# Nutritional Benefits of Specialty Grain Hybrids in Beef Feedlot Diets

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## ABSTRACT

The study of grain hybrids with faster or more extensive rates of ruminal starch fermentation has been a key research area. Because grain sorghum starch is generally regarded as less accessible to enzymatic degradation than starch in other grains, it has received the greatest research emphasis. However, all grains have been evaluated to some extent. Grain sorghum hybrids appear to be more variable in digestibility, in vitro and in vivo, and in rate of starch fermentation than are corn hybrids. The greater variation may be partially because grain sorghum hybrids are developed and evaluated under more stressful environmental conditions (high temperature and limited water conditions) than are corn hybrids. In vitro and in vivo studies indicate that differences in grain hybrids exist, but these differences may not totally explain differences in cattle performance. The response to feeding high-lysine corn to cattle has been variable. Although high-lysine corn supplies more lysine in the diet, lysine flow to the abomasum was not increased. Hybrids selected for increased lysine content have been shown to have faster in vitro rates of starch digestion, suggesting that improvements in animal performance may be related to the indirect selection for improved energy utilization. In one study in which high-oil corn was evaluated, feed conversion was not improved compared with a control corn diet. At the present time additional studies in which other genetic modifications of grain hybrids are evaluated are in progress, but the results have not been published.



(**Key words**: grain, starch, protein, oil, digestibility, cattle)

**Abbreviation key**: **IVRSD** = in vitro starch disappearance.

## INTRODUCTION

Cereal grains are the primary dietary source of energy and protein for most finishing cattle. Cereal grains may be altered by genetic means to produce modifications in starch, oil, protein, seed coat, or other characteristics. As a result of these genetic modifications, differences in the feeding value of grain hybrids may occur. In some instances, modification of one characteristic, such as starch type, may also affect another characteristic, such as availability of protein. Specialty grain hybrids have received less attention in beef feedlot diets than in nonruminant or dairy diets because of the perception that the specialty grain hybrids have less value in beef feedlot diets. Research that has been published includes evaluation of grains based on differences in digestibility due to endosperm type, rate of ruminal starch fermentation, lysine content, and oil content. The objective of this review is to present and evaluate information from individual research reports on nutritional changes in cereal grains that have occurred because of genetic modifications. Reports summarized include refereed journal articles, abstracts, and university research reports.

## DISCUSSION

### Grain Sorghum: Digestibility

Starch is the major component of cereal grains and is the primary energy source for cattle in feedlots. Grains can be categorized as having different rates and extents of starch fermentation (9). Wheat has the fastest rate of ruminal starch digestion, followed by barley and corn; grain sorghum has the slowest rate of ruminal starch fermentation. Ruminal starch digestion appears to be the key to efficient utilization of grain by ruminants (24). In general, increasing the rate and extent of ruminal starch fermentation has resulted in improvements in efficiency of animal gain provided that the incidence of subacute acidosis was minimized. Therefore, identifying hybrids possessing faster or more extensive rates of starch fermentation has been a key research area.

Because grain sorghum starch is generally regarded as less accessible to enzymatic degradation than starch in other grains (27), it has received the greatest research emphasis. One of the earliest examples of genetic manipulation was the use of tannins in

bird-resistant grain sorghum hybrids to decrease bird deprivation and preharvest mold. Although tannin does decrease losses associated with birds and mold, the bird-resistant hybrids were less digestible than bird-susceptible hybrids (21, 22) and reduced starch digestion in vitro (13, 14, 28). Studies have been conducted with grain sorghum hybrids that varied in endosperm type, endosperm color, and seed coat color. Samford et al. (29) evaluated the effects of endosperm type on ruminal carbohydrate digestion using four abomasally cannulated steers. They characterized four varieties of grain sorghum with similar chemical and physical characteristics except for a difference in endosperm type (floury, normal, corneous, and waxy). Endosperm type was determined by visual observation. A floury endosperm was soft and starchy in appearance, whereas the corneous endosperm was hard and translucent. The normal endosperm type contained corneous material located to the outside of the endosperm enveloping floury material in the center. A variety with approximately equal proportions of floury and corneous material was used to represent the normal endosperm type. A waxy endosperm type had a hard, dense structure and was similar in appearance to the corneous endosperm. Because of a higher content of amylopectin starch, the endosperm appeared glossy, leading to the term waxy endosperm. Ruminal carbohydrate digestibility was estimated based on carbohydrate content of the diet and carbohydrate flow at the abomasum. Diets containing floury and waxy endosperm grains were similar in ruminal carbohydrate digestibility (80.1 vs. 75.0%) and both were higher ($P < 0.05$) in digestibility compared with the diet containing the normal endosperm (68.1%). The diet containing the corneous endosperm was least digestible (48.4%; $P < 0.05$).

