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Chemical characterization and in situ nutrient degradability of wet distillers' grains derived from barley-based ethanol production

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Abstract

A study was conducted to characterize the carbohydrate and protein fractions of barley-based distillers grains (BDG) derived from a mix of 70% barley, 20% wheat and 10% rye/triticale. Amino acid composition, ruminal escape protein and amino acid values, and ruminal nutrient degradability of BDG were determined relative to wheat-based distillers' grains (WDG) derived from 100% wheat. On a dry matter (DM) basis, BDG contained 743 g kg^{-1} neutral (NDF) and 311 g kg^{-1} acid (ADF) detergent fibre, and 154 g kg^{-1} crude protein (CP). More than 50% of BDG protein was associated with NDF while 17% was associated with ADF. Glutamic acid was the most abundant amino acid in both distillers grains and was lower ($p < 0.05$) in BDG (184 g kg^{-1} of amino acids) than WDG (243 g kg^{-1} of amino acids). The concentration of lysine was higher ($p < 0.05$) in BDG than in WDG while that of methionine was similar in both byproducts. Ruminal escape protein value was greater ($p < 0.05$) for BDG than for WDG. However, the ruminal escape values for most of the amino acids were not different between BDG and WDG. Ruminal degradability of NDF from WDG (454 g kg^{-1} of NDF) was higher ($p < 0.05$) than that from BDG (360 g kg^{-1} NDF). The results of this study showed that fibre and protein fractions of BDG are less degradable in the ruminal than the corresponding fraction from WDG. However, data of amino acid composition and ruminal undegradability suggest that the quality of amino acids of BDG reaching the small intestine of ruminants is equal or better than that from WDG.

Keywords: Barley; Distillers' grains; Nutrient degradability

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1. Introduction

Stillage is the byproduct of the distilling industry in which cereal grains are fermented into alcohol (Lee et al., 1991). Traditionally, whole stillage is dried and marketed as distillers' grains with or without solubles. Distillers' grains are identified by the type of grain used in the distillation process. Corn is by far the most common cereal grain used for ethanol production (Aines et al., 1986). In western Canada, wheat is the principal grain used by ethanol distilleries. Barley grain is another important crop grown in western Canada and can be used alone or in combination with wheat to reduce the cost of ethanol production. Due to differences in hull content between barley and wheat, barley-based distillers' grains are expected to have a different nutrient composition and feeding value than wheat-based distillers' grains. The chemical characteristics and the feeding value of wheat-based wet distillers grains' were reported previously (Ojowi et al., 1997).

Few published data exist on the nutritive value of barley-based distillers' grains. Wu (1986) reported that barley distillers' grains had 326 g kg^{-1} crude protein, 60 g kg^{-1} fat, 44 g kg^{-1} ash, and 166 g kg^{-1} crude fibre. Weiss et al. (1989) found that wet distillers' grains produced from a mix of 65% barley and 35% corn contained 380 g kg^{-1} neutral detergent fibre, 270 g kg^{-1} crude protein. Data on the nutritive value of distillers' grains derived from 100% barley or a blend of barley and wheat are not available. The objectives of this research were to determine the chemical composition and in situ nutrient degradability of barley-based distillers' grains derived from a commercial ethanol production facility.

2. Materials and methods

2.1. Sample preparation and chemical analysis

Samples of wet barley-based distillers' grains ($n = 5$) were supplied by Pound-Maker Agventures, ethanol plant at Lanigan, Saskatchewan. The fermentation substrate consisted of 700 g kg^{-1} barley, 200 g kg^{-1} wheat and 100 g kg^{-1} rye/triticale mixture.

Distillers' grain samples were freeze dried and analyzed for ash, ether extract, crude protein (CP, Kjeldahl N $\times$ 6.25), acid detergent fibre (ADF) and acid detergent lignin (ADL) according to the methods of the Association of the Official Analytical Chemists (AOAC, 1990). Neutral detergent fibre (NDF) was determined according to Van Soest et al. (1991). Neutral and acid detergent insoluble protein were determined on neutral and acid detergent fibre residues, respectively (Kjeldahl method, AOAC, 1990). Buffer soluble protein and non-protein nitrogen were determined as described by Licitra et al. (1996). Total starch was determined using the $\propto$ amylase amyloglucosidase method (Megazyme kit, NSW, Australia).

