Seasonal Variations in the Nutritive Parameters of Barley Grains for Cattle

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Introduction

Barley is the predominant constituent of ruminant rations in used Western Canada. It has an attractive energy content and protein content when compared to corn and wheat (NRC, 2001) and its amino acid composition is more favourable than corn (Pond *et al*., 1995). There are three types of barley; the two-row cultivars (traditionally known as *Hordeum distichum*), four-row (*Hordeum tetrastichum*) and six-row barley (*Hordeum vulgare*). The two-rowed cultivars are the oldest in evolutionary terms and are lower in protein than the six-row cultivars. However they are higher in starch content and thus energy. It is relatively cold tolerant and is considered the most drought, alkali and salt tolerant among the small grains (Smith, 1995). The relatively early maturity and low water use of barley are the major factors for adaptation to drought and temperature extremes. Barley is not well adapted to acid and wet soil conditions (Poehlman, 1985). Traditionally, barley breeding has focused on producing cultivars that are suitable for the brewing industry but due to its importance in animal feed cultivars have been produced for the animal feed market. The aim of this study is to evaluate 6 barley cultivars, harvested over three consecutive growing seasons, in order to examine their chemical composition and thus, their predicted nutritive quality for ruminant livestock.

Material and methods

Barley samples

Six, two row cultivars of spring sown barley, *cv.* AC Metcalf, CDC Cowboy, CDC Dolly, CDC Helgason, CDC Trey and McLeod, were produced, without irrigation, at a field site close to Saskatoon for three consecutive years commencing in 2003. Sub-samples of grain collected at harvest were provided by the Crop Development Centre, University of Saskatchewan.

Chemical analysis

Barley samples (~60 g) were milled to pass through a 1 mm^2 (Christy Norris 8” laboratory mill, Ipswich, UK) screen and a sub-sample (~2 g) further milled to pass through a 0.25 mm^2 (Retsch ZM-100, Brinkmann Instruments Ltd., Ontario, Canada). All analysis was carried out on samples that had passed through the 1 mm^2 screen unless otherwise stated. Dry matter (DM) and ash was determined by drying the samples to a constant weight at 135°C (AOAC 930.15) followed by dry ignition at 550°C for 24 h (MAFF, 1986). Ether extract (EE) was determined by refluxing samples in the presence of ethoxyethane for 6 h (AOAC 954.02). Crude protein (CP) was determined using the

Kjeldahl method (AOAC 984.13) using an auto-titrator (Kjeltic 1030, FOSS Teactor, Sweeden). Starch was determined on the 0.25 mm^2 milled samples by the method of McCleary *et al.* (1997). Neutral detergent fibre (NDF) was determined in beakers, using the method of Robertson and Van Soest (1980), with a heat stable α-amylase (Termamyl 120; A3402, Sigma Aldrich, Canada) with the omission of sodium sulphite. Acid detergent fibre (ADF) was determined in beakers by the method of Van Soest *et al*. (1991). All other reagents for NDF and ADF were as described by Van Soest *et al*. (1991). Residues of NDF and ADF were filtered through a Whattman 54 filter paper and subsequently analysed for neural detergent insoluble protein (NDIP) and acid detergent insoluble protein (ADIP) respectively using the Kjeldahl method as described by Licitra *et al.* (1996). Acid detergent lignin (ADL; Van Soest and Robertson, 1980) was determined with 26 N sulphuric acid following extraction with acid detergent solution using fibre bags (ANKOM Technology, Fairport, New York, USA). Non protein nitrogen (NPN) and soluble CP (SCP) were determined using the Kjeldahl method following extraction with sodium tungstate solution and borate phosphate buffer solution respectively as described by Licitra *et al.* (1996).

