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In situ degradability of Iranian barley grain cultivars

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Abstract

Our objectives were to determine the extent of genetic variability in the rate and extent of ruminal digestion among 10 cultivars of barley. Barley samples (*Hordeum vulgare* L.) were ground through a 2 mm screen, and bags containing 1 g of ground grains were incubated in the rumen of three ruminally cannulated rams for 0, 2, 4, 6, 8, 12 and 24 h. The rate and extent of ruminal digestion were estimated. The soluble DM fraction ranged from 37.5 to 43%, the degradable DM fraction ranged from 42.2 to 49%, and the rate of degradation of DM ranged from 25.6 to 31.5% h^{-1}. The small variability observed in the ruminal digestion characteristics of barley cultivars indicated that genetic selection does not hold promise as a means of enhancing the nutritional quality of barley for ruminants.

Keywords: Barley cultivars; In situ; Degradability

1. Introduction

Barley is mainly used as a feed grain for livestock in Iran. Historically, barley has been traded at a significantly lower price than corn in the world market (Hickling, 1995). The feeding of barley-based high concentrate diets has been linked to an increased incidence of digestive disorders including reduced feed intake, cattle going off-feed, laminitis, bloat, acidosis, rumenitis, and liver abscesses (Ørskov, 1986; Givens et al., 1993). It is assumed that the rapid rate of fermentation of starch in barley grain contributes to these nutritional and health problems. Between 80 and 90% of barley starch and wheat starch are digested in the rumen, whereas the values for sorghum and corn range from 55 to 70% (Nocek and Tamminga, 1991).

Differences in chemical composition exist between barley cultivars (Bhatty et al., 1975). Givens et al. (1993) reported that individual barley varieties differ in terms of the composition of the protein matrix in the starchy endosperm of the grain and this characteristic might be expected to influence degradability in the rumen. Results of studies conducted by Kemalyan et al. (1991), Hartfield et al. (1993) and Khorasani et al. (2000) have confirmed that differences in rate of degradation can occur between barley cultivars. Although these differences may indicate that certain cultivars of barley are more desirable as feed grains than others, no data are available for Iranian barley grains to make solid recommendations in this regard.

The objective of this research was to determine if differences in rumen degradability characteristics exist between the grain of barley cultivars grown in Iran.

2. Materials and methods

2.1. Animals and diet

Three ruminally cannulated rams weighing 45 ± 3 kg and consuming 1.2± 0.2 kg DM were used. Two weeks

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Table 1
Chemical composition of barley cultivars

Varietal description	DM (%)	CP (%)	ADF (%)
Zar	92.0	10.5	10.6
Gohar	92.5	10.0	8.4
Kavir	93.5	10.7	6.9
Faez	93.6	11.6	5.9
Sina	93.8	10.0	6.4
Aras	94.0	9.0	6.2
Eram	92.8	10.5	7.3
Gorgan 4	92.6	11.7	6.4
Rayhan	93.7	9.0	6.8
Imported	93.0	10.9	6.7

before starting the study, the rams were fed a diet to meet their maintenance requirements (NRC, 1985). Rams were fed a total mixed ration consisting of 50% alfalfa hay and 50% whole barley grain. The ration was fed twice daily with one half at 0800 and the other half at 1600 h.

2.2. Barley cultivars

During the summer of 1999, nine barley cultivars (Table 1) were grown at Karaj Research Station, and one cultivar was imported barley. Karaj is located in central Tehran, approximately 30 km west of Tehran. The barley cultivars were grown in the same field under the same soil and environmental conditions. A premix blend of ammonium phosphate and potassium chloride (10–50–10) fertilizer was broadcast at 112 kg ha^{-1} prior to seeding. Plots were seeded in a single field as large plots. Plots were seeded as two strips measuring approximately 70 m × 2 m each. Grain was harvested in the first two weeks of July, cleaned, and representative samples were sent to the Isfahan University of Technology, Isfahan, Iran for testing. A 1 kg clean subsample of each cultivar was used in this study.