The equations of Sniffen et al. (1992) were used to fractionate total carbohydrate and protein based on rates of ruminal degradation. Total carbohydrates were fractionated into fraction A (rapidly degradable), fraction B1 (intermediately degradable), fraction B2 (slowly degradable), and fraction C (unavailable cell wall). Total CP was fractionated into fraction A (non-protein nitrogen), fraction B (true protein) and fraction C (unavailable protein). True protein was further sub-fractionated into B1 (highly degradable), B2 (intermediately degradable), and B3 (slowly degradable).

Samples were analyzed for amino acids (AOAC, 1984) following oxidation in performic acid (16 h) and hydrolysis in 6 N HCl (24 h), respectively. The oxidation step was not used for phenylalanine and histidine. Tryptophan was measured after alkaline hydrolysis (Miller, 1967). All amino acids were determined using a Brinkmann (System 6300) High Performance Analyzer. For comparison purposes, five wheat distillers' grain samples used in the study of Ojowi et al. (1997) were also analyzed for amino acids. These samples were also collected as wet distillers' grains.

2.2. In situ ruminal nutrient degradability

Equal portions of the five wet barley-based distillers' grain samples were composited and ground though a 2-mm screen using a Christie Norris mill. A composited sample of five wheat distillers' grain samples used in a previous study (Ojowi et al., 1997) was included for comparison purposes. Seven grams of barley-based distillers' grains and wheat distillers' grains were weighed in duplicate into nylon bags (9 × 21 cm; 41 μm porosity). The bags were then placed into polyester mesh bags (25 × 33 cm) and incubated in the ventral sac of a ruminally fistulated cow for 4, 8, 12, 18, 24, 48, 72 and 96 h. The cow was maintained on a 50 : 50 concentrate; barley silage diet at 1.5% body weight (dry matter basis). Zero hour disappearance was estimated by washing duplicate bags of each treatment in tap water. Three incubations were carried out for replications. Following removal from the ruminal, the bags were washed and handled as described by McKinnon et al. (1991).

Contents of duplicate bags were composited, ground and subjected to moisture, CP and NDF analysis as described previously. Nylon bag residues from the 12 h incubations were analyzed for CP and amino acids to determine ruminal escape protein and amino acid values. Ruminal escape protein value was expressed as g kg^{-1} of total protein while ruminal escape amino acid values were expressed as g kg^{-1} of ruminal undegraded protein (Klemesrud et al., 1998).

The disappearance of DM, CP and NDF at each incubation time was calculated from the concentration of these nutrients in the original sample and the residues and was used to estimate ruminal kinetic parameters according to the equation of (Ørskov and McDonald, 1979) with the addition of a lag time:

$$p = a + b(1 - e^{-c(t-\text{lag})})$$

where p is ruminal disappearance at time t, a the in situ soluble fraction, b the slowly degradable fraction, and c the rate of degradation of the slowly degradable fraction. Effective ruminal degradability of DM, CP and NDF was estimated using the equation of (Ørskov and McDonald, 1979), assuming a ruminal flow rate of 5% h^{-1}.

2.3. Statistical analysis

All data were analyzed as a completely randomized design using the General Linear Model procedure of SAS (1989). When a significant difference was found, means were separated using the Student Newman's Keul procedure (Steel and Torrie, 1980).

3. Results and discussion

3.1. Chemical composition of wet barley-based distillers' grains

3.1.1. Carbohydrate composition

The major constituent in barley-based distillers' grains dry matter (DM) is carbohydrate (743 g kg^{-1} of DM, Table 1). Similar to our findings, Ojowi et al. (1997) reported that carbohydrate content was 641.0 g kg^{-1} of DM in wheat distillers' grains. The NDF and ADF of barley-based distillers' grains averaged 792.0 and 310.8 g kg^{-1} (DM basis), respectively. The ADL constituted a small portion of NDF in barley-based distillers' grains. Weiss et al. (1989) reported lower NDF (563 g kg^{-1}) and ADF (293 g kg^{-1}) values for distillers' grains derived from a mix of 650 g kg^{-1} barley and 350 g kg^{-1} corn than the values reported in our study. These differences in fibre content are likely due to the fact that distillers' grains used in that study contained solubles. It has been shown that distillers' grains have higher fibre content than distillers' grains plus solubles (Larson et al., 1993).

