Iran Agricultural Research 22: 197-205 (2003)

NOTE

IN SITU DRY MATTER AND CRUDE PROTEIN DEGRADABILITY IN CORN, WHEAT AND MILLET GRAIN

PISHNAMAZI, R., G.R. GHORBANI[1] AND M. ALIKHANI[2]

Department of Animal Sciences, College of Agriculture, Isfahan University of Technology, Isfahan, I.R. Iran.

(Received: October 28, 2003)

ABSTRACT

Rumen degradability was determined for six wheat, three corn and three millet cultivars in six ruminally cannulated sheep. The sheep were fed a ration containing 55% alfalfa and 45% ground barley. All grains were incubated for 2, 4, 8, 12, 24 and 48 h in dacron bags (50-μm pore size). The mean soluble and degradable portions, rate of degradation and effective degradability of dry matter ranged from 3.3 to 8.2%, 80.9 to 92.8%, 5.4 to 27.5% and 44.8 to 74.2% for wheat, corn and millet, respectively. Corresponding values for crude protein of wheat corn and millet ranged from 5.7 to 9.6%, 45.7 to 83%, 5.3 to 28.9% and 35.1 to 78.4%, respectively. It was concluded that grains varied widely in their ruminal degradability and this information may aid in synchronizing degradation of protein and starch in the rumen to improve lactation performance.

Key words: *In situ*, Grain, Dry matter, Crude protein, Effective degradability.

تحقیقات کشاورزی ایران

۲۲: ۱۹۷-۲۰۵ (۱۳۸۲)

1. Corresponding author (gghorbani@yahoo.com).

2. Former Graduate Student, Professor and Assistant Professor, respectively.

تجزیه‌پذیری ماده خشک و پروتئین خام دانــه هــای ذرت، گنـدم و ارزن به روش *in-situ*

رضا پیشنمازی، غلامرضا قربانی و مسعود علیخانی

بـه ترتیـب، دانشـجوی پیشـین کارشناسـی‌ارشـد و اسـتاد و اسـتادیار گـروه علـوم دامـی دانشـکده کشاورزی دانشگاه صنعتی اصفهان، اصفهان، جمهوری اسلامی ایران.

چکیده

تجزیه‌پذیری شش واریته گندم، سه واریته ذرت و سـه واریتـه ارزن بـا روش *in-situ* در شـش گوسفند فیستولاگذاری شده تعیین شد. گوسفندان با جیره‌ای دارای ۵۵٪ یونجه و ۴۵٪ جو آسیا شده تغذیه شدند. غلات مـورد مطالعـه در سـاعتهای ۰، ۲، ۴، ۸، ۱۲، ۲۴ و ۴۸ در کیسـه‌هـای نـایلونی (۵۰ میکرومتر اندازه سوراخ‌ها) در شکمبه قرار داده شدند. دامنه ماده خشک محلول، تجزیه‌پذیری، میـزان تجزیه‌پذیری و تجزیه‌پذیری مؤثر برای گندم، ذرت و ارزن به ترتیب، از ۳/۳ تا ۸/۲٪، ۸۰/۹ تا ۹۲/۸٪، ۵/۴ تا ۲۷/۵٪، و ۴۴/۸ تا ۷۴/۲٪ بود. دامنه پـروتئین محلـول، تجزیـه‌پـذیری، میـزان تجزیـه‌پـذیری و تجزیه‌پذیری موثر برای گندم، ذرت و ارزن به ترتیب، از ۵/۷ تا ۹/۶٪، ۴۵/۷ تـا ۸۳٪، ۵/۳ تـا ۲۸/۹٪ و ۳۵/۱ تا ۷۸/۴٪ بود. این دانه ها از نظر قابلیت دسترسی در شکمبه، با یکـدیگر تفـاوت داشـتند و ایـن اطلاعات می‌توانـد در هماهنـگ کـردن تجزیـه پـروتئین و نشاسـته در شـکمبه بـرای بهبـود عملکـرد شیردهی، سودمند باشد.

