CORN HYBRID BY PROCESSING METHOD CONSIDERATIONS

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SUMMARY

The nutritional value of corn grain is influenced by numerous factors. These included the growing conditions, storage and handling, processing techniques and genetics. Corn hybrids differ in both physical and chemical characteristics that can influence feed value. Nutrient content and availability are influenced by both physical and chemical differences that are discussed throughout these Proceedings. The most important chemical factor that impacts the feeding value of corn grain is the amount and type of starch in the kernels. Commercial corn hybrids differ in the proportion of vitreous and floury endosperm; this is related directly to rate and degree of starch availability of the raw grain. Vitreous starch granules are highly compact being embedded in a protein matrix with a high amount of zein protein. Zein protein, being resistant to ruminal microbial digestion, reduces accessibility of the starch contained in these cells (McAllister 1993). More extensive processing such as steam flaking or high moisture ensiling will minimize hybrid differences largely due to disruption of this protein matrix and allow greater access of starch to microbial and enzymatic digestion. Studies conducted by several researchers indicate the presence of an interaction between hybrid starch type and processing method in determining their feeding value (Owens, 2002; Harrelson et al., 2006; Macken et al., 2003; Szazs et al., 2006). Soft-textured hybrids, because they have more floury endosperm generally have greater feeding value than the harder textured, more vitreous endosperm hybrids when fed as dry rolled grain. However, no difference is apparent when the grain is steam flaked or fed as ensiled high moisture corn.

Physical characteristics also are related to the feeding value of corn hybrids. Absolute density, determined by fluid displacement and measured as grams per ml, is highly correlated with the degree of vitreousness; thus it can be used to predict feed value for grain fed as dry rolled corn (Phillippeau et al., 1999; Correa et al., 2002; Jaeger et al., 2004). Bulk density (test weight usually measured as pounds per bushel or kg per hl) is a poor predictor of the feeding value of dry rolled corn because both kernel size and kernel density influences bulk density. Kernel weight (mg/kernel) appears more reliable and can be determined easily by weighing a representative number of kernels (generally greater than 100). Kernel weight is correlated positively with feed efficiency for corn fed as dry rolled corn. This has several potential reasons. Small kernels often have a thicker pericarp layer, usually are richer in protein and fiber and thereby lower in starch, often have more vitreous starch, and, due to their small size, they may escape processing if the roll gap is not very narrow. Larger kernels with high density are preferred for steam flaking because they produce durable flakes with less fines and faster grain flow through the flaker than soft textured hybrids (Owens Personal Communication). Pioneer and Nebraska research both indicate that the difference among hybrids in total tract starch digestion is very small after flaking and starch digestibility approaches 100%. However, the site of starch digestion still can vary considerably. Hybrids with a higher density appear to have greater percentage of their starch digested post-ruminally than softer textured hybrids. When selecting hybrids for high moisture ensiling, kernel size and texture appears unimportant if the grain is ensiled above 28% moisture (Szasz et al., 2006). During the ensiling process much of the protein is solublized and starch availability increases. However, as with dry rolling, large kernels are preferred when rolling high moisture corn to assure that all kernels are adequately processed.

Research has shown hybrids differ in feeding value and that differences are largest when the grain is minimally processed. As feed costs increase and feeders face greater competition from industrial processors, economics will make maximum feed efficiency and low processing cost even more. Selecting corn hybrids that have high yields and are nutritionally suited for the operation can help livestock producers stay competitive. Operations that can grow, store and feed their own grain are ideally suited to capitalize on a deeper understanding of the nutritional differences between corn hybrids.

BACKGROUND

Corn grain is a commodity traditionally graded and traded on rather ambiguous quality standards including test weight, kernel damage and foreign material. Yield and agronomics have been the primary drivers for hybrid selection by farmers, and nearly all the recent biotechnology developments have focused on insect protection, herbicide resistance, and drought tolerance. With the exception of food corn, plant breeders have given little attention to the end-use value of corn grain.

Seed companies now are beginning to characterize their corn hybrids for such traits as high extractable starch (HES) for the wet milling industry, high total fermentables (HTF) for the ethanol industry, and high available energy (HAE) for non-ruminant feeds. The development of NIR calibrations that permits rapid and cost effective screening of corn hybrids for these traits has allowed end-users to quantify value and thereby improve productivity or efficiency in their operations (Haefele et al., 2004).