Calculations and statistical analysis
Non fibrous carbohydrates (NFC) were calculated according to Van Soest *et al*. (1991) and carbohydrate (CHO) was calculated according to Sniffen *et al.* (1992). Truly digestible NFC (tdNFC), CP (tdCP), fatty acids (tdFA) and NDF (tdNDF) were calculated according to NRC (2001). Subsequently, total digestible nutrient (TDN), digestible energy for production (DE_p), metabolisable energy for production (ME_p) and net energy for lactation (NE_l) were calculated at 3 and 4 x maintenance for dairy cattle (NRC, 2001) and ME, NE for maintenance (NE_m) and NE for growth (NE_g) for beef cattle (NRC, 2000). Protein and carbohydrate sub-fractions were calculated according to the Cornell Net Carbohydrate and Protein System (Sniffen *et al*., 1992).
Results were fitted to the model $y_{ij}=\mu + \alpha_i + \beta_j + \varepsilon_{ij}$ using the PROC MIXED procedure of SAS (version 9.1). Where y_{ij} is the measured variable, μ the overall mean, α the effect of cultivar (i = 1 to 6), β the effect of year (j = 1 to 3) and ε_{ij} is the associated error. Statistical differences were declared at $P \leq 0.050$.

Results
The effects of cultivar and year on the chemical composition of barley grain are presented in Table 1. There was no effect of cultivar on crop DM with a mean values of 94.5%, there was a small but significant (P<0.05) effect of year with the lowest DM being recorded in 2004. Ash content was significantly (P<0.05) effected by both cultivar and year. There was no effect of either cultivar or year on EE content with means of 1.97 and 1.97% DM respectively. The NDF and ADF contents were both significantly (P<0.05) effected by both cultivar and year. There was no effect of cultivar or year on ADL content with means of 2.75 and 2.75 % DM respectively. Starch, CHO and NFC were significantly different between cultivars whereas, year only affected starch and CHO content and not NFC with a mean value of 68.71 % DM. There was no difference between the CP of the cultivars with a mean of 12.14 % DM however, CP was lowest (P<0.05) in 2003 in comparison to the other years. There was no difference in NPN, SCP, NDIP or ADIN in terms of cultivar with means of 5.87, 19.22, 0.48 and 6.13% CP respectively or in terms of year with means of 5.87, 19.21, 0.48 and 8.37 % CP respectively.

Table 1 Effect of cultivar and year on the chemical composition of barley grain (% DM unless otherwise stated)

	Cultivar								Year				
	AC Metcalf	CDC Cowboy	CDC Dolly	CDC Helgason	CDC Trey	McLeod	S.E.M.	*P*	2003	2004	2005	S.E.M.	*P*
DM (% FW)	94.34	94.18	94.67	94.57	94.79	94.65	0.237	0.500	94.69[B]	94.10[A]	94.82[B]	0.168	0.028
Ash	2.39[a]	2.58[b]	2.43[a]	2.50[ab]	2.44[a]	2.59[b]	0.036	0.013	2.56[B]	2.53[B]	2.38[A]	0.026	0.001
EE	2.04	1.69	1.82	2.53	2.09	1.62	0.141	0.010	2.06	1.98	1.86	0.099	0.422
NDF	18.30[bc]	13.45[a]	17.99[c]	12.97[a]	12.19[a]	19.34[c]	0.403	<0.001	16.45[B]	15.52[A]	15.15[A]	0.285	0.025
ADF	4.64[b]	4.94[bc]	3.98[a]	5.18[c]	4.91[bc]	6.59[d]	0.164	<0.001	5.32[B]	4.88[A]	4.93[A]	0.116	0.045
ADL	2.90	3.12	2.55	2.35	2.52	3.05	0.251	0.245	2.66	2.57	3.02	0.177	0.213
Starch	49.15[a]	52.09[bc]	50.84[ab]	51.00[ab]	53.66[c]	52.57[bc]	0.749	0.022	50.34[A]	52.98[B]	51.34[AB]	0.530	0.017
CHO[†]	83.43[abc]	82.72[a]	83.69[bc]	83.20[ab]	83.39[abc]	83.99[c]	0.237	0.050	84.05[B]	83.14[A]	83.02[A]	0.168	0.003
NFC[‡]	66.20[a]	70.30[b]	66.67[a]	71.30[bc]	72.27[c]	65.51[a]	0.428	<0.001	68.59	68.64	68.90	0.303	0.740
CP	12.14	13.00	12.06	11.77	12.08	11.80	0.261	0.069	11.33[A]	12.35[B]	12.74[B]	0.185	0.001
NPN (%CP)	5.17	7.67	7.05	4.08	5.82	5.43	1.672	0.694	4.93	5.58	7.11	1.182	0.439
SCP (%CP)	18.87	19.88	17.09	20.37	20.55	18.54	0.905	0.147	20.04	19.85	17.75	0.640	0.054
ADIP (%CP)	0.84	0.19	0.10	0.38	1.03	0.32	0.970	0.075	0.35	0.54	0.55	0.686	0.629
NDIP (%CP)	8.80	1.03	8.12	9.12	8.83	0.86	0.970	0.051	8.64	8.31	8.16	0.686	0.443

