Nutritional Evaluation of Low-Grade Corn for Ruminants

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ABSTRACT

Two experiments, involving in vitro evaluations and one metabolism study, were conducted to determine the digestibility and utilization of low grade corn (corn that suffered germ discoloration because of respiration damage). Seven samples of corn grain containing various percentages of total kernel damage (TKD) were obtained either from a grain exchange or a grain elevator in the Texas High Plains. Diets evaluated contained: 1) No. 1 grade, 2% TKD; 2) No. 2 grade, 4.8% TKD; 3) No. 5, 11.8% TKD; 4) sample grade (SG), 18.6% TKD; 5) SG, 20.1 % TKD; 6) SG, 41.6% TKD; and 7) SG, 55% TKD. In vitro DM and OM digestibilities and pepsin digestible protein (PDP) did not differ ($P > .05$) among the seven samples. Moreover, the samples were similar in ash, CP, ADF, and starch content and readily available starch. Ether extract values were less (1.5 to 2.2%) than commonly reported for corn and increased ($P < .05$) linearly as TKD increased. In a metabolism study with sheep, four treatments were evaluated: 1) 75% No. 1 grade corn; 2) 37.5% No. 1 and 37.5% SG; 3) 18.75% No. 1 and 56.25% SG; and 4) 75% SG corn. Digestibilities of dietary DM and OM, ADF, and nitrogen (N) as well as retention of dietary N in growing wethers did not differ ($P > .05$) when No. 1 corn was replaced with SG corn. Therefore, SG is a nutritionally viable alternative to No. 1 corn in ruminant diets.

KEY WORDS: Low Grade Corn, Ruminants, Digestibility, Starch Availability

Corn grain is a major source of dietary energy for livestock in the U. S., particularly in growing and finishing diets of beef cattle. Grain for cattle feeding is often purchased from external sources and grain quality is important. The USDA has a grain grading system for standardization and communication of the quality of a particular quantity of grain and in most instances these USDA grades (1978) are used to establish the price paid for a particular lot of grain. In the Texas High Plains, another scale (Southwest Scale of Grain Premiums and Discounts) is used in grain trading (Table 1). The content of total kernel damage (TKD) is one grading factor for which corn grain is discounted under the Southwest Scale. Total kernel damage is a very general category, and although the discount rate changes when the percentage of TKD exceeds 15%, this scale does not reflect the particular type(s) of damage (with the exception of heat damage) within a corn sample.

Germ damaged kernels (GDK), distinguished by a brown to black discoloration of the germ or embryo, are often encountered in improperly stored grain. Kernel damage of this type is frequently the result of excess moisture in stored grain, sufficient to

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promote microbial growth or spontaneous heating (Pomeranz, 1974). Kernels in which only the germs are discolored do not visually seem to be severelydeteriorated. Because this form of damage contributes to the TKD of a corn sample, it often results in the sample being severely discounted.

Table 1. Southwest Scale of Grain Discounts[1].

Item	Discount
Trading basis for No. 2 corn per hundredweight	
Moisture	Moisture reductions are by weight equal to 1.5 times percentage moisture above 15.5%. Deductions for moisture shall be taken from the net weight before other discounts are applied.
Test weight	\$.01 for each lb. or fraction thereof from 53.9 to 50 lbs.; \$.05 for each lb. or fraction thereof below 50 lbs.
Broken kernels & foreign material	\$.02 for each 1% or fraction thereof from 5.1% to 10%; \$.04 for each 1% or fraction thereof from 10.1 to 20%
Heat damage	\$.01 for each 0.1% from 0.3 through 3%.
Total damage	\$.02 for each 1% or fraction thereof from 5.1 to 15.0%; \$.04 for each 1% or fraction thereof from 15.1 to 20%.
Heating	\$.05
Musty*	\$.10
Sour*	\$.10
Weevily*	\$.05

*When grain is musty, sour or weevily, the buyer has option of applying discounts or returning grain to seller at seller's expense.
[1]Premium = \$.15 for No. 1

The actual value of GDK corn as an energy source for ruminants has not been well established. Therefore, these studies were conducted with the following objectives: 1) to determine the chemical composition of GDK low grade corn (LGC); 2) to measure the digestibilities of starch and protein of GDK corn; and 3) to determine the relative in vivo digestibilities of DM, OM, ADF, CP, and N retention by growing wethers fed different levels of sample grade corn (18.6% TDK) by replacement of No. 1 grade corn.