The NDF and ADF values in this study for barley-based distillers' grains were 5.4 and 22.5%, respectively, higher than the values previously reported for wet wheat distillers' grains (Ojowi et al., 1997). Differences in fibre content between barley- and wheat-based distillers' grains can be attributed to the higher hull content of barley relative to wheat. Bhatty et al. (1975) reported that the hull constitutes 100–130 g kg^{-1} of barley grain. Our results and those of Ojowi et al. (1997) suggest that differences in carbohydrate content between barley- and wheat-based distillers' grains is due to differences in ADF rather than NDF content. In a previous study, Mustafa et al. (1998) also found greater differences in ADF than in NDF levels between barley and wheat milling byproducts.

Table 1
Ash, ether extract and carbohydrate analysis and fractionation of wet barley-based distillers grains ($n = 5$)

Parameter	Mean	SD[a]
Dry matter (DM, g kg^{-1})	289.1	11.9
Ash (g kg^{-1} of DM)	41.5	1.5
Ether extract (g kg^{-1} of DM)	59.8	2.9
Carbohydrate analysis (g kg^{-1} of DM)		
Neutral detergent fibre (NDF)	792.0	2.9
Acid detergent fibre	310.8	7.7
Acid detergent lignin (g kg^{-1} of NDF)	88.1	8.7
Total carbohydrate	744.6	5.5
Non-structural carbohydrate (NSC)	38.8	5.8
Starch (g kg^{-1} of NSC)	109.8	15.1
Carbohydrate fractions (g kg^{-1} of DM)		
A (Rapidly degradable carbohydrate)	33.4	4.2
B1 (Intermediately degradable carbohydrate)	4.0	0.8
B2 (Slowly degradable carbohydrate)	538.2	8.8
C (Unavailable carbohydrate)	167.4	9.5

[a] Standard deviation.

Table 2
Protein analysis and fractionation of wet barley-based distillers grains ($n = 5$)

	Mean	SD[a]
Protein analysis		
Crude protein (CP, g kg^{-1} of DM)	154.2	5.3
Soluble protein (g kg^{-1} of CP)	76.6	14.1
Non-protein nitrogen (g kg^{-1} of CP)	68.7	12.0
Neutral detergent insoluble protein (g kg^{-1} of CP)	560.4	19.2
Acid detergent insoluble protein (g kg^{-1} of CP)	161.6	6.3
True protein fractions (g kg^{-1} of CP)		
Total	768.2	5.8
B1 (Rapidly degradable true protein)	9.0	5.7
B2 (Intermediately degradable true protein)	360.5	21.5
B3 (Slowly degradable true protein)	398.7	21.8

[a] Standard deviation.

Fractionation of total carbohydrate in barley-based distillers' grains according to rate of degradation in the ruminal (Table 1) showed that slowly degradable carbohydrate (B2 fraction) constitutes the largest part of carbohydrate (538.2 g kg^{-1}) followed by the unavailable (C fraction, 167.4 g kg^{-1} of DM) and rapidly degradable (A fraction, 33.4 g kg^{-1} of DM) fractions, respectively. Intermediately degradable carbohydrate (B1 fraction) made up a small portion of total carbohydrate. A similar order of carbohydrate fractions was reported for wet wheat distillers' grains by Ojowi et al. (1997).

3.1.2. Protein composition

The average CP and soluble protein values of barley-based distillers' grains were 154 g kg^{-1} of DM and 77 g kg^{-1} of CP, respectively (Table 2). These values are 42 and 69%, respectively lower than the values reported by Ojowi et al. (1997) for wheat distillers' grains. Weiss et al. (1989) reported a higher CP value (269 g kg^{-1}) for barley-based distillers' grains than the value in this study. This again is likely due to the fact that these authors utilized distillers' grains with solubles in their study. In this study, more than 500 g kg^{-1} of total protein in wet barley-based distillers' grains was associated with NDF while 162 g kg^{-1} was associated with ADF (Table 2). Ojowi et al. (1997) reported comparable neutral (471 g kg^{-1} of CP) and lower acid (59 g kg^{-1} of CP) detergent insoluble protein values for wet wheat distillers' grains. According to Sniffen et al. (1992), wet corn distillers' grains, contain 548 and 120 g kg^{-1} of CP in the form of neutral and acid detergent insoluble protein, respectively. These results indicate that most of distillers' grain protein is bound to the cell wall.