Hibberd et al. (13) evaluated nine hybrids of grain sorghum differing in endosperm type (waxy, normal, or floury), seed coat color, and bird resistance, and four corn hybrids. Hybrids were grown in three consecutive years. A wide range in in vitro DM disappearance and in vitro gas production was observed among the grain sorghum hybrids. The variable in vitro results suggest that a wide variation in feeding value among grain sorghums is not strictly caused by endosperm type and may involve other aspects, such as protein solubility or degradability. In a follow-up study (14), purified starch was isolated from the same nine-grain sorghum and four corn hybrids. Isolated waxy starch generally gave higher in vitro gas production than nonwaxy starches. However, small differences in in vitro gas production were observed among the grain sorghum and corn starches, suggesting that factors other than starch was affecting digestibility.

Streeter et al. (32, 33, 34) compared grain sorghum hybrids varying in endosperm type on site and extent of starch and nitrogen digestion. The sites of starch and nitrogen digestion were altered by the hybrids evaluated, but variation appeared to be as large among hybrids with a similar endosperm type as among hybrids varying in endosperm type.

In general, grain sorghum hybrids are grown under more stressful environmental conditions (nonirrigated, higher temperatures, and less fertile soils) than corn. Environmental conditions may interact with grain sorghum hybrids. In addition, harvesting (mechanical vs. hand, stage of maturity) and processing (cleaning, grinding) methods of grain samples likely are important considerations. All of these factors need to be controlled if accurate evaluation of hybrids is to be made.

As a result of the differences in endosperm types, protein:starch matrix, environmental conditions under which grain sorghum hybrids are grown, and method of harvesting and processing grain samples, evaluating one or two hybrids that represent an entire population is probably not adequate. In addition, the laboratory technique used to evaluate the hybrids must be able to predict or estimate differences in finishing cattle performance. Wester et al. (36) evaluated 48 commercial grain sorghum hybrids on the basis of in vitro starch disappearance (**IVRSD**) and starch content. Hybrids were grown under similar, nonirrigated conditions over 2 yr, harvested by hand, and cleaned by hand to remove broken kernels and foreign material. Although hybrid IVRSD was affected by year and replication, there was no hybrid-by-year interaction. Significant replication variation suggests that IVRSD values should not be taken as absolute, but rather as relative values leading to the ranking of grain hybrids. Starch content ranged from 64.3 to 70.3% ($P < 0.01$), and IVRSD ranged from 5.2 to 6.3%/h ($P < 0.01$). In the next year, 20 experimental grain sorghum hybrids consisting of 17 hybrids being developed for livestock diets and three for human diets were ranked according to IVRSD, starch content, and CP content. In these samples, IVRSD varied from 6.0 to 9.1%/h. Starch content and CP were not correlated to IVRSD. Starch content was not correlated to CP content. Seed coat color (cream and bronze) was not related to starch content, IVRSD, or CP content. Three genetically similar hybrids differing in genes for amylopectin content were also evaluated. A waxy hybrid had the fastest IVRSD value, whereas the nonwaxy had the slowest IVRSD, and

the heterowaxy IVRSD was intermediate. To validate the IVRSD technique, we selected four grain sorghum hybrids from the original 48 hybrids (two hybrids from the fast IVRSD group and two hybrids from the slow IVRSD group) and fed them to finishing cattle. Gain:feed and IVRSD were highly correlated ($R^2$ = 0.94). The in vitro rate of starch disappearance appears to be a valid indicator of differences in nutritional value of grain sorghum hybrids. However, the IVRSD technique requires ruminally cannulated animals and is very labor intensive. Richards et al. (26) evaluated modifications of the IVRSD technique. They noted that grinder, grind size, and ruminal fluid inoculum:artificial saliva ratios affected rate of starch disappearance. The diet of ruminal fluid donor affected the rate of starch disappearance, but not the relative ranking of the grains. Thus, if rates are to be compared across in vitro runs, these processing and dietary facts must be kept constant.