INTRODUCTION

Cereal grains are the most common sources of rapidly available energy for livestock and may comprise up to 60% of the total diet for high yielding dairy cows. The importance of the amount and site of digestion of starch in the diet of the high producing dairy cow has been emphasized in critical reviews by Nocek and Tamminga (10) and

Reynolds *et al.* (15). An alternative strategy for manipulating the site of starch digestion is by appropriate choice of the grain incorporated into the concentrate supplement. Grains consist of a fibrous pericarp surrounding the starch endosperm and the germ. The protein matrix surrounding the starch granules within the endosperm is believed to be responsible for the differences in the extent of ruminal starch digestion (11). The rate and extent of ruminal fermentation vary widely with grain source and hybrid (14). The rate and extent of fermentation of wheat are greater than those of barley, sorghum, or corn. About 80-90% of starch in barley and wheat is digested in the rumen; this value ranges from 55 to 70% for sorghum and corn (10). Little information is available on characteristics of degradation in the rumen of three cereal grains (wheat, corn and millet) used for livestock in Iran. Such information would allow combining of grain and protein sources with similar ruminal degradation, and thus a more efficient use of energy and protein in ruminant diets.

The objective of this study was to determine DM, and CP degradation of different cultivars of three cereal grain cultivar using the *in situ* method.

MATERIALS AND METHODS

Samples (4.0 kg) of six commercial wheat grains (Barakat, Mahdavi, Roushan, Omid, Niknejad and Ghods), three corn grains (704, 901 and native), and three millet grains (*Setaria italica*, *Panicum miliaceum*, and native) were obtained from Karaj Research Station, approximately 30 km west of Tehran, grown under the same soil and environmental conditions. The samples were ground on a Willy mill to pass a 2-mm screen and analyzed (1) for DM (dry matter), EE (ether extract), CP (crude protein), P (phosphorus) and ADF (acid detergent fiber).

Six ruminally fistulated Naeini lambs (40 kg average BW) were used to determine *in situ* DM, and CP degradability of the twelve grain samples. Lambs were housed in individual stalls and fed at maintenance level for 15 d before and during the study (45% barley and 55% alfalfa hay).

Bags were made of Dacron cloth (13 x 7 cm) with an approximate pore size of 50 μm. Approximately 2 g of grain were weighed into a previously dried (60°C) and tarred bag. Each sample was replicated three times. All bags were tied to a weighted chain and placed in the ventral sac of the rumen approximately 2 h after the morning feeding. Bags were removed after 2, 4, 8, 12, 24 and 48 h of incubation. Immediately after removal from the rumen, bags were washed with cold tap water until rinse water was clear. Bags were dried for 72 h at 60°C in a forced air oven, after which residues were removed and analyzed for DM and CP.

The disappearance rate was fitted to the following equation (12):

Disappearance (%) = $a + b\ (1-e^{-ct})$ [1]

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

Degradation curves were fitted by the non-linear regression procedure of SAS (16). 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 (ED) of DM and CP was calculated by the equation of Ørskov and McDonald (12):

ED (%) = $a + bc / (c + k)$ [2]

where k is the estimated rate of outflow from the rumen and a, b and c as defined in equation 1. Effective degradability of DM and CP was estimated at ruminal outflow rates of 8% h^{-1} (12).

The data were analyzed using the General Linear Model procedure of SAS (16) based on a factorial experiment in a completely randomized design which employs the use of least-square means for each parameter. In cases where the overall F-test was significant ($P<0.05$), multiple comparisons were made using the protected least-significant technique. The following model was used for analysis of data:

$Y_{ijk} = \mu + A_i + B_{ij} + AB_{ik} + e_{ijk}$

Where:

μ = mean

A_i = grain effect

B_{ij} = cultivar effect

AB_{ik} = interaction effect of grain and cultivar

e_{ijk} = residual (error)

RESULTS AND DISCUSSION

Composition of the grains are presented in Table 1. Average protein content of wheat, corn and millet was 13.5, 8.3 and 10.6%, respectively. Wheat grains had on average 39 and 21% higher mean concentration of protein, a 33 and 75% lower mean concentration of ADF than corn and millet, respectively. The fat content was almost the same. Compared with NRC (5) the crude protein content of the cereals was lower (wheat 13.5 vs. 14.2%, corn 8.3 vs. 9.4% and millet 10.6 vs. 13.2%) the ADF content was higher (wheat 6.6 vs. 4.4%, corn 10.3 vs. 4.2% and millet 26.9 vs. 17%) and ether extract was also slightly higher (wheat 2.4 vs. 2.3%, corn 4.4 vs. 4.2% and millet 5.3 vs. 4.3%).