Fractionation of protein according to rate of degradation in the ruminal indicated that wet barley-based distillers' grains contained equal portions of slowly (B3) and intermediately (B2) degradable protein fractions (Table 2). Ojowi et al. (1997) reported that wet wheat distillers' grains contain more slowly than intermediately degradable true protein.

Table 3
Amino acid (AA) composition of wet barley-based and wheat distillers grains ($n = 5$, DM basis)

	Distillers' grains[a]		SEM[b]
	Barley-based	Wheat	
Essential (*g kg^{-1} of AA*)			
Arginine	77.1 a	61.7 b	0.71
Histidine	28.0	26.8	0.78
Isoleucine	41.6	41.8	0.38
Leucine	80.0 a	78.1 b	0.40
Lysine	52.8 a	41.9 b	0.56
Methionine	20.2	20.6	0.46
Phenylalanine	50.8	47.9	1.26
Threonine	44.3 a	38.4 b	0.31
Tryptophan	12.2 a	9.6 b	0.75
Valine	62.4 a	59.1 b	0.56
Non-essential (*g kg^{-1} of AA*)			
Alanine	61.4 a	52.1 b	0.62
Aspartic acid	85.0 a	73.6 b	0.92
Glutamic acid	184.0 b	243.1 a	2.37
Glycine	60.3 a	51.8b	0.99
Proline	66.1 b	84.7 a	2.36
Serine	50.1 a	47.7 b	0.53
Total AA (g kg^{-1} of CP)	884.0	920.9	12.36

[a] Means in the same row with different letters are different ($p < 0.05$).
[b] SEM, pooled standard error of the mean.

3.1.3. Amino acid composition

Glutamic acid was the most abundant amino acid in both distillers' grains and was higher ($p < 0.05$) in wheat than barley-based distillers' grains (Table 3). Similar results were previously reported for wheat and barley-based thin stillage (Mustafa et al., 1999). The amino acid profiles of barley-based distillers' grains and wheat distillers' grains reported in this study are in good agreement with those previously reported for barley (Wu, 1986) and wheat (Wu et al., 1984) distillers' grains. Wu (1986) found that amino acid composition of barley distillers' grains to be similar to that of barley. However, wheat distillers' grains were found to have higher lysine, threonine and isoleucine content than wheat (Wu et al., 1984). Relative to wheat distillers' grains, barley-based distillers' grains had higher ($p < 0.05$) arginine, leucine, lysine, threonine, tryptophan, valine, alanine, aspartic acid, glycine and serine and lower ($p < 0.05$) glutamic acid and proline content (Table 3). These results confirm the findings of Wu (1986) which indicated that barley distillers' grains have a superior amino acid profile than wheat distillers' grains.

3.2. Ruminal escape crude protein and amino acids

Ruminal escape crude protein value was higher ($p < 0.05$) for barley-based distillers' grains than wheat distillers' grains (Table 4). The higher ruminal escape protein value of barley-based distillers' grains relative to wheat distillers' grains is likely related to its

Table 4
Ruminal escape of crude protein (CP) and amino acids (AA) of wet barley-based and wheat distillers grains following 12 h-ruminal incubation

	Distillers grains[a]		SEM[b]
	Barley-based	Wheat-based	
Ruminal escape CP (g kg^{-1} of CP)	490.0 a	414.5 b	14.12
Ruminal escape CP[c] (g kg^{-1} of CP)	372.3	330.6	18.03
Ruminal escape amino acid[d]			
Arginine	37.4	41.8	3.00
Histidine	16.7	18.8	1.20
Isoleucine	20.8	24.5	2.24
Leucine	56.0	62.8	4.12
Lysine	35.7 a	27.6 b	2.23
Methionine	18.7	16.6	1.32
Phenylalanine	27.0 b	38.1 a	2.11
Threonine	3.14	30.9	1.64
Valine	35.5	35.5	2.38
Alanine	49.1	39.2	3.57
Aspartic acid	571.6	494.9	9.45
Glutamic acid	121.5 b	232.6 a	10.31
Glycine	45.4	38.7	3.30
Proline	51.4 b	75.5 a	4.37
Serine	43.3	46.1	2.77