2.3. Rumen incubations

A standard procedure for small nylon bags was used to estimate ruminal disappearance of DM (De Boer et al., 1987). All barley samples were ground to pass a 2 mm screen. Approximately 1 g (air dry) of samples were weighed in triplicate into 5 cm × 12 cm nylon bags (porosity = 50 μm) for each cultivar and incubation time (0, 2, 4, 6, 8, 12, and 24 h). Three days were required to incubate all of the different samples in the rumen of the three rams utilized in the experiment and each sample was replicated three times, so a total of 35 days was required to complete the trial. Upon removal from the rumen, nylon bags were immediately rinsed under tap water until the effluent was clear and then were dried at 55 °C for 48 h. Percentage disappearance of DM at each incubation time was calculated from the proportion remaining in the bag after incubation in the rumen. The disappearance rate was fitted to the following equation given by Ørskov and McDonald (1979):

$$\text{Disappearance}\,(\%) = a + b(1 - e^{-ct}) \quad (1)$$

where a is the soluble fraction (% of total), b the degradable fraction (% of total), t the time of incubation (h), and c is the rate of degradation.

Barley degradation curves were fitted by non-linear regression technique (SAS Institute, 1993). Although this equation allows estimation of DM disappearance at any incubation time, it does not predict the amount that will actually be degraded in the rumen (i.e., effective degradability). Thus, effective degradability of DM (EDDM) was calculated by the equation of Ørskov and McDonald (1979):

$$\text{EDDM}\,(\%) = a + b(c/c + k)$$

where k is the estimated rate of outflow from the rumen, and a, b, and c are as defined in Eq. (1). Effective degradability of DM was estimated at ruminal outflow rates of 8% h^{-1} (Ørskov and McDonald, 1979).

The data was analyzed using the General Linear Model procedures of SAS (1993) which employs the use of least-square means for each parameter. In cases where the overall F-test was found to be significant ($P < 0.05$), multiple comparisons were made using the protected least-significant technique.

2.4. Chemical analysis

Feed DM was determined by oven-drying at 55 °C for 48 h. The crude protein (CP) and acid detergent fiber (ADF) content were determined according to the Association of Official Analytical Chemists (1990).

3. Results and discussions

Chemical analysis of barley cultivars is presented in Table 1. The DM of barley cultivars ranged from 92 to 94%, CP from 9 to 11.7%, and ADF from 6.2 to 10.6%. Campbell et al. (1995) reported CP values for six cultivars of barley grown at 12 different locations throughout Manitoba over three consecutive years (9.3–18.2%). However, the range in CP content of barley cultivars observed in our study is much smaller than the range of 7.2–21.4%, and 9.3–18.2% for CP reported by Reynolds et al. (1992), and Campbell et al. (1995). Bradshaw et al. (1992) have shown that environmental and seasonal variations can affect the chemical composition of barley cultivars.

The DM disappearance (%) of the individual barley cultivars at different rumen incubation times and the mean, maximum, and minimum values are presented in Tables 2 and 3, respectively. There were no differences in DM disappearance among cultivars at the 0, 2, and 4 h rumen incubation times. After 6 h of rumen incubation, DM disappearance was highest ($P < 0.05$) for Rayhan and Gorgan 4 (78%) and lowest for Eram (73.5%), all other varieties had intermediate responses that did not differ ($P > 0.05$) from these three varieties. At 8 h, Kavir and Aras had the highest ($P < 0.05$) disappearance rate and Eram had the least (79%). Kavir and Aras did not differ from Zar, Gorgan 4, Rayhan, or imported varieties. After 12 and 24 h, Eram continued to be the least degradable cultivar numerically (82.5 and 83%, respectively), but these responses were not different ($P > 0.05$) from numerous other cultivars. The range in rates of DM disappearance among barley cultivars was very small for these varieties (Table 3). Khorasani et al. (2000) reported a much greater range in rates of disappearance among 60 barley cultivars evaluated in Canada. He reported an 82% DM disappearance for AC-Lacombe after 24 h, whereas a similar disappearance for Waxbar was achieved in 2 h.

