Variation in Crude Protein and Initial *In Vitro* Dry Matter Digestibility of Wheat Forage

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Abstract

Annually 6 to 7 million spring-born calves (*Bos taurus* L.) are received in the southern Great Plains and pastured on winter wheat (*Triticum aestivum* L.) before feedlot finishing. Frothy bloat can be a serious problem for ruminant livestock grazing pastures of winter wheat. Decreased ADG with non-lethal bloat episodes, lethal yearly average herd losses up to 2%, and the cost and uncertainties of active bloat intervention strategies take a toll on the profitability of raising stocker cattle. Wheat pastures have high digestibility, crude protein (CP), and soluble N fractions associated with bloat-provoking forages. We assessed the variation in CP concentration and initial *in vitro* dry matter digestibility (IVDMD) of released wheat varieties and experimental lines to provide information needed to identify varieties and evaluate the feasibility of developing genotypes that could offer a decreased frequency and severity of bloat. Late fall forage from seven variety trials (34 varieties, 15 to 23 varieties per trial) and late fall and late winter forage samples from 221 diverse experimental breeding lines were analyzed. Significant ($P < 0.05$) differences among varieties and breeding lines were found for CP and IVDMD traits; trait variation among breeding lines was often substantially greater than among varieties. Differences in CP levels among breeding lines was as great as 47% and averaged 15% for the seven variety trials. Differences in the percent IVDMD occurring in the first 8 h of incubation among breeding lines was as great as 97% and averaged 24% for the seven variety trials. Correlations between CP and initial IVDMD traits were not significant or at best very weakly correlated (variety trials, $r = 0.11$, $P = 0.01$, $n = 484$), thus the development of wheat varieties with both reduced CP and low initial rates of IVDMD will require simultaneous selection for both traits.

1. Introduction

- Each year stocker cattle producers in the southern Great Plains that graze wheat pastures loose as much as $100 million dollars due to cattle deaths caused by bloat.
- Non-lethal episodes of bloat and induced rumen dystension can reduce feed intake and average daily gain (ADG) of ruminants (Branine and Galyean, 1990; Min et al., 2006; Villalba et al., 2009), thus increasing economic losses beyond those attributed to bloat induced deaths.
- The causes of pasture bloat arise from a complex integration of forage, animal, management, and climatic factors (Clarke and Reid, 1974; Horn, 2006). Wheat pastures have high digestibility, crude protein (CP), and soluble N fractions; all traits associated with bloat-provoking forages. Rapid cell breakdown of consumed forage is believed to be a critical trait of bloat-provoking forages. Screening for this trait led to the development of bloat-reduced alfalfa (Coulman et al., 2000; Berg et al., 2000).

2. Objective

- An assessment of the extent of variation in the in vitro DM digestion (IVDMD) and CP of released wheat varieties and experimental lines could provide information needed to identify genotypes that would lessen the frequency and severity of bloat in stocker livestock.
- This research tested the null hypothesis that neither the initial IVDMD nor CP concentrations differ among adapted varieties or among experimental lines with a broad genetic base

3. Materials and Methods

3.1 Varieties and Experimental Lines

Juvenile wheat plants were sampled from selected forage variety trials in the Oklahoma State Small Grains Variety Testing Program (2004, 2007, 2008; 34 varieties, 15 to 23 varieties per trial), and from a breeding trial [221 experimental lines (ExpLines) and four hard red winter wheat check (Ck) varieties].

The variety trials were randomized complete designs with four replications. The experimental design for the breeding trial was an augmented randomized complete block consisting of the experimental lines distributed among 12 blocks and the four varieties within each block. Complete experimental details of the 2004 and 2005 trials was reported earlier (MacKown et al., 2008).

3.2 Crude Protein

Crude protein concentration of the ground forage samples was estimated by multiplying total N concentration by 6.25. Concentration of total N was determined using an automated flash combustion and multiplying by 6.25.

