	4.75

[a]Collection dates: 1=May 4; 2=May 12; 3=May 20; 4=May 28; 5=June 5; 6=June 13; 7=June 25; 8=July 9.
[b]SEM = standard error of the mean.
[c]Quadratic effect of time ($P < 0.05$).
[d]UIP = Undegradable intake protein, calculated as follows: UIP (% DM) = (NDIN at 75% total mean retention time * 6.25) / sample DM.
[e]Linear effect of time ($P < 0.05$).
[f]TTIDP = total tract indigestible dietary protein, calculated as follows: TTIDP (% DM) = (fecal NDIN * 6.25) / sample DM.
[g]UIPDIG = UIP digestibility, calculated as follows: UIPDIG (% of UIP) = 1 - (TTIDP / UIP).

Table 4. Protein characteristics of harvested forages and supplement ingredients used in four growing trials.

Item	MET[a]	BM	FM	SP	CGM	DDGA	DDGB	BRAN21	BRAN30	SS	COBS	SEM[b]
CP, %DM	47.4	84.7	85.8	49.7	70.1	29.7	31.0	14.4	14.4	8.89	3.78	—
IVDMD, %	—	—	—	—	—	—	—	—	—	61.6	47.0	—
UIP, %CP[c]	101[f]	89.5[g]	60.4[j]	65.3[i]	69.7[h]	55.7[k]	51.3[k]	18.6[l]	16.6[l]	19.9[l]	91.1[g]	1.98
TTIDP, %CP[d]	34.5[f]	11.8[hi]	16.4[i]	2.20[j]	3.55[j]	5.52[jk]	5.70[jk]	12.7[hi]	10.6[hk]	12.6[hi]	44.1[g]	1.84
UIPDIG, %UIP[e]	65.9[f]	89.6[h]	72.9[i]	96.6[h]	94.9[h]	90.0[h]	88.9[h]	31.3[j]	35.4[j]	36.3[j]	51.6[g]	3.38

[a]Samples: MET=Smartamine M™; BM=bloodmeal; FM=feathermeal; SP=SoyPass™; DDGA and DDGB=dried distillers grains from two sources; BRAN21 and BRAN30=corn bran ruminally incubated for 21 and 30 hours, respectively; SS=sorghum silage; COBS=corn cobs.
[b]SEM = standard error of the mean.
[c]UIP = Undegradable intake protein, calculated as follows: UIP (% CP) = (residue CP * residue wt) / (sample CP * sample wt) where residue is the remaining sample after ruminal incubation for 75% total mean retention time for SS and COBS, 21 h and 30 h for BRAN21 and BRAN30, respectively, or 16h for all other samples.
[d]TTIDP = total tract indigestible dietary protein, calculated as follows: TTIDP (% CP) = (fecal CP * fecal wt) / (sample CP * sample wt).
[e]UIPDIG = UIP digestibility, calculated as follows: UIPDIG (% of UIP) = 1 - (TTIDP / UIP).
[fghijkl]Superscripts within row differ ($P < 0.05$).

month interaction ($P < 0.03$) for CP, IVDMD, UIP, and TTIDP in Experiment 1. From May to September, the CP and IVDMD values decreased($P < 0.05$) 39.8 and 28.2% , respectively, for meadow. For range, the CP and IVDMD values decreased ($P < 0.05$) 22.7 and 22.4%, respectively, from May to September. Meadow had higher ($P < 0.01$) CP values compared to range from May to August and meadow also had a higher ($P < 0.01$) IVDMD value in June compared to range. Undegradable intake protein (% DM) of meadow was similar ($P > 0.07$) from May to August, and UIP was also similar ($P > 0.12$) in July, August, and September. From June to September, UIP decreased 32.9% for meadow. For range, UIP was similar ($P > 0.05$) in May, June, and July and from July to September, UIP increased 64.6%. For meadow, TTIDP was similar ($P > 0.10$) from May to September. For range, TTIDP was similar ($P > 0.38$) from May to July and then there was an 81.5% increase from July to September. In August and September, UIP and TTIDP were higher ($P < 0.02$) for range than for meadow. There was not a forage x month interaction ($P = 0.57$) for UIPDIG and there was also no main effect ($P = 0.24$) of forage which would suggest that meadow and range have similar UIPDIG from May to September. There was, however, a main effect ($P < 0.01$) of month. From May to September, UIPDIG decreased 85.1% and 67.5% for meadow and range, respectively.