Solubility of barley cultivars ranged from 37.9 to 43.4%, whereas Lehman et al. (1995) and Khorasani et al. (2000) reported solubility values of 25–40.7% and 35.2–59.4%, respectively. The difference in solubility measured can be attributed to differences in pore size of the bags, the ratio of sample weight:bag surface area (Uden et al., 1974; Mehrez and Ørskov, 1977; Van Hellen and Ellis, 1977), and washing technique used in the studies (De Boer et al., 1987).

The soluble fraction in barley is assumed to be readily degradable by bacteria and contributes to a rapid lowering of pH in the rumen after feeding. The proportion of total DM in the soluble fraction of the barley samples is presented in Tables 3 and 4. The soluble fraction of the barley cultivars ranged between 37.5 and 43%, which was very similar to the measured solubility of the barley. This range is similar to fraction A (25–40%) obtained by Lehman et al. (1995) but lower than the 45–58% and 33–56% obtained by Ramsey (1994) and Khorasani et al. (2000), respectively. Cultivar differences were observed for the soluble fraction; Faez had the lowest ($P < 0.05$)

Table 2
Ruminal DM disappearance (%) at different times of ruminal incubation[a]

Cultivar	Time of incubation (h)						
	0.0	2.0	4.0	6.0	8.0	12.0	24.0
Zar	39.8	59.0	70.5	76.5 ab	82.5 ab	86.0 a	86.5 a
Gohar	40.3	59.5	70.0	76.5 ab	81.5 b	85.0 ab	85.5 ab
Kavir	40.2	59.5	71.0	77.0 ab	83.5 a	87.0 a	87.0 a
Faez	37.9	57.0	68.0	74.5 ab	81.5 b	85.0 ab	85.5 ab
Sina	38.4	57.5	68.5	75.0 ab	81.5 b	85.5 ab	85.5 ab
Aras	40.7	60.5	71.5	77.5 ab	84.0 a	87.0 a	87.0 a
Eram	39.4	57.5	67.5	73.5 b	79.0 c	82.5 b	83.0 b
Gorgan 4	42.6	62.0	72.0	78.0 a	83.0 ab	85.5 ab	86.0 a
Rayhan	43.4	62.5	72.5	78.0 a	83.0 ab	84.5 ab	84.5 ab
Imported	39.5	58.5	70.0	76.5 ab	82.5 ab	85.5 ab	85.5 ab
S.E.	1.9	1.8	1.8	1.1	1.1	1.2	1.3

[a] Means within columns followed by different letters differ, $P < 0.05$.

Table 3
The mean, minimum, maximum and standard deviation (S.D.) for the in situ parameters measured

Time of incubation (h)	DM disappearance (%)			
	Mean	Minimum	Maximum	S.D.
0.0	40.2	37.9	43.4	1.8
2.0	59.4	57.0	62.5	1.9
4.0	70.2	67.5	72.5	1.7
6.0	76.3	73.5	78.0	1.5
8.0	82.2	79.0	84.0	1.4
12.0	85.4	82.5	87.0	1.3
24.0	85.6	83.0	87.0	1.2
Ruminal DM degradation characteristics				
Soluble fraction (%)	39.9	37.5	43.0	2.8
Degradable fraction (%)	46.5	42.2	49.0	3.4
Rate of degradation (% h^{-1})	27.4	25.6	31.5	3.0
Effective degradability of DM[a] (%)	71.3	75.4	79.5	4.1

[a] Assuming a 8% h^{-1} fractional outflow rate from the rumen.

soluble fraction of DM and Rayhan and Gorgan 4 had the highest ($P < 0.05$) soluble fraction of DM.

The degradable fraction reflects the proportion of DM that is degraded in the rumen at a measurable rate. The degradable fraction is nutritionally important because it provides the major source of slowly fermenting starch for rumen microbes. The degradable fraction in barley cultivars ranged between 42.2 and 49.0% (Table 4). Okine and Kennelly (1994) have reported that the slowly degradable fraction of starch in barley is about 60%.