The *in situ* degradability values are presented in Table 2. The soluble dry matter fraction (A) was highest ($P<0.05$) for wheat (8.2%) and lowest for millet (3.3%). There were no significant differences among the wheat and corn cultivars for dry matter A fraction but amongst the three millet cultivars, *Panicum* had the lowest (1.65%) A fraction (P<0.05). Soluble dry matter for corn was lower than in previously reported as 16.6% (7), 22.1% (18), 18.6% (4) , 14.4% (2) and 25.4% (13). Dry matter A fraction for wheat was also lower than the reported values of 32.7% (13) and 34.3% (18).

Wheat had the highest (P<0.05) soluble crude protein fraction (9.6%) while corn and millet were intermediate (6.4 to 5.7%). These values were lower than those reported

Table 1. Chemical composition† of several wheat, corn and millet cultivars.

	Dry matter†	CP	ADF	EE
Wheat		% of dry matter		
Barakat	98.3	11.3	5.5	2.1
Omid	98.1	14.9	7.1	1.6
Niknejad	99.1	14.8	6.5	2.6
Roushan	96.9	13.7	9.1	2.6
Ghods	98.1	14.1	7.5	2.5
Mahdavi	97.6	12.3	4.2	3.1
Corn				
704	96.5	8.2	9.5	4.5
901	97.3	8.2	10.2	4.2
Native	97.8	8.4	11.1	4.5
Millet				
Seteria	97.3	10.2	27.5	5.6
Panicum	96.4	11.5	26.3	5.1
Native	97.8	10.2	26.9	5.2

† Samples were pre-dried, CP: Crude protein, ADF: Acid detergent fiber, EE: Ether extract.

Table 2. *In situ* degradability of wheat, corn and millet.

	A	B	C	EDDM†
DM				
Wheat	8.2^a	80.9^b	27.5^a	74.2^a
Corn	6.5^b	92.8^a	5.4^b	50.7^b
Millet	3.3^c	87.6^a	5.5^b	44.8^c
CP				
Wheat	9.6^a	83.1^b	28.9^a	78.4^a
Corn	5.7^b	74.3^b	5.3^c	39.7^b
Millet	6.4^b	45.7^c	10.2^b	35.1^c

† Effective dry matter degradability

A: Rapidly degraded fraction, B: Potentially degradable fraction, C: Rate of degradation

a,b,c Means in the same column with similar superscript are not significantly different (P>0.05).

by Batajoo and Shaver (2), for wheat (9.6 vs. 31.9%) and corn (5.7 vs. 9.6%), respectively. Tamminga *et al.* (17) reported higher crude protein A fraction values for corn than in the present experiment (9.6 vs. 15%). Variation in this fraction between studies could be due to differences in feed particle size or differences in analytical techniques. In the present study, feeds were ground to 2-mm, which may have contributed to lower soluble fraction observed in some feeds.

The degradable dry matter fraction (B) for all feeds (Table 3) ranged from 71.1 (*Panicum*) to 95.9% (yellow millet) and wheat and corn had the lowest and highest B fraction, respectively (Table 2).

Among the wheat cultivars, Niknejad had the highest (P<0.05) B fraction (84.2%) while Ghods had the lowest one (76.1%). Among the millet cultivars, *Panicum* (71.1%) and *Setaria* (95.9%) had the lowest and highest B fractions (P<0.05), respectively. No significant differences were observed among corn cultivars.

The dry matter degradability for corn (92.8%) was higher (Table 2) than reported values of 80.6% (9), 81.6% (2), 71.8% (3), 73.8% (13) and 70.5% (18).

Crude protein B fraction (Table 2) for millet (45.7%) was significantly lower compared to wheat (83.0%) and corn (74.3%). Significant differences were observed between corn cultivars; corn 704 had a higher B fraction (83.1%) compared to the other two cultivars (Table 4).

Crude protein B fraction value for corn (74.3%) was higher than reported values of 87% (2), 70.5% (18) and 73.6% (13). This value was also higher for wheat (83%) than reported values of 50.5% (18) and 62.8% (13).