[a] Means in the same row with different letters are different ($p < 0.05$).
[b] SEM, pooled standard error of the mean.
[c] Corrected for acid detergent insoluble CP in ruminal undegraded residues
[d] Expressed as g kg^{-1} of residual CP after 12 h of ruminal incubation.

high acid detergent insoluble protein (Table 2). This is in agreement with other studies which showed that the ruminal escape protein value of distillers' grains increased as the concentration of acid detergent insoluble protein content increased (Ham et al., 1994; Boila and Ingalls, 1994). The ruminal escape protein values reported in this study for both distillers' grains are in good agreement with those reported for corn distillers' grains with similar levels of acid detergent insoluble protein (Ham et al., 1994). In the present study, the amount of acid detergent insoluble protein in the ruminal undegraded protein (following 12 h of ruminal incubation) was higher ($p < 0.05$) in barley-based distillers' grains (117.6 g kg^{-1} of ruminal undegraded protein) than in wheat distillers' grains (83.9 g kg^{-1} of ruminal undegraded protein). According to Sniffen et al. (1992), this protein fraction is unavailable for intestinal digestion and thus does not contribute to the metablizable protein pool. When corrected for acid detergent insoluble protein in the ruminal undegraded residues, ruminal escape protein value was similar in both distillers' byproducts (average 352 g kg^{-1} of total protein). This portion of ruminal escape protein represents the amount of ruminal undegraded protein that is available to the animal postruminally. These findings confirm our previous conclusion that differences in ruminal escape protein between barley-based and wheat distillers' grains are largely due to differences in acid detergent insoluble protein content.

Differences in ruminal escape amino acid values between barley-based and wheat distillers' grains were small (Table 4). Relative to wet wheat distillers' grain, barley-based distillers' grains contained lower ($p < 0.05$) levels of ruminal escape phenylalanine, glutamic acid, and proline and a higher ($p < 0.05$) level of ruminal escape lysine. No differences in ruminal escape values were observed for the other amino acids. The differences observed in ruminal escape value of some amino acids may be related to their concentration in the initial samples. As reported earlier (Table 3), the concentrations of phenyalanine and glutamic acid were lower while the concentration of lysine was higher in barley-based than in wheat distillers' grains. As noted for the initial distillers' grain samples (Table 3), glutamic acid had the highest concentration of any other amino acid in the ruminal undegraded protein. Similar observations were also reported for dried distillers' grains prepared from 100% wheat or a blend of 75% wheat and 25% corn (Boila and Ingalls, 1994). The ruminal escape amino acid values reported in this study for wet wheat distillers' grains are in good agreement with those reported for dried corn distillers' grains by NRC (1996).

3.3. In situ ruminal nutrient degradability

Barley-based distillers' grains had similar in situ soluble DM content and rate of degradation of slowly degradable DM to wheat distillers' grains (Table 5). However,

Table 5
In situ ruminal nutrient kinetic parameters of wet barley-based and wheat distillers grains

	Distillers' grains[a]		SEM[b,c]
	Barley-based	Wheat	
Dry matter (DM)			
Soluble (g kg^{-1} of DM)	215.5	251.0	10.90
Slowly degradable (g kg^{-1} of DM)	497.5 b	607.4 a	7.00
Degradation rate (% h^{-1})	4.1	3.5	0.41
Lag time (h)	3.5 a	2.0 b	0.13
Effective degradability[c] (g kg^{-1})	439.2 b	521.8 a	3.91
Crude protein (CP)			
Soluble (g kg^{-1} of CP)	197.7 b	340.8 a	5.90
Slowly degradable (g kg^{-1} of CP)	684.4 a	594.0 b	3.80
Degradation rate (% h^{-1})	7.8 a	6.3 b	0.19
Lag time (h)	0.1	0.2	0.02
Effective degradability[c] (g kg^{-1})	616.0 b	651.1 a	7.80
Neutral detergent fibre (NDF)			
Soluble (g kg^{-1} of NDF)	148.9 b	195.5 a	1.95
Slowly degradable (g kg^{-1} of NDF)	529.8 b	669.9 a	18.90
Degradation rate (% h^{-1})	3.3	3.1	0.18
Lag time (h)	1.3	1.3	0.20
Effective degradability[c] (g kg^{-1})	359.8 b	454.0 a	5.77