Ruminant animals currently consume an estimated 1 billion bushel of grain in the U.S.; this is approximately 19% of the total U.S. production. In addition, ruminants consume the majority of the grain byproducts produced by industries. To date, no NIR calibrations for estimating metabolizable energy or the net energy value of corn grain for ruminants have been released. The complexity of the ruminant digestive system and the multitude of processing techniques utilized in ruminant diets have prolonged the development of rapid assay technology to estimate the true feeding value of corn grain for this use.

This paper will review the chemical and physical factors that can influence feeding value of different corn hybrids and illustrate the need for greater characterization of corn hybrids in order to optimize the feeding value of corn grain for ruminants.

NUTRIENT COMPOSITION

The nutrient composition of corn grain is determined largely by the relative proportions of different kernel parts. Figure 1 illustrates the corn kernel anatomy. The largest portion of the kernel, the endosperm, normally represents between 80 to 85% of the total mass of the kernel. The endosperm is composed primarily of starch (80 to 85%). There are two types of starch in the endosperm. The vitreous or horneous endosperm is the dark yellow fraction located on sides of the kernel that sometimes is called the grit. As shown in the electron microscope picture in the upper right of Figure 1, vitreous starch is highly compacted in honey comb-shaped cells and embedded in a protein matrix. The floury endosperm located near the center of the kernel is more opaque in color. The starch granules contained in the floury endosperm shown in the upper left in Figure 1 are large spherical granules that are loosely organized and not embedded in a protein matrix. The proportion of vitreous to floury endosperm varies between hybrids being influenced largely by amount of flint genetics in the parental lines. Flint grains, grown mostly in Europe and South America, contain a much higher proportion of vitreous starch than the dent genetics typically grown in North America. Within the US, the shorter season corn hybrids tend to have a greater proportion of vitreous endosperm than fuller season hybrids presumably due to a heritage that is predominately from Northern Europe.

The germ or embryo located near the tip to the kernel typically represents 10 to 12% of the total kernel mass. With over 30% oil, the germ provides nearly all of the oil in the kernel. Hybrids with a larger proportion of germ have higher oil content. The germ also contains approximately 20% protein; richer in lysine and tryptophan, this protein has greater nutritional value than protein from the endosperm.

The pericarp, also sometimes called the bran, is the layer of cells that cover the outside of the kernel; typically the pericarp represents less than 5% of the total kernel mass. However, paricarp thickness varies among hybrids and appears associated with the rate that corn will lose moisture as it matures. Low test weight corn usually has a thinner paricarp layer than high test weight corn. The primary defense against insect and fungal damage to the kernel, the pericarp and is composed mainly of NDF. Thus hybrids having thicker paricarp or a greater proportion of paricarp will tend to have higher NDF content. Because shape and size will influence the ratio of surface to volume, larger and more circular kernels have less percentage of pericarp and less NDF than smaller, more irregular kernels.

The hilum or tip cap attaches the kernel to the cob that is the point of black layering. The black layer consists of several cell layers that collapse during grain maturation. Once these cells have collapsed, nutrient translocation to the kernel will cease. Representing less than 1% of the total kernel mass, the hilum is composed mainly of NDF.