Table 4
Rumen degradation characteristics of DM[a]

Cultivar	A (%)	B (%)	C (% h^{-1})	EDDM[b]
Zar	39.5 ab	47.7 ab	26.9 ab	78.5 ab
Gohar	40.0 ab	46.2 ab	26.9 ab	77.8 ab
Kavir	40.0 ab	48.0 ab	27.1 ab	79.3 a
Faez	37.5 b	49.0 a	25.6 b	77.2 ab
Sina	38.0 b	48.6 a	25.9 b	77.5 ab
Aras	40.5 ab	47.5 ab	27.4 ab	79.5 a
Eram	39.1 ab	44.7 ab	25.9 b	75.4 b
Gorgan 4	42.6 a	44.0 ab	28.5 ab	78.9 ab
Rayhan	43.0 a	42.2b	31.5a	78.4 ab
Imported	39.0 ab	47.4 ab	28.5 ab	78.2 ab
S.E.	1.1	1.3	1.2	1.4

[a] Means within columns followed by different letters differ, $P < 0.05$. A: rapidly degraded fraction, B: slowly degraded fraction, and C: rate of degradation.

[b] Assuming a 8% h^{-1} fractional outflow rate from the rumen.

As the rate of degradation of DM increases, the amount of starch being made available to rumen bacteria per unit time becomes larger. Therefore, barley cultivars with a lower rate of rumen degradation would be desirable. Values for rate of rumen degradation varied among barley cultivars. The slowest rate (25.6% h^{-1}) was observed for Faez and the fastest was observed for Rayhan (31.5% h^{-1}) (Table 4). Lehman et al. (1995) also reported that the in situ rumen degradation rate for barley DM digestion of 22 different cultivars ranged from 25 to 35%. In the study by Khorasani et al. (2000) the degradation rate ranged from 20 to 62% h^{-1}. Several factors are likely to be responsible for the differences observed between the Khorasani et al. (2000) and our work. Factors that influence the extent and rate of ruminal digestion of in situ studies are again differences in pore size of the bags, the ratio of sample weight:bag surface area (Uden et al., 1974; Mehrez and Ørskov, 1977; Van Hellen and Ellis, 1977), particle size (Mohamed and Smith, 1977; Khorasani et al., 1995), and washing technique used in the studies (De Boer et al., 1987).

Little information is available relating characteristics of barley degradation to animal performance. Givens et al. (1993) suggested that barley with slower rate of degradation might be superior for ruminant feeding because as rate of degradation of grain increases, susceptibility to digestive problems such as metabolic acidosis, bloat, and grain overload would

be expected to increase. Although Owens et al. (1986) suggested that starch digested in the small intestine provides 42% more energy to the animal than starch digested in the rumen, Taniguchi et al. (1995) concluded that starch should be digested in the rumen rather than in the lower digestive tract. Ramsey (1994) was unable to demonstrate that the rate of ruminal degradability of barley grain was significantly correlated with either rate or efficiency of live weight gain in feedlot steers. Further research is warranted to determine the optimal rate of degradation of barley under a variety of production conditions.

If research confirms that barley degradability characteristics are related to animal production, a decision can be made as potential directions for barley breeding programs.

4. Conclusions

Considering the importance of barley as a livestock feed in Iran, there has been limited research on rumen and intestinal degradability characteristics of different barley varieties in ruminants. The results of this experiment indicate that even though there were significant differences in the soluble fraction, degradable fraction and rate of degradation for different cultivars, but they only varied by as much as 20% and there was no distinct ranking of varieties in terms of degradation over time. The result of this experiment also indicates that the CP content of Iranian cultivars is much smaller than barley cultivars grown in west. It is not clear if these characteristics would respond to selection. Environmental conditions may also affect the nutrient content of the barley cultivars, so further studies are also needed to determine the effect of cultivars and the environment on rumen degradation characteristics of barley grain. Further studies on the nitrogen and carbohydrate degradabilities may prove useful in further determining the feed value of barley.

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