METHODS AND MATERIALS

Experiment 1

For the *in vitro* study, five, 200-g samples of yellow corn were furnished by a grain inspection service in Amarillo, TX. Germ damage (evidenced by germ discoloration) was the only type of damage present in the samples. Broken kernels and foreign material had previously been removed. Test weights were not furnished for each sample; however, the grain inspector stated that all the corn samples had a test weight of approximately 57 lb./bu. All five samples from Amarillo were grown in the Texas Panhandle. One sample of damaged corn (containing 18.6% TKD) was obtained from a grain elevator in Castro County, TX and a sample of No. 1 grade corn from the Texas Tech University Feed Mill also were included in the study. The type of kernel damage present in the two samples graded in Lubbock also was described as germ damage by heat (evidenced by germ discoloration). In addition, the sample from Castro County contained a slight amount of visible mold. The TKD amounts are shown in Table 2.

Table 2. Grade and total kernel damage content of corn grain used in the in vitro experiment[s].

Grain	Total kernel damage, %
No. 1 grade yellow corn	2.0
No. 2 grade yellow corn	4.8
No. 5 grade yellow corn	11.8
Sample grade yellow corn	18.6
Sample grade yellow corn	20.1
Sample grade yellow corn	41.6
Sample grade yellow corn	55.0

[a]Corn was graded according to the Official United States (USDA Standard for Grain, 1978).

Corn samples were ground through a Wiley Mill (Model 4, Arthur Thomas Co., Philadelphia, PA) to pass a 1-mm screen before laboratory analyses. Samples were stored in airtight containers and refrigerated to prevent deterioration. Treatments for in vitro evaluations were arranged in a completely random design and analyzed by analysis of variance. Bartlett's test was used to determine homogeneity of treatment variances (Steel and Torrie, 1980). The effect of increased amounts of TKD on chemical composition and digestibility of corn were determined using orthogonal polynomials (linear and deviations from linearity) according to Steel and Torrie (1980).

Dry matter content of the corn samples was determined by drying samples in a forced-air oven for 48 h at 101°C. Ash, CP (Kjeldahl), pepsin digestible protein (PDP), and ether extract (EE) were determined by official AOAC (1990) methods. A commercial laboratory determined total starch content (SC) and readily available starch (RAS). Acid detergent fiber was determined by the method of Goering and Van Soest (1970).

In vitro dry matter digestibility (IVDMD) and *in vitro* organic matter digestibility (IVOMD) were evaluated in triplicate by the Moore modification of the two-stage Tilley and Terry procedure described by Harris (1970), which was further modified by using 2-g samples and 100-mL buffer:ruminal fluid solution (70:30) in 250-mL centrifuge tubes (Summers and Sherrod, 1976). Ruminal fluid was collected (6 h after feeding) from a steer fitted with a ruminal cannula receiving a cracked corn and cottonseed hull-based diet. Residue contents of each centrifuge tube were filtered through a sintered glass crucible following the pepsin stage of digestion. Residues in crucibles were ashed, and IVOMD was calculated after drying.

Experiment 2

Diets used in a sheep metabolism study contained approximately 75% ground corn, 15% cottonseed hulls, and 10% protein, mineral, and vitamin supplement. Corn in the diets was supplied by different levels of SG corn and No. 1 grade corn as described in Table 3. Composition of the diets and supplements are presented in Tables 4 and 5, respectively.

Eight crossbred wether lambs (initial weight 77 lb.) were paired randomly by weight and allotted to a replicated 4 x 4 Latin square design. Initial pairs were maintained for the duration of the experiment. Lambs were housed in individual crates designed for total fecal and urine collection. The four diets were offered to the lambs during a 14-d adjustment period before collection of feces and urine. Urine, feces, and orts were collected daily over a 7-d period. Ten percent of the urine volume was measured and composited daily. Total daily fecal excretion and orts were collected and stored for subsequent analyses and samples of each diet were taken for further analyses. Before sub-sampling, feces were homogenized in a mixer with distilled water.

Table 3. Grades of corn used in the metabolism study, Experiment 2[a].

U.S. Grade	Test weight (lb./bushel)	Moisture, %	Damaged kernels, (total), %	Broken corn and foreign material, %
No. 1 yellow corn	57	13.3	2.0	1.6
Sample grade yellow corn (musty)	57	10.3	18.6	3.9

[a]Corn was graded according to the Official United States USDA Standard for Grain, 1978.

Table 4. Composition of diets used in the metabolism study, Experiment 2.

	Treatments			
Item	1	2	3	4
Ingredient[a]	-----	%	-----	
Sample grade corn	0	37.34	56.01	74.68
No. 1 grade cor	74.68	37.34	18.67	0
Cottonseed hulls	15.02	15.02	15.02	15.02
Supplement	10.30	10.30	10.30	10.30
Chemical composition	-----	%	-----	
DM	89.52	89.77	89.94	89.87
Ash	3.99	4.08	4.10	4.22
ADF	13.37	12.91	13.55	14.25
CP	13.34	13.38	13.18	13.15

[a] As fed basis.