3.3 In Vitro DM Digestion

Standard forage quality protocols using near-infrared reflectance spectroscopy (NIRS; Infrasoft International, 1999) and IVDMD using rumen fluid (ANKOM Technology, 2005, 2006) were used. Measured and predicted values for 0, 8, and 48 h forage digestions were obtained. To estimate an IVDMD for an incubation time of 0 h, percent neutral detergent fiber (NDF) was subtracted from 100%, which represents the non-NDF component of the dry forage. Initial IVDMD as a percentage of 48 h IVDMD was estimated using the following calculation:

$$\text{Initial IVDMD} = [(8\text{ h IVDMD} - 0\text{ h IVDMD})/(48\text{ h IVDMD} - 0\text{ h IVDMD})] \times 100$$

3.4 Statistical Analyses

All statistical analyses for CP and IVDMD responses were performed using JMP 8.0.1 software (SAS Institute, 2009). The Fit Model Platform in JMP software was used for each experiment. The variety trial data were analyzed using conventional ANOVA for a randomized complete block design. The protocol described by Scott and Milliken (1993) for the ANOVA of an augmented randomized complete block design was used for the breeding trial data. Each sampling event for the breeding trial (late fall, late winter regrowth of late fall clipping, and late winter) was analyzed separately.

4. Results

4.1 Variety trials

Table 1. Mean ($n = 4$) crude protein concentrations of samples collected from forage variety trials in El Reno and Stillwater, OK.

	2004	2007			2008		
	El Reno	El Reno		Stillwater	El Reno		Stillwater
Variety	CT†	CT	NT	CT	CT	NT	CT
	g kg⁻¹						
2137	235 c-g‡	—§	—	—	—	—	—
2145	236 c-e	—	—	—	—	—	—
2174	248 ab	—	—	—	—	—	—
AP502CL	231 d-h	—	—	—	—	—	—
Armour	—	—	—	—	223 a-e	216 f-h	251 c-f
Centerfield	—	231 a-c	233 b-d	243 b-e	230 ab	232 bc	250 d-f
Custer	235 c-f	—	—	—	—	—	—
Cutter	246 a-c	—	—	—	—	—	—
Deliver	226 e-h	**209 e**	225 c-e	249 a-d	220 a-e	**212 gh**	238 h-j
Doans	—	214 de	227 c-e	**232 e**	212 de	216 e-h	239 g-i
Duster	—	213 e	**211 f**	244 b-e	**209 e**	217 d-h	**238 h-k**
Endurance	**224 f-h**§	**207 e**	**218 e-f**	**239 de**	**210 e**	**212 gh**	**230 jk**
Fannin	**220 h**	**205 e**	**221 d-f**	248 a-d	**210 e**	**211 h**	**234 i-k**
Fuller	—	229 a-c	230 b-e	249 a-d	212 de	226 c-f	251 c-f
Jackpot	—	213 e	223 c-f	**237 de**	215 c-e	230 b-d	239 g-i
Jagalene	249 ab	234 ab	242 ab	260 a	226 a-d	240 ab	246 d-g
Jagger	237 b-e	235 ab	243 ab	260 a	222 a-e	229 b-e	259 a-c
Keota	—	—	—	—	—	—	243 f-h
Mace	—	—	—	—	—	—	**229 k**
Ok101	**223 g-h**	—	—	—	—	—	—
Ok102	239 b-d	—	—	—	—	—	—
OK Bullet	—	226 b-d	234 bc	243 b-e	218 a-e	225 c-g	240 g-i
Okfield	—	228 a-c	229 c-e	243 b-e	—	—	—
OK Rising	—	—	—	—	220 a-e	215f-h	246 e-h
Overley	236 c-e	227 a-d	224 c-e	242 c-e	211 e	213 gh	244 f-h
Santa Fe	—	218 c-e	228 c-e	255 a-c	218 b-e	225 c-h	243 f-h
Shocker	—	240 a	248 a	244 b-e	233 a	247 a	262 a
Sturdy 2K	243 a-d	—	—	—	—	—	—
TAM 111	—	—	—	**240 de**	—	—	240 g-i
TAM 112	—	—	—	—	—	—	255 a-d
TAM 203	—	—	—	256 ab	228 a-c	236 a-c	261 ab
TAM 304	—	—	—	242 c-e	—	—	253 b-e
Thunderbolt	254 a	—	—	—	—	—	—
Winterhawk	—	—	—	—	—	—	240 g-i
P > *F*	0.0041	< 0.0001	< 0.0001	0.0041	0.0302	< 0.0001	< 0.0001
Mean	236	222	229	246	219	224	245
Range	220 - 254	205 - 240	211 - 248	232 - 260	209 - 233	211 - 247	229 - 262
CV	4.2	5.0	4.2	3.1	3.4	4.8	3.8
LSD	12	13	13	14	15	13	9
Tukey HSD	22	24	22	25	27	24	16