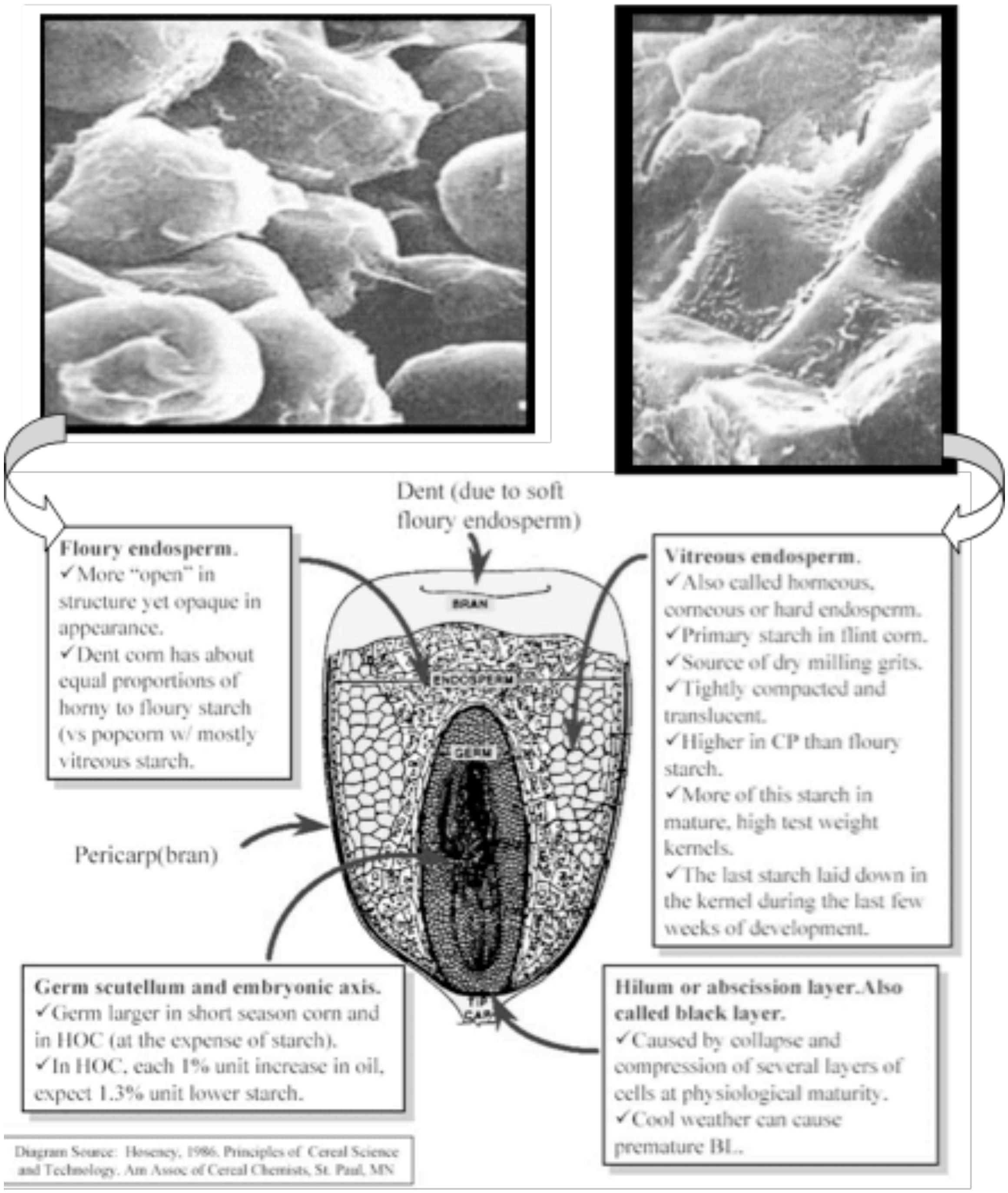


Figure 1. Diagram with electron microscope illustrations.

The nutrient composition for corn grain is discussed in detail by other authors in these proceedings. In general, corn hybrids with a higher percentage of starch will have less protein and oil.

Figure 2 shows Pioneer starch, protein and oil data form nearly 30,000 samples across 306 commercial Pioneer corn hybrids. Starch content ranged from 70.5 to 73.0% with a mean of 71.8% and a standard deviation of .43%. Crude protein ranged from 8.2 to 10.4% with a mean of 9.25% and a standard deviation of .43%. Protein and starch content across hybrids were negatively correlated ($R^2 = 0.3955$). Oil content ranged from 3.5 to 4.6% with a mean of 3.92% and a standard deviation of .22%. Oil was negatively correlated with starch (R^2=0.19). These data support the concepts that as the proportion of endosperm within a hybrid increases, the proportion of germ declines as the reciprocal. However, compositional changes associated with genetic differences across hybrids may differ those attributed to environmental or maturity factors.