Characteristics for diet samples collected from animals grazing smooth bromegrass in 2002, 2003, and 2004 are shown in Tables 2 and 3, respectively. In 2002 and 2003, CP and forage quality, measured as IVDMD, declined ($P < 0.05$) from May to June. In 2003, both the CP and IVDMD increased from June to July. In 2004, CP and IVDMD were generally high and did not change much. The fact that forage quality did not decline in 2004 as it did in 2002 and 2003 is likely related to the amount of precipitation and heat in June. The UIP content declined ($P < 0.05$) from May to June in 2002, however; in 2003 and 2004, there was an increase ($P < 0.05$) in the UIP content from May to July. The TTIDP content decreased ($P < 0.05$) in 2002 from May to June, while in 2003 and 2004, there was an increase ($P < 0.05$) in TTIDP from May to July. This resulted in an increase ($P < 0.05$) in UIPDIG from May to June in 2002. From May to July, UIPDIG tended to decrease ($P = 0.12$) in 2003 and did decrease ($P < 0.05$) in 2004.

The protein characteristics of harvested forages and supplement ingredients used in growing trials is shown in Table 4. This data set represents feedstuffs with a wide range of CP and UIP contents. Several protein sources such as BM, SP, CGM and distillers grains had UIPDIG values which were

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greater than 80%, while samples used as amino acid sources (FM and MET) had UIPDIG values slightly lower than 80%. Harvested forages (SS and COBS) and corn bran had UIPDIG values that fit within the range of the grazed forage samples tested in this data set; UIP content and digestibility were low.

These data suggest there is large variation in UIPDIG among feedstuffs. Compared to the constant 80% UIP digestibility currently used by the 1996 Beef NRC, forages tend to have lower UIPDIG values and several protein sources tend to have higher UIPDIG values. The protein characteristics tended to act similar across the grazed forages tested. With the exception of smooth bromegrass collected in 2002, both UIP and TTIDP content increased and UIPDIG decreased as grazing season progressed and forage quality declined. The UIPDIG is highly variable across grazed forages and is likely related to forage quality and CP content. The UIPDIG ranged from 58.1% of UIP for smooth bromegrass that was 69.5% IVDMD and 25.3% CP in May of 2003 to 6.5% for mature subirrigated meadow in September of 2000 that was 50.4% IVDMD and 8.5% CP.

All UIPDIG measured in grazed forages were much lower than the 80% currently used by the 1996 Beef NRC model. Our data suggest forages supply little MP in the form of UIP because of low UIP and UIPDIG values and MP supply may be overestimated using current prediction models. Using a simple model to estimate total MP supply with the option to change UIP digestibility from 80%, we calculated the total MP for two forage samples from this study. In our model, microbial efficiency was reduced with lower forage quality. For smooth bromegrass that had 58.1% UIP digestibility, total MP supply was reduced 6.4% by using 58.1% instead of 80% UIP digestibility in the model. For subirrigated meadow that had 6.5% UIP digestibility, total MP supply was reduced 33.8% by using 6.5% instead of 80% UIP digestibility. From the modeling, it appears that using a constant 80% UIP digestibility is more of a problem for lower quality forages where the true UIP digestibility may be much lower. While 80% may be an appropriate value on average, more specific data for different feedstuffs is needed if accurate metabolizable protein (MP) balances are to be determined for different classes of cattle.

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