† CT, conventional tillage; NT, no tillage.
‡ Means within a column not followed by the same letter are significantly different based on LSD mean comparison test ($\alpha = 0.05$). Means in bold font are in the ≤ 20% quintile and are significantly less than those varieties with the highest means based on LSD (Student's *t*-Test) mean comparison test ($\alpha = 0.05$).
§ —, variety not included in trial.

Table 2. Mean ($n = 4$) percent of 48 h *in vitro* dry matter digestion (IVDMD) that occurred during the first 8 h of incubation of samples collected from forage variety trials in El Reno and Stillwater, OK.

	2004	2007			2008		
	El Reno	El Reno		Stillwater	El Reno		Stillwater
Variety	CT†	CT	NT	CT	CT	NT	CT
	8 h IVDMD % of 48 h IVDMD						
2137	49.2 c-g‡	—	—	—	—	—	—
2145	48.1 c-g	—	—	—	—	—	—
2174	49.4 c-f	—	—	—	—	—	—
AP502CL	**47.2** e-g	—	—	—	—	—	—
Armour	—§	—	—	—	46.9 a	43.1	44.2 a-f
Centerfield	—	36.3 cd	37.6 c-f	**33.4** hi	43.7 cd	41.2	**42.2 f-g**
Custer	51.7 a-c	—	—	—	—	—	—
Cutter	51.5 a-d	—	—	—	—	—	—
Deliver	50.4 b-e	36.6 cd	37.6 c-f	40.4 ab	44.3 bc	42.7	45.5 a-c
Doans	—	**31.4** g	**30.8** h	31.6 l	**40.5** e	40.6	**39.6** h
Duster	—	35.9 c-e	35.4 e-g	37.2 d-g	43.5 cd	41.6	42.7 d-g
Endurance	**45.3 g**	33.2 fg	**34.7** fg	35.3 f-h	**41.3** de	41.4	42.5 e-g
Fannin	48.2 c-g	36.7 cd	38.0 c-e	40.4 a-c	43.4 cd	42.9	44.6 a-e
Fuller	—	37.8 bc	38.7 cd	36.8 e-g	44.8 a-c	43.6	44.8 a-d
Jackpot	—	40.3 ab	41.8 ab	40.2 a-c	46.5 ab	45.0	45.7 a-c
Jagalene	53.3 ab	34.2 d-f	34.9 d-g	33.7 hi	45.7 a-c	44.3	46.2 a
Jagger	47.6 d-g	**32.9** fg	35.7 fg	**32.0** l	43.6 cd	42.8	44.8 a-d
Keota	—	—	—	—	—	—	46.1 ab
Mace	—	—	—	—	—	—	44.6 a-e
Ok101	49.0 c-g	—	—	—	—	—	—
Ok102	**46.4** fg	—	—	—	—	—	—
OK Bullet	—	40.3 ab	42.3 a	41.7 a	46.6 ab	44.7	45.4 a-c
Okfield	—	**32.6** fg	**34.4** g	33.8 hi	—	—	—
OK Rising	—	—	—	—	44.7 a-c	42.2	45.6 a-c
Overley	55.2 a	41.1 a	38.9 bc	38.8 b-e	44.2 bc	42.1	44.0 b-g
Santa Fe	—	33.6 e-g	35.4 e-g	37.0 d-g	**41.6** de	42.6	44.9 a-c
Shocker	—	36.1 c-e	40.3 a-c	37.9 e-f	45.0 a-c	45.4	43.8 c-g
Sturdy 2K	47.3 e-g	—	—	—	—	—	—
TAM 111	—	—	—	34.7 g-h	—	—	**41.9** g
TAM 112	—	—	—	—	—	—	44.3 a-f
TAM 203	—	—	—	39.4 a-d	43.7 cd	41.3	44.8 a-d
TAM 304	—	—	—	37.6 d-f	—	—	**42.2** f-g
Thunderbolt	49.3 c-f	—	—	—	—	—	—
Winterhawk	—	—	—	—	—	—	43.7 c-g
P > *F*	0.0005	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0810	< 0.0001
Mean	49.3	35.9	37.1	36.7	44.1	42.8	44.1
Range	45.3-55.2	31.4-41.1	30.8-42.3	31.6-41.7	40.4-46.9	40.6-45.4	39.6-46.2
CV	5.2	8.4	4.1	8.4	4.1	3.3	3.6
LSD	3.9	2.6	3.0	2.6	2.5	3.1	2.2
Tukey HSD	7.0	4.7	5.4	5.2	4.6	5.7	4.1