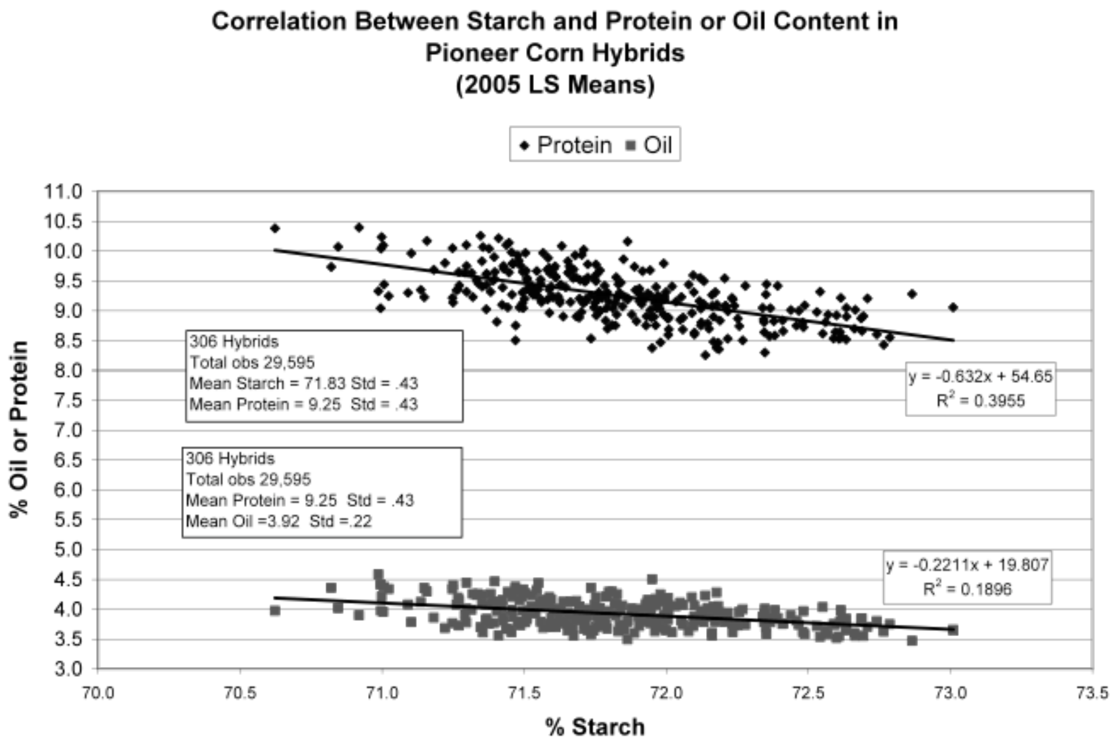


Figure 2. Correlation between starch and protein or oil content in Pioneer corn hybrids. (2005 LS means).

To examine seasonal effects, the impact of year on composition of shelled corn, flaked corn, high moisture corn grain, and high moisture ear corn, analyses of commercial corn samples were examined using information from the Dairy One Forage Lab (2007). Effects of year on the sample was analyzed (mean of samples from May through April of the years 2000 through 2006) on nutrient compositions as well as effects of form were examined simultaneously. Year effects were detected for crude protein (higher in 2001 and 2002 than thereafter, perhaps due to differences in N fertilization), NDF [highest in 2000 and linearly decreasing ($P < 0.05$ since)], and phosphorus content [lowest in 2005 with a tendency to decrease ($P < 0.10$) over time)]. Within each forms of corn, standard deviations were provided. For comparing means (dry matter basis) and standard deviations among forms, each year was considered to be a replicate. Means for are shown in Tables 1 and 2.

As expected, DM content was lower and variability was greater for high moisture corn grain and high moisture ear corn than for shelled and flaked corn. Crude protein was lower for flaked and high moisture corn grain with the highest variation in crude protein being for shelled corn. Fermented products had a higher fraction of the crude protein in a buffer soluble form. Flaking decreased protein solubility as expected from denaturation of protein by heat. Due to presence of the cob and possibly some husk, high moisture ear corn contained more NDF and ADF than shelled or flaked corn; these did not differ in NDF or ADF. However, NDF content was greater for high moisture corn than for flaked corn samples.

Table 1. Dry matter, protein, soluble protein, ADF, and NDF means and standard deviations for corn harvested or processed by different methods*

Form	DM	DM(SD)	CP	CP(SD)	SolCP	(SCPSD)	ADF	ADF(SD)	NDF	NDF(SD)
Shelled	89.4[a]	2.58[c]	9.31[a]	1.48[a]	20.3[c]	5.44[c]	3.49[b]	1.44[b]	9.84[bc]	3.13[b]
Flaked	88.0[a]	2.00[c]	8.38[b]	0.78[b]	11.4[b]	6.64[c]	3.62[b]	0.99[b]	9.18[c]	1.89[c]
HMC	71.8[b]	6.35[b]	9.15[a]	0.82[b]	30.7[b]	11.35[b]	3.56[b]	1.17[b]	10.3[b]	2.25[c]
EARHMC	64.5[c]	7.51[a]	8.42[b]	0.93[b]	36.5[a]	14.34[a]	9.27[a]	3.64[a]	20.7[a]	6.63[a]

*DM, dry matter; SD, standard deviation; CP, crude protein; SolCP, soluble CP; ADF, acid detergent fiber; NDF, neutral detergent fiber; SD, standard deviation; HMC, high moisture corn; EARHMC, high moisture ear corn.
[a,b,c]Means with different superscripts within a column are different ($P < 0.05$).