[†] Carbohydrate (CHO) calculated as 100 – CP – EE – ash according to Sniffen *et al.* (1992)

[‡] Non fibrous carbohydrate (NFC) calculated as 100 – ((NDF-NDIP) + EE + ash) according to Van Soest *et al.* (1991)

Rows within cultivar and year not sharing a common superscript letter differ significantly (*P*<0.050)

The effects of cultivar and year on the predicted energy content of barley grain are presented in Table 2. All truly digestible and estimated energy contents for dairy and beef cattle were affected by cultivar type. Year only effected the tdCP fraction with it being lowest (P<0.050) in 2003. There was no difference in tdNFC, tdFA, tdNDF, TDN, DE 1x, DE 3x, ME 3x, NEl 3x, DE 4x, ME 4x, NEl 4x, ME, NEm and NEg with mean values of 70.03, 0.97, 6.08, 83.15 %DM, 3.65, 3.35, 2.94, 1.88, 3.20, 2.79, 1.77, 3.00, 2.03 and 1.37 Mcal/kg DM respectively. The effects of cultivar and year on the CNCPS protein and carbohydrate fractions of barley grain are presented in Table 3.

There was no effect of cultivar on the NPN fraction (PA), rapidly degradable fraction (PB1), intermediately degradable fraction (PB2), slowly degradable fraction (PB3) and bound protein (PC) with mean values of 7.87, 13.35, 74.42, 7.89 and 0.48 % CP respectively. There was no effect of year on PA, PB1, PB3 and PC with mean values of 5.87, 13.35, 7.89 and 0.48 % CP respectively. However, PB2 was affected by year with the lowest value being reported for 2003 and the highest in 2005 and an intermediate value for 2004. The sugar fraction (CA) and the starch and non starch polysaccharide fraction (CB1) were significantly (P<0.05) affected by cultivar and year. The fibre fraction (CB2) was effected by cultivar but not year with a mean value of 9.69 % CHO. The unavailable fibre fraction (PC) was unaffected by cultivar and year with mean values of 7.92 and 7.92 % CHO respectively.

Table 2 Effect of cultivar and year on the predicted energy content of barley grain

	Cultivar								Year				
	AC Metcalf	CDC Cowboy	CDC Dolly	CDC Helgason	CDC Trey	McLeod	S.E.M.	*P*	2003	2004	2005	S.E.M.	*P*
Truly digestible fractions (%DM)													
tdNFC	67.47^{a}	71.65^{b}	67.95^{a}	72.67^{bc}	73.66^{c}	66.77^{a}	0.436	<0.001	69.90	69.96	70.22	0.309	0.743
tdCP	11.70^{a}	12.88^{b}	12.00^{a}	11.56^{a}	11.46^{a}	11.59^{a}	0.232	0.013	11.19^{A}	12.02^{B}	12.39^{B}	0.164	0.001
tdFA	1.04^{ab}	0.69^{ab}	0.82^{ab}	1.53^{c}	1.09^{b}	0.62^{a}	0.141	0.010	1.06	0.98	0.86	0.099	0.422
tdNDF	7.49^{b}	4.29^{a}	7.79^{b}	4.73^{a}	4.07^{a}	8.11^{b}	0.463	<0.001	6.65	6.16	5.43	0.327	0.070
TDN	81.99^{b}	83.39^{c}	82.58^{bc}	85.41^{d}	84.65^{d}	80.87^{a}	0.336	<0.001	83.11	83.35	82.99	0.238	0.578
Dairy[†] (Mcal/kg DM; NRC 2001)													
DE 1x	3.60^{ab}	3.68^{cd}	3.63^{bc}	3.74^{e}	3.71^{de}	3.55^{a}	0.016	<0.001	3.64	3.66	3.65	0.011	0.417
DE 3x	3.31^{b}	3.37^{cd}	3.34^{bc}	3.44^{e}	3.41^{de}	3.26^{a}	0.014	<0.001	3.34	3.36	3.36	0.010	0.446
ME 3x	2.89^{ab}	2.96^{c}	2.92^{b}	3.02^{d}	2.99^{cd}	2.85^{a}	0.014	<0.001	2.93	2.95	2.94	0.010	0.383
NE_l 3x	1.84^{ab}	1.89^{cd}	1.86^{bc}	1.93^{e}	1.91^{de}	1.81^{a}	0.010	<0.001	1.87	1.88	1.88	0.007	0.426
DE 4x	3.16^{ab}	3.22^{cd}	3.19^{bc}	3.28^{e}	3.26^{de}	3.12^{a}	0.014	<0.001	3.20	3.21	3.20	0.010	0.458
ME 4x	2.74^{b}	2.81^{c}	2.77^{b}	2.87^{d}	2.84^{cd}	2.70^{a}	0.013	<0.001	2.78	2.79	2.79	0.009	0.431
NE_l 4x	1.74^{b}	1.78^{cd}	1.75^{bc}	1.82^{e}	1.80^{de}	1.71^{a}	0.010	<0.001	1.76	1.78	1.77	0.007	0.375
Beef (Mcal/kg DM; NRC 1996)													
ME	2.95^{ab}	3.02^{c}	2.98^{b}	3.07^{d}	3.04^{cd}	2.91^{a}	0.012	<0.001	2.99	3.00	3.00	0.008	0.392
NEm	1.99^{ab}	2.04^{cd}	2.01^{bc}	2.09^{e}	2.06^{de}	1.96^{a}	0.010	<0.001	2.02	2.03	2.03	0.007	0.527
NEg	1.34^{b}	1.38^{c}	1.36^{b}	1.42^{d}	1.40^{cd}	1.31^{a}	0.008	<0.001	1.36	1.38	1.37	0.006	0.319