Rooney and Pflugfelder (27) indicated that the endosperm protein matrix must be disrupted if sorghum-feeding potential is to be realized. Thus, protein digestibility may be a potential measure of starch utilization in ruminants. Bramel-Cox et al. (7) conducted a 2- and 5-yr location evaluation of 100 $S_1$ families for grain yield, protein concentration, in vitro protein digestibility, and bloom date. Their objective was to determine the potential of selecting for improved protein digestibility in a random-mated population of grain sorghum on various criteria including grain yield. Phenotypic correlations indicated a negative relationship between protein digestibility and grain yield ($P < 0.01$) or protein content, and a positive relationship between protein digestibility and bloom date. Selection for improved protein digestibility was possible, but resulted in families with lower grain yields and increased maturity. Thus, selection for a single trait did not identify high yielding, high protein digestible families.

These data illustrate that variability exists in commercially available grain sorghum hybrids and hybrids with superior feed value can be identified. Current laboratory techniques, such as in vitro starch disappearance, gas production, or protein digestibility, may provide results that relate to animal performance, but the techniques are very labor intensive. Some of the similarity observed among hybrids may be the result of close genetic relationship. Parental cultivar crosses of commercial hybrids are not publicly known and there may be, in fact, only a small number of parental cultivars actually used in commercial hybrid production. In addition, many commercial grain sorghum hybrids are available for only a few years. By the time the superior hybrids are identified, they may not be available in the market. Therefore, it appears that evaluation of commercial hybrids may be a futile effort and the focus of evaluation should be placed on the parental cultivars if improvements in feed quality are to be made. Probably, grain yield, drought, and heat tolerance cannot be sacrificed to produce grains that have higher nutritional value for feedlot cattle. Thus, selection will likely be the result of selecting for several factors that may not be positively related.

### Corn: Digestibility

Ladely et al. (19) conducted two trials to evaluate three different corn hybrids selected on the basis of IVRSD and grown under irrigation. Hybrids were fed as dry rolled or as early harvested, high-moisture corn to finishing cattle. Processing of grains affected IVRSD and cattle performance to a greater extent than differences among the grain hybrids. Differences in IVRSD among the hybrids were smaller in yr 2, which indicates that environmental factors may have influenced the feeding value of corn hybrids. The IVRSD of the grain hybrids was correlated with gain: feed for both trials ($r = 0.76$, $r^2 = 0.58$, $P < 0.001$). Differences in IVRSD among the corn hybrids were smaller than differences among grain sorghum hybrids reported by Wester et al. (1992). Potential reasons include a smaller sampling of hybrids within the corn population, potentially less genetic variation among corn hybrids, less stressful environmental conditions (corn was produced under irrigation conditions), different growing seasons, or a combination of these factors.

Because a waxy endosperm has been shown to improve digestibility of grain sorghum hybrids, a similar response might be expected to occur with corn hybrids. However, results have been conflicting as to the beneficial effects of feeding waxy corn. Braman et al. (36) reported an interaction between the type of corn fed and the source of supplemental protein. Yearling steers fed waxy corn and supplemented with soybean meal gained faster and more efficiently than steers fed waxy corn supplemented with a combination of soybean meal and urea or steers fed normal corn supplemented with either soybean meal or soybean meal and urea ($P < 0.05$). Johnston and Anderson (17) observed increased daily gain, higher DM intakes, and improved feed conversion of receiving calves during the initial 40 d in the feedlot when waxy corn was fed compared with feeding nonwaxy corn ($P < 0.05$). However, Farlin and McCormick

(10), Brady and Farlin (5), and Johnston and Anderson (16) observed no improvement in finishing performance when waxy corn was fed. Because corn is digested to a greater extent than grain sorghum, the waxy endosperm in corn hybrids may have less effect on improving feed conversion of feedlot cattle than the waxy endosperm in grain sorghum. However, the amount of data evaluating waxy corn is limited.