[b] Percentage of DM, determined

Table 5. Composition of supplement used in the metabolism study, Experiment 2.

Ingredient[a]	%
Cottonseed meal	69.03
Urea (47% N)	7.08
Ammonium sulfate	3.85
Sodium chloride	2.02
Potassium chloride	7.08
Molasses	1.53
Calcium carbonate	9.11
Trace mineral	.20
Vitamin A, D, and E Premix[b]	.10

[a]Dry matter basis.
[b]Premix contained vitamin A 60,000 IU/g, vitamin D 400,000 IU/g, and vitamin E 275 IU/g.

Fecal DM was determined by drying the feces for 72 h at 65°C. Dry matter content of the diets and orts was determined by drying at 101°C for 48 h. Ash and Kjeldahl N were determined according to AOAC (1975) methods. Acid detergent fiber determinations were conducted using the procedure described by Goering and Van Soest (1970). Results for a replicated Latin square were analyzed using analysis of variance and orthogonal polynomials (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Chemical composition of the corn samples is shown in Table 6. Ash values of the seven corn samples (1.2 to 1.47%) are slightly less than the ash content (1.5%) of ground corn reported by the NRC (1982). Ash content of corn samples did not vary ($P > .10$) with increasing levels of TKD.

Table 6. *In vitro* and chemical analyses.

	Treatment[a]							
Item, %[a]	1	2	3	4	5	6	7	SEM
Total damage	2.0	4.8	11.8	18.6	20.1	4.06	55.0	
Dry matter	86.93	86.03	86.59	88.52	87.15	86.41	85.60	
Ash[b]	1.26	1.44	1.28	1.27	1.47	1.23	1.20	.02
Crude protein[b]	8.62	9.59	8.11	8.66	9.39	8.82	8.54	.17
Acid detergent fiber[b]	3.55	3.69	4.09	3.51	3.23	3.21	3.42	.05
Ether extract[b,c]	1.58	1.97	1.64	1.62	1.67	2.21	2.20	.21
Total starch[b]	71.26	69.97	74.77	70.72	69.30	73.72	70.27	.81
Readily available starch[b]	25.70	26.55	22.96	24.02	22.79	24.13	26.37	2.00
Pepsin degradable protein[d]	38.03	39.16	33.07	37.81	35.40	37.70	42.15	.96

[a]1=No. 1 grade corn; 2=No. 2 grade corn; 3=No. 5 grade corn; 4, 5, 6, and 7=sample grade corn with different levels of total damage.
[b]Percentage of dry matter.
[c]Linear effect ($P < .05$).
[d]Percent of total crude protein.

Crude protein values were transformed using an angular transformation before statistical analysis because of heterogeneity of variance (Steel and Torrie, 1980). The untransformed CP values of corn samples are listed in Table 6. The CP content of the samples ranged from 8.11 to 9.59% which was less than the figure of 10% given by NRC (1982). Crude protein did not vary (P > .10) with the level of TKD in corn samples. The PDP (as a percentage of CP) of the corn samples also failed to demonstrate a response (P > .10) due to kernel damage.

Acid detergent fiber content of corn samples did not vary (P > .10) with increasing TKD content. The ADF content of the corn samples used in this study (3.21 to 4.09%) was similar to the ADF value (3.0%) for ground corn reported by the NRC (1982).The EE content increased (P < .05) in a linear fashion as the level of TKD increased. The EE values observed in this study (1.58 to 2.21%) were somewhat lower than the value of 4.3% reported by NRC (1982), and similar to that of Summers and Sherrod (1976), who reported an EE content of 2.4% for SG corn (59% TKD), and Quakenbush et al. (1963), whose results showed a total oil content of corn breeds ranging from 1.2 to 5.7% when extracted with a hexane:acetone mixture.

Total SC of corn samples used in this study (69.3 to 74.77%) was similar to the value of 72% reported by Inglet (1970) and was not affected (P > .10) by TKD content (Table 6).

Table 7 shows the untransformed IVDMD and IVODMD digestibilities of the corn samples. Heterogeneity of variance was detected, and the data were transformed using angular transformation before statistical analyses were conducted (Steel and Torrie, 1980). Neither IVDMD nor IVOMD exhibited a response (P > .10) to TKD content.

Table 7. *In vitro* dry matter (IVDMD) and organic matter (IVOMD) digestibility.