† CT, conventional tillage; NT, no tillage.
‡ Means within a column not followed by the same letter are significantly different based on LSD mean comparison test ($\alpha = 0.05$). Means in bold font are in the ≤ 20% quintile and are significantly less than those varieties with the highest means based on LSD (Student's *t*-Test) mean comparison test ($\alpha = 0.05$).
§ —, variety not included in trial.

4.2 Breeding line trial

Late fall (11/29/05)

Source	*P*
Ck	<0.0001
ExpLines(Ck)	0.4648
ExpLines	CP (g kg⁻¹)
Range	207 – 298
x ± CI	252 ± 1.9
Ck x ± CI	
Duster	244 ± 8.8
Endurance	252 ± 9.3
Jagger	245 ± 7.9
Overley	234 ± 8.5

Regrowth (2/27 –/1/06)

Source	*P*
Ck	<0.0001
ExpLines(Ck)	0.1764
ExpLines	CP (g kg⁻¹)
Range	133 – 219
x±CI	166 ± 2.0
Ck x ± CI	
Duster	167 ± 7.8
Endurance	183 ± 8.2
Jagger	161 ± 4.2
Overley	147 ± 8.2

Late winter (2/27 –/1/06)

Source	*P*
Ck	<0.0001
ExpLines(Ck)	0.0270
ExpLines	CP (g kg⁻¹)
Range	108 – 213
x±CI	159 ± 2.4
Ck x ± CI	
Duster	165 ± 11
Endurance	173 ± 9.2
Jagger	157 ± 10
Overley	148 ± 6.1