Degradation rate of DM (Table 2) was the fastest (P<0.05) for wheat (0.27/h) followed by millet (0.055/h) and corn (0.054/h). Niknejad and Roshan had the lowest (P<0.05) rate compared to other cultivars of wheat. No differences were observed among the millet or corn cultivars. Dry matter degradation rate for wheat was higher than reported values of 0.12/h (4) and 0.12/h (18) but lower than reported value of 0.34/h (13). Dry matter degradation rate for corn was lower than reported values of 0.091/h (7) and 0.067/h (13) but higher than reported values of 0.047/h (4), 0.02/h (18) and 0.041/h (2).

Fastest rate of CP degradation (Table 2) was observed in wheat (0.29/h; P<0.05). Degradation rate was intermediate for millet (0.12/h; P<0.05) and slowest for corn (0.053/h; P<0.05). Rate of degradation was almost similar to the rate of 0.25/h reported by Herrera-Saldana *et al.* (4).

Effective DM and CP degradability was highest in wheat (74.2 and 78.4%; P<0.05), intermediate in corn (50.7 and 39.7%; P<0.05) and the lowest in millet (44.8 and 41.8%; P<0.05). Ghods (71.9%) and corn 901 (46%) had the least effective DM degradability among the wheat and corn cultivars, respectively (Table 3).

Microbial attachment to the feed particles has been shown to underestimate CP degradability in fibrous feeds (8). We did not correct for bacterial N contamination of the bag residue, and this may account for some of the differences between studies in CP degradation. However, Nocek (6) did not find significant differences between N

Table 3. Dry matter degradability of several wheat, corn and millet cultivars.

	A	B	C	EDDM†
Wheat				
Barakat	7.7[abc]	81.3[cd]	31.5[a]	75.9[a]
Mahdavi	8.8[a]	79.2[cd]	29.1[a]	74.6[abc]
Roushan	8.1[ab]	85.4[bc]	21.8[b]	75.1[ab]
Omid	8.8[a]	78.8[cd]	31.8[a]	75.1[ab]
Niknejad	7.2[abcd]	84.2[c]	20.3[b]	72.7[bc]
Ghods	8.4	76.1[de]	30.5[a]	71.9[c]
Corn				
704	6.3[cd]	93.7[a]	6.1[c]	53.5[d]
901	7.1[bcd]	90.9[ab]	4.5[c]	45.9[e]
Native	6.1[d]	93.9[a]	5.6[c]	52.6[d]
Millet				
Seteria	4.7[e]	95.9[a]	4.7[c]	45.4[e]
Panicum	1.7[f]	71.1[e]	8.5[c]	43.9[e]
Native	4.1[e]	94.3[a]	3.9[c]	42.7[e]

a,b,c,d,e,f Means in the same column with similar superscript (s) are not significantly different (P>0.05).

A: Rapidly degraded fraction, B: potentially degradable fraction, C: rate of degradation.

† Effective dry matter degradability.

Table 4. Crude protein degradability of several wheat, corn and millet cultivars.

	A	B	C	EDCP†
Wheat				
Barakat	9.1[c]	83.1[a]	27.8[bc]	77.4[c]
Mahdavi	10.1[b]	82.9[a]	26.9[c]	77.8[bc]
Roushan	7.8[d]	85.2[a]	30.1[a]	78.8[ab]
Omid	10.3[b]	83.3[a]	28.9[ab]	79.3[a]
Niknejad	11.5[a]	81.9[a]	29.9[a]	79.8[a]
Ghods	9.1[c]	81.7[a]	30.1[a]	77.2[c]
Corn				
704	5.8[e]	83.1[a]	4.5[f]	40.9[e]
901	4.7[f]	72.5[b]	4.8[f]	36.2[f]
Native	6.5[e]	67.2[c]	6.7[e]	41.9[d]
Millet				
Seteria	6.7[e]	46.1[d]	10.2[d]	35.7[f]
Panicum	5.8[e]	44.9[d]	10.1[d]	33.9[g]
Native	6.2[e]	45.1[d]	9.3[d]	34.6[f]

† Effective crude protein degradability.

A: Rapidly degraded fraction, B: Potentially degradable fraction, C: Rate of degradation.

a,b,c,d,e,f,g Means in the same column with similar superscript (s) are not significantly different (P>0.05).

disappearance rate constant determined with or without correction for bacterial N contamination.