[a] Means in the same row with different letters are different ($p < 0.05$).
[b] SEM, pooled standard error of the mean.
[c] Calculated assuming ruminal flow rate of 5% h^{-1}.

wheat distillers' grains contained greater ($p < 0.05$) slowly degradable DM fraction than barley-based distillers' grains. Effective ruminal degradability of DM was higher ($p < 0.05$) for wheat distillers' grains (522 g kg^{-1}) than for barley-based distillers' grains (439 g kg^{-1}, Table 4). The effective ruminal degradability of DM reported for wheat distillers' grains in this study is in good agreement with the values reported by Ojowi et al. (1997) and Boila and Ingalls (1994).

Relative to wheat distillers' grains, barley-based distillers' grains had lower ($p < 0.05$) in situ soluble protein fraction (Table 5). However, slowly degradable protein fraction and the rate of degradation of that fraction were higher ($p < 0.05$) in barley-based than wheat distillers' grains. Effective ruminal protein degradability of barley-based distillers' grains was lower ($p < 0.05$) than that of wheat distillers' grains (Table 5). This is likely a combination of a lower CP and a higher acid detergent insoluble protein content for barley-based distillers' grains relative to wheat distillers' grains. It has been shown that high levels of acid detergent insoluble protein reduce ruminal degradability of wheat and corn distillers' grains (Ham et al., 1994; Boila and Ingalls, 1994). The results of this study together with those of Ojowi et al. (1997) indicate that protein of wet distillers' grains prepared from wheat and barley is readily degraded in the ruminal. This is in contrast with Boila and Ingalls (1994) who reported an effective ruminal protein degradability of 487 (g kg^{-1} of CP) for dried wheat distillers grains. The reduced ruminal degradability of wheat distillers' grains reported by Boila and Ingalls (1994) may be related to the fact that these authors used dried distillers' grains in their study. Boila and Ingalls (1994) also reported a lower degradation rate for dried wheat distillers' grain protein (2.6% h^{-1}) than the rates reported in the present study for barley-based (7.8% h^{-1}) and wheat (6.3% h^{-1}) distillers' grain protein.

Barley-based distillers' grains had lower ($p < 0.05$) in situ soluble and slowly degradable NDF fractions than wheat distillers' grains (Table 5). However, rate of degradation of the slowly degradable fraction and lag time were similar in both distillers byproducts (average 3.2% h^{-1} and 1.3 h, respectively). Relative to wheat distillers' grains, barley-based distillers' grains had a lower ($p < 0.05$) effective ruminal degradability of NDF (360 vs. 454 g kg^{-1} of NDF). Varga and Hoover (1983) determined in situ (24 h) disappearance of NDF of dried corn distillers' grains to be 766 g kg^{-1}. In the present study, the respective disappearance for wheat and barley-based distillers' grains was 740 and 570 g kg^{-1}, respectively (data not shown). The most likely explanation of the lower ruminal NDF degradability of barley-based distillers' grains is the high hull content of barley relative to other cereal grains. It has been shown that barley hulls are poorly digested in the ruminal (Mustafa et al., 1998; McAllister et al., 1990). Nordkvist et al. (1984) reported that the highest concentration of phenolic acids, particularly *p*-coumaric acid in barley grain is found in the hull. Several studies have indicated that *p*-coumaric acid is the lignin component most negatively related to digestion (Jung et al., 1983; Reeves, 1985; Garleb et al., 1991). The large difference in ruminal degradability of NDF between the two distillers byproducts suggest that the difference in ruminal dry matter degradability between barley-based and wheat distillers grains' is largely due to differences in degradability of NDF rather than CP.

4. Conclusions

The results reported in the present study indicate that distillers' grains derived primarily from barley is characterized by low protein and high fibre content. When compared with wet wheat distillers' grains derived from 100% wheat, wet barley-based distillers' grains had a better or similar amino acid composition. Protein from wet barley-based distillers' grains has a higher ruminal escape value than that from wet wheat distillers' grains. However, the quality of ruminal undegraded protein of wet barley-based distillers' grains may be compromised by its high acid detergent insoluble protein content. Data from this study also indicate that fibre from wet barley-based distillers' grains is less degradable in the ruminal than fibre from wet wheat distillers' grains largely because of the higher level of acid detergent fibre in wet barley-based distillers' grains.

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