	Treatment[a]						
Item, %	1	2	3	4	5	6	SEM
Total damage	2.0	4.8	11.8	18.6	20.1	41.6	
IVDMD	96.63	98.14	95.19	94.13	96.07	95.00	1.26
IVOMD	97.07	98.00	95.71	94.75	96.47	95.42	1.05

[a]1=No. 1 grade corn; 2=No. 2 grade corn; 3=No. 5 grade corn; 4, 5, 6, and 7=sample grade corn with different levels of total damage.

In vivo digestibility and N retention of the corn diets are shown in Table 8. In vivo DM, OM, ADF, N digestibility and N retention (as a percentage of N intake) did not differ (P > .10) among treatments. However, DM and OM digestibilities tended (P > .10) to vary in a cubic fashion as percentage of TKD increased in the diet. Acid detergent fiber responded to dietary LGC levels in a cubic manner (P = .05). Bolsen et al. (1981) reported that *in vivo* DM and protein digestibility of a diet containing insect-damaged sorghum was not significantly higher than a diet containing either a control (not subjected insect or fungal damage) sorghum or a fungal-damaged sorghum, but was significantly higher than a diet containing 50% control sorghum and 50% fungal damaged sorghum. Furthermore, the digestibility values of the DM and CP in the diets containing either the control or the fungal-damaged sorghum were higher (though not reported as significant) than the diet containing 50% control and 50% fungal-damaged sorghum. Although the increase or decrease of certain digestibilities reported in the present study might not conform to a more logical expected result (linear increase or decrease in response to damage) they do not appear to be unique to this study.

Table 8. *In vivo* digestibles and nitrogen retention of corn diets by lambs in Experiment 2.

Item, %	Treatments[a] 1	2	3	4	SEM
Dry matter digestibility[b]	79.5	77.8	79.5	77.2	.73
Organic matter digestibility[b]	80.2	7.6	80.2	77.9	.74
Acid detergent fiber digestibility[c]	32.1	29.4	37.1	32.7	2.09
Nitrogen digestibility	68.5	67.6	68.9	67.1	.99
Nitrogen retention, g/d	23.0	26.2	25.3	25.0	2.52

[a]1=74.68% No. 1 corn; 2=37.34% sample grade corn and 37.34% No. 1 grade corn; 3=56.01% sample grade corn and 18.67% No. 1 grade corn; 4=74.68% sample grade corn
[b]Cubic trend ($P < .10$).
[c]Cubic effect ($P = .05$).

In this study, neither ash, CP, ADF, nor total SC exhibited a consistent increase or decrease as a reflection of TDK (when damage was in the form of germ discoloration). These findings are partially supported by the data of Lichtenwalner et al. (1979) in which no significant difference was found between weathered or unweathered sorghum grainsin terms of EE, CP, crude fiber, and N-free extract. Values for ash, CP, cell walls and estimated soluble carbohydrate as determined by Summers and Sherrod (1976), did not consistently increase or decrease among corn samples containing various levels of TKD. However, a tendency for EE to decrease as TKD increased was observed. The positive linear relationship between EE and TKD observed in these studies might have been the result of varietal differences in the corn samples examined. The TKD content of the corn samples did not seem to affect IVDMD, IVOMD, SC, or availability of CP in a manner that would suggest this grading factor (when a result of the form of kernel damage present in the corn samples examined) can be used to predict these properties of grain. Corn samples used in this study were likely of different varieties, agronomic background, cultivation, and storage history. The history of corn grain is not always available to the grain purchaser when corn is traded on the basis of grade. The amount of information obtained concerning the background and treatment history of corn used in this study was representative of that commonly furnished when grain is purchased for livestock feed.

Corn samples, in both the in vitro and in vivo studies, with greater levels of TKD, did not necessarily have lower nutritional value than corn samples with less damage. The TKD content did not seem to reflect the in vivo digestibilities nor N utilization of diets containing various levels of damaged corn. This observation, along with results of in vitro digestibilities and chemical composition determinations, suggest that the general grading factor of "TKD" is not a reliable indicator of the nutritional value of corn grain for ruminants. The grading factor of TDK encompasses several different forms of kernel damage, of which only one form was examined in this study.

IMPLICATIONS

The applicability of the results from these in vitro and in vivo studies, using corn grain with germ discoloration and a very small amount of mold, to the nutritional value of corn grain containing other forms of kernel damage is not known. Discounting grain on the basis of TKD, without considering the type(s) of kernel damage present, is unwarranted in terms of nutritional value for ruminants. However, processing qualities coupled with storability are important considerations in determining the relative value of LGC in commercial livestock enterprises. The effect of kernel damage on these grain qualities was not examined in this study.

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