### Corn: High-Lysine

The major source of dietary protein in finishing diets is grain, which supplies 50 to 60% of the dietary protein. Grain protein is also a major source of metabolizable protein. In general, grains are high in methionine but low in lysine. Although microbial protein is a good source of lysine, lysine is still considered to be one of the first limiting AA in finishing diets. Increasing the lysine content of grains may be one possibility of meeting this need. Nelson et al. (23) and Slabbert et al. (30) observed increased daily gains and feed efficiency for steers fed high-lysine corn, whereas Thomas et al. (35) observed lower gains and similar feed efficiencies for steers fed high-lysine corn. Stock et al. (31) and Ladely et al. (20) reported that feed efficiency was improved with finishing cattle fed high-lysine corn compared to control corn. Ladely et al. (20) supplemented both the control and high-lysine corn diets with urea, blood meal and urea, or corn gluten meal and urea. They observed no effects on finishing performance caused by the source of supplemental protein, suggesting that the high-lysine corn was not supplying more escape lysine than the control corn or that neither lysine nor methionine was first limiting. Using abomasally cannulated steers, Redd et al. (25) attempted to quantify the amount of AA reaching the abomasum when steers were fed normal or high-lysine corn. Although the high-lysine corn diet was higher in CP and higher in AA concentration, total AA flow and flow of lysine at the abomasum were not different. The percentage of dietary N reaching the abomasum was smaller for the high-lysine corn, which suggests that it was more soluble or degraded to a greater extent in the rumen compared to the normal corn. Ladely et al. (20) evaluated both the control and high-lysine corns with the IVRSD procedures of Wester et al. (36) and the in situ rate of starch disappearance. Both IVRSD and the in situ rate of starch disappearance were faster for the high-lysine corn. In a metabolism study, ruminal starch digestibility was numerically increased for the high-lysine corn, and total tract starch digestion was significantly increased. All corn fed in the trials of Ladely et al. (20) was grown under similar agronomic conditions and was from similar genetic parentage. These data indicate that the improved feed efficiency observed with the feeding of high-lysine corn was likely not caused by escape lysine but was the result of improved energy utilization. These data also indicate that genetic modification of one trait may have ramifications for other grain characteristics.

### Corn: High-Oil

Recently, high-oil corn has received a large amount of attention especially with nonruminants. Because many feedlots typically feed a supplemental fat source, high-oil corn may have additional value for finishing cattle. Andrae et al. (1) fed dietary treatments containing: 1) 82% control corn, 12% silage; 2) 82% high-oil corn, 12% silage; or 3) 74% high-oil corn, 20% silage (formulated to be isocaloric to the control diet). The lipid content of control and high-oil corn was 4.9 and 7.0%, respectively. Dry matter intake was significantly greater and daily gain was numerically higher for the control corn. Feed efficiency was not different among the treatments. Marbling scores of the carcasses were higher ($P < 0.05$) for the high-oil corn treatment (#2). In yearling steers, improvements in feed efficiency due to the addition of different fat sources and amounts of supplemental fat to dry corn diets has been variable (15, 18). Corn typically contains more lipid (1 to 1.5%) than other cereal grains. Perhaps, yearling steers fed dry-rolled corn diets and having high feed intakes simply are consuming enough lipid to meet their metabolic needs. However, the effect of high-oil corn is not well documented. Currently, several universities are evaluating high-oil corn hybrids, but their results have not been published yet.

### Other Grains

Varieties of wheat (8, 11, 12) and barley (2, 3, 4, 37) have been evaluated on a limited basis. Commercial varieties have been evaluated to determine effects on finishing performance and in vivo digestion. However, most of the focus has been on determining the feeding value of current commercial varieties. Attention to the development of new hybrids that have improved feeding value for finishing cattle has not been attempted.

## IMPLICATIONS

Specialty grain hybrids will be developed that have added value. However, most of the grain produced

today is traded as a commodity. In a commodity driven market, it is very difficult for a product to be rewarded for having added value. For livestock-production units to use a specialty grain hybrid, they must have rapid, inexpensive, reliable techniques and equipment to determine and ensure a hybrid's nutritional value. These techniques are available to predict specific chemical components such as starch, oil, protein, and lysine content, but they are far less reliable for predicting energy value or ease of mechanical processing. Specialty grain hybrids that have improved energy or processing value will need to be marketed as branded products. To ensure acceptability and confidence by the customer, product sales must be supported by independent research and by a strong commitment to customer service.

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