Table 2. Starch, fat, and phosphorus means and standard deviations for corn harvested or processed by different methods*

Form	Starch	Starch(SD)	Fat	Fat(SD)	Phosphorus	Phosphorus(SD)
Shelled	70.5[b]	4.25[b]	4.37[a]	1.33[a]	0.32[a]	0.10[a]
Flaked	72.2[a]	3.91[b]	3.95[ab]	1.66[a]	0.24[c]	0.08[a]
HMC	70.1[b]	3.08[b]	4.15[ab]	0.59[b]	0.32[a]	0.03[b]
EARHMC	59.3[c]	6.91[a]	3.70[b]	0.51[b]	0.30[b]	0.03[b]

*SD; standard deviation; HMC, high moisture corn; EARHMC, high moisture ear corn.
[a,b,c]Means with different superscripts within a column are different ($P < 0.05$).

Starch, fat, and phosphorus contents were lowest and starch content was most variable for high moisture ear corn due to dilution of grain with differing amounts of cob. However, starch content was greater and phosphorus content was lower for flaked than for shelled and high moisture corn grain. The higher starch and lower protein, fat, and phosphorus content of flaked than of shelled or high moisture corn might reflect differences in sample origin (and hybrid) or loss of fine particles during field sampling of flaked grain. On a percentage basis when compared with shelled corn, flaking increased starch by 2.4% and this alone cannot explain the 7% decrease in NDF, the 10% decrease in protein and fat, and the 25% decrease in phosphorus content. Variation in phosphorus content was lower for wet products, perhaps due to phytase degradation during storage increasing extractability of the starch.

Stepwise regression revealed that starch content across sample types and across years was driven primarily ($R^2 = 0.97$) by NDF content, with starch decreasing by 1.1% for each 1% increase in NDF. Even when high moisture ear corn was removed from the data set, NDF remained the factor most closely related to starch (R2 = 0.54). Compared with cleaned grain from hybrids discussed above, commercial grain samples are more likely to be diluted with foreign matter that would be rich in NDF. This may explain the difference in relationships of components of cleaned hybrid corn and commercial samples of corn grain.

Monthly information also is available for samples analyzed at Dairy One (Dairy One Forage Laboratory, 2007). Using only samples from New York state, solubility of protein is plotted for samples analyzed different months from grain presumably harvested from 2002 through 2006 breaking the harvest season at September (Figure 3). Solubility of protein was consistently lowest in November when new crop samples would be predominant. Thereafter, protein solubility increased reaching a peak in August or September that should represent grain that had fermented for a longer time period. High soluble protein and increases in protein solubility with high moisture corn over time have been noted by Thornton (1976), Prigge et al. (1976), and Benton et al. (2005). If starch availability increases with protein solubility, the rate and extent of ruminal digestion must be increasing markedly during storage of high moisture corn. This may require re-formulation of diets to avoid acidosis.

Similar means for solubility of protein from corn silage are shown in Figure 4. In contrast with high moisture corn, solubility increased for 4 to 5 months and remained relatively stable thereafter. Consequently, once corn silage has been stored for several months, it should be more consistent as a feed ingredient than high moisture corn is.

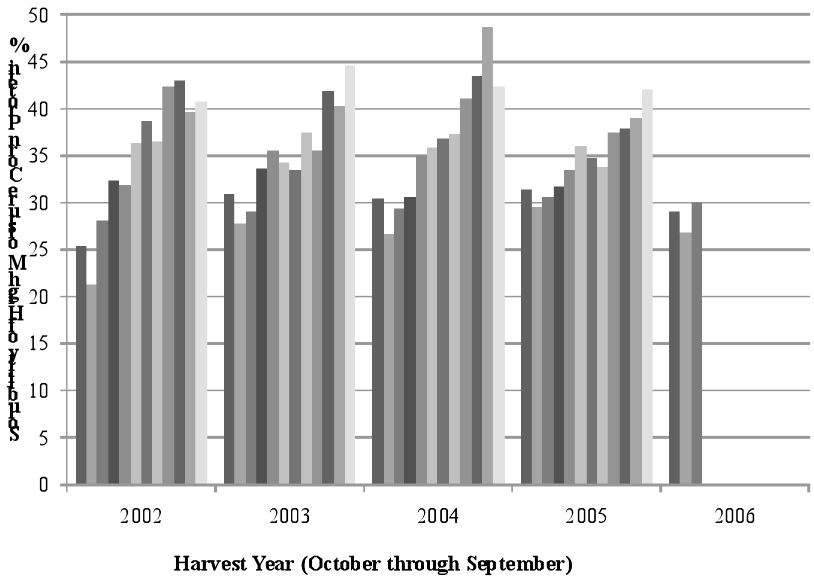


Figure 3. Solubility of protein in high moisture corn samples from New York analyzed each month at Dairy One (Dairy One Forage Lab, 2007).