[†] Calculated assuming a total diet TDN of 74%

Rows within cultivar and year not sharing a common superscript letter differ significantly (*P*<0.050)

Table 3 Effect of cultivar and year on the CNCPS protein and carbohydrate fractions of barley grain

	Cultivar								Year				
	AC Metcalf	CDC Cowboy	CDC Dolly	CDC Helgason	CDC Trey	McLeod	S.E.M.	*P*	2003	2004	2005	S.E.M.	*P*
Protein fractions (%CP)													
PA	5.17	7.67	7.05	4.08	5.82	5.43	1.672	0.694	4.93	5.58	7.11	1.182	0.439
PB1	13.70	12.21	10.04	16.29	14.73	13.11	1.760	0.277	15.12	14.27	10.65	1.245	0.065
PB2	72.34	72.11	74.79	70.51	70.62	74.12	1.016	0.065	71.32^{A}	71.84^{AB}	74.08^{B}	0.718	0.048
PB3	7.96	7.82	8.01	8.74	7.80	7.02	0.370	0.131	8.29	7.77	7.62	0.261	0.216
PC	0.84	0.19	0.10	0.38	1.03	0.32	0.221	0.075	0.35	0.54	0.55	0.156	0.629
Carbohydrate fractions (%CHO)													
CA	20.43^{bc}	22.00^{cd}	18.91^{b}	24.41^{d}	22.32^{cd}	15.41^{a}	0.970	0.001	21.72^{B}	18.86^{A}	21.16^{B}	0.686	0.033
CB1	58.91^{a}	63.00^{bc}	60.76^{ab}	61.30^{ab}	64.35^{c}	62.59^{bc}	0.885	0.019	59.89^{A}	63.73^{B}	61.85^{AB}	0.625	0.005
CB2	12.30^{b}	5.94^{a}	13.01^{b}	7.52^{a}	6.07^{a}	13.28^{b}	1.082	0.001	10.80	10.00	8.26	0.765	0.104
CC	8.35	9.06	7.32	6.78	7.26	8.72	0.723	0.242	7.60	7.42	8.73	0.511	0.193

Rows within cultivar and year not sharing a common superscript letter differ significantly ($P<0.050$)

Conclusions

- The growing season had very little practical effect on any of the measured parameters and was therefore considered negligible.
- Barley cultivars only differed chemically in NDF, ADF, starch and ash content.
- McLeod and CDC Helgason had the lowest and highest predicted energy contents for ruminants respectively
- However, the predicted CHO fractions of McLeod were more favorable than CDC Helgason in terms of reducing acidosis

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