CONCLUSIONS

Grain cultivars varied in their DM and CP degradation. Variation in ruminal DM degradability can be used to maximize substrate available for microbial growth and protein synthesis or to enhance the intestinal starch supply. Our estimates of the kinetics of ruminal degradation of feeds provide values for use in dynamic models of carbohydrate and protein digestion. However, variation between our estimates and others in the literature was considerable for these feeds. This could be due to inherent differences between feeds (i.e., source of ingredient and particle size) or differences in analytical procedures between laboratories. Routine *in situ* procedures should emphasize on standardization with regard to fineness of grinding, pore size of the bag material and washing procedure, etc.

LITERATURE CITED

1. AOAC, 1980. Association of Official Analytical Chemists. Official Methods of Analysis. 12th ed. Washington, DC., U.S.A.

2. Batajoo, K.K. and R.D. Shaver. 1998. In situ dry matter, crude protein, and starch degradability of selected grains and by-product feeds. Anim. Feed Sci. Tech. 71: 165-176.

3. Cerneau, P. and B. Michalet-Doreaue. 1991. *In situ* starch degradation of different feeds in the rumen. Reprod. Nutr. Dev. 31: 65-74.

4. Herrera-Saldana, R., R. Gomez-Alarcon, M. Torabi and J.T. Huber. 1990. Influence of synchronizing protein and starch degradation in the rumen on nutritive utilization and microbial protein synthesis. J. Dairy Sci. 73: 142-148.

5. National Research Council. 2001. Nutrient Requirements of Dairy Cattle. 6th ed. Natl. Acad. Sci. Washington, DC. U.S.A.

6. Nocek, J.E. 1985. Evaluation of specific variables affecting *in situ* estimates of ruminal dry matter and protein digestion. J. Anim. Sci. 60: 1347-1358.

7. Nocek, J.E. 1987. Characterization of *in situ* dry matter and nitrogen digestion of various corn grain forms. J. Dairy Sci. 70: 2291-2301.

8. Nocek, J.E. and A.L. Grant. 1987. Characterization of *in situ* nitrogen and fiber digestion and bacterial nitrogen contamination of hay crop forages preserved at different dry matter percentages. J. Anim. Sci. 64: 552-564.

9. Nocek, J.E. and J.B. Rusell. 1988. Protein and energy as an integrated system: relationship of ruminal protein and carbohydrate availability to microbial synthesis and milk production. J. Dairy Sci. 71: 2070-2107.

10. Nocek, J.E. and S. Tamminga. 1991. Site of digestion of starch in the gastrointestinal tract of dairy cows and its effect on milk yield and composition. J. Dairy Sci. 74: 3598-3629.

11. Orskov, E.R. 1986. Starch digestion and utilization in ruminants. J. Anim. Sci. 63: 1624-1633.

12. Orskov, E.R. and I. McDonald. 1979. The estimation of protein degradability in the rumen from incubation measurements weighed according to rate of passage. J. Agric. Sci. (Camb.) 92: 499-503.

13. Petit, H.V. and G.T.D. Santos. 1996. Milk yield and composition of dairy cows fed concentrate based on high moisture wheat or high moisture corn. J. Dairy Sci. 79: 2292-2296.

14. Philippeau, C., F. Le Deschault de Monderon and B. Michalet-Doreau. 1999. Relationship between ruminal starch degradation and the physical characteristics of corn grain. J. Anim. Sci. 77: 238-243.

15. Reynolds, C.K., J.D. Sutton and D.E. Beever. 1997. Effects of feeding starch to dairy cattle on nutrient availability and production. In: Recent Advances in Animal Nutrition. P.C. Garnsworthy and J. Wiseman (ed.) Nottingham University Press, Nottingham, 105-134.

16. SAS. 1987. SAS User's Guide, Statistics. Version 6 Edition, SAS Inst., Inc., Cary, NC.

17. Tamminga, S., A.M. van Vuuren, C. J. van der Koelen, R.S. Ketelaar and P.L. van der Togt. 1990. Ruminal behavior of structural carbohydrate, non-structural carbohydrates and crude protein form concentrate ingredients in dairy cows. Neth. J. Agric. Sci. 38: 513-519.

18. Umucalilar, H.D., B. Coskun and N. Gulsen. 2002. *In situ* rumen degradation and *in vitro* gas production of some selected grains from Turkey. J. Anim. Physiol. Anim. Nutr. 86: 288-297.