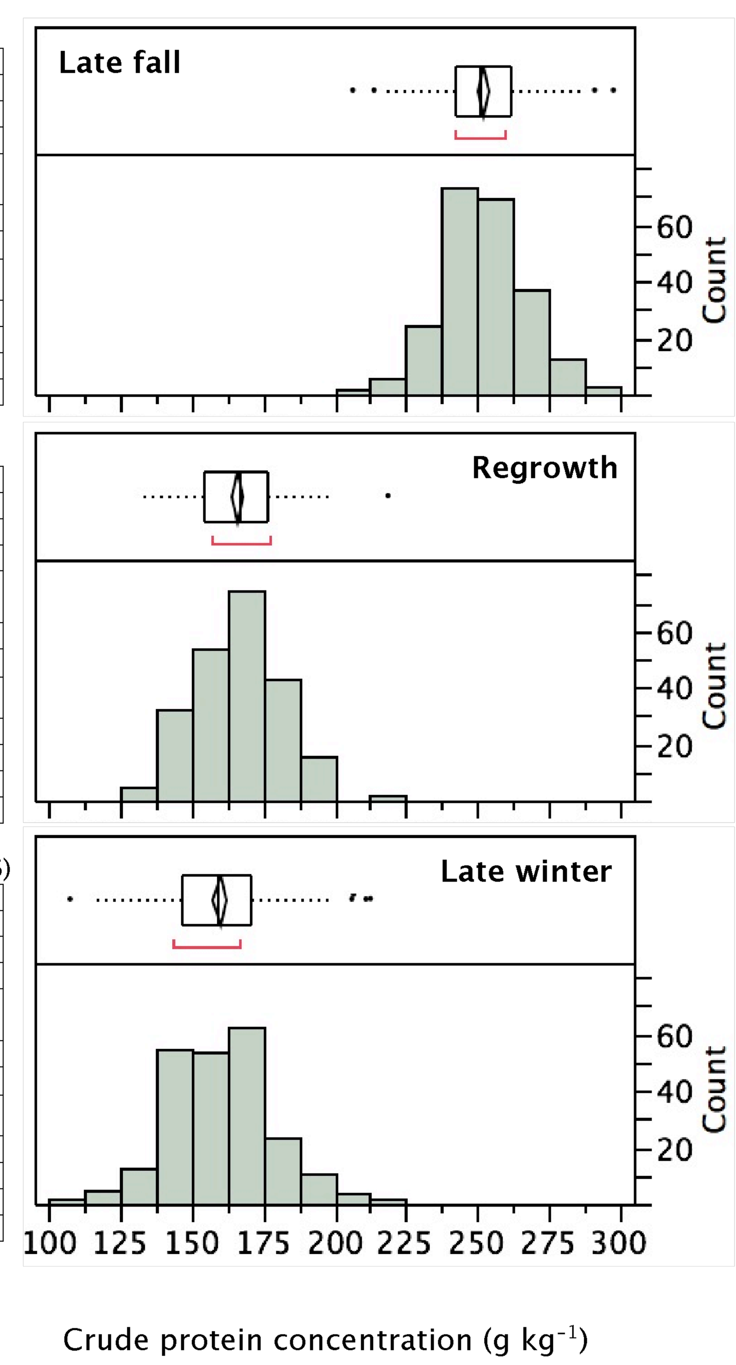

Figure 1. Distributions of crude protein (CP) concentrations for forage sampled from plots of experimental lines in late fall and in late winter pre Feekes Stage 6.

Late fall (11/29/05)

Source	*P*
Ck	0.3122
ExpLines(Ck)	0.2771
ExpLines	8 h IVDMD (% of 48 h)
Range	46.3 – 69.0
x ± CI	56.2 ± 0.5
Ck x ± CI	
Duster	56.7 ± 2.0
Endurance	56.0 ± 1.7
Jagger	58.1 ± 1.9
Overley	56.5 ± 2.5

Regrowth (2/27 –/1/06)

Source	*P*
Ck	0.0057
ExpLines(Ck)	0.1915
ExpLines	8 h IVDMD (% of 48 h)
Range	40.5 – 64.4
x±CI	52.1 ± 0.5
Ck x ± CI	
Duster	51.9 ± 2.6
Endurance	52.4 ± 1.9
Jagger	53.2 ± 1.7
Overley	55.9 ± 2.0

Late winter (2/27 –/1/06)

Source	*P*
Ck	0.0057
ExpLines(Ck)	0.1915
ExpLines	8 h IVDMD (% of 48 h)
Range	35.1 – 57.0
x±CI	47.4 ± 0.5
Ck x ± CI	
Duster	49.0 ± 2.4
Endurance	48.9 ± 3.3
Jagger	49.2 ± 1.6
Overley	49.8 ± 2.6

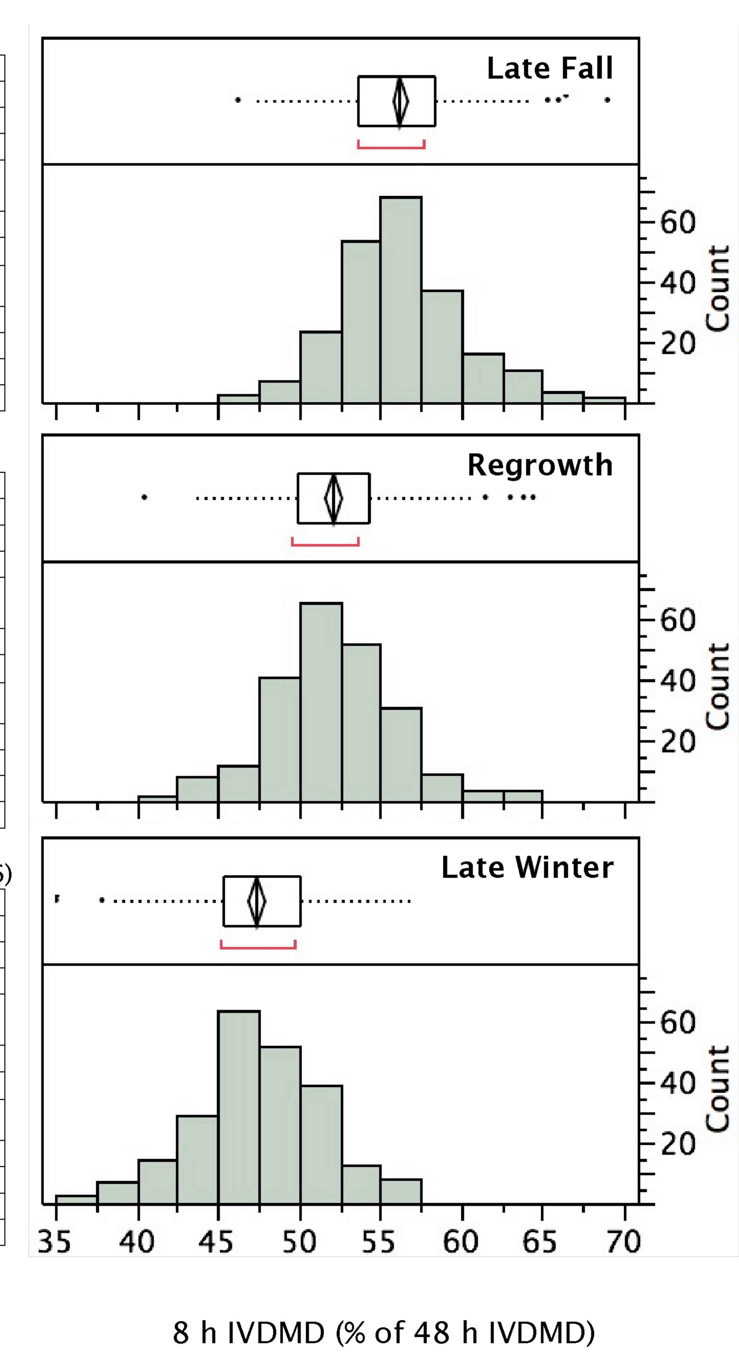

Figure 2. Distributions of the percent of *in vitro* dry matter digestibility (IVDMD) at 48 h that was measured during the first 8 h of digestion for sampled from plots of experimental lines in late fall and in late winter pre Feekes Stage 6.

5. Conclusions

- Substantial differences in forage CP and initial IVDMD was observed during the grazing period of dual-purpose wheat.
- Forage CP and initial IVDMD deviations among the varieties tended to be less than that among the breeding lines.
- While it probably would be beneficial to reduce CP levels and initial rates of DM digestion of wheat forage to lessen the incidence and severity of pasture bloat, it will be necessary to simultaneously select for these traits.

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7. References

Provided with handout on table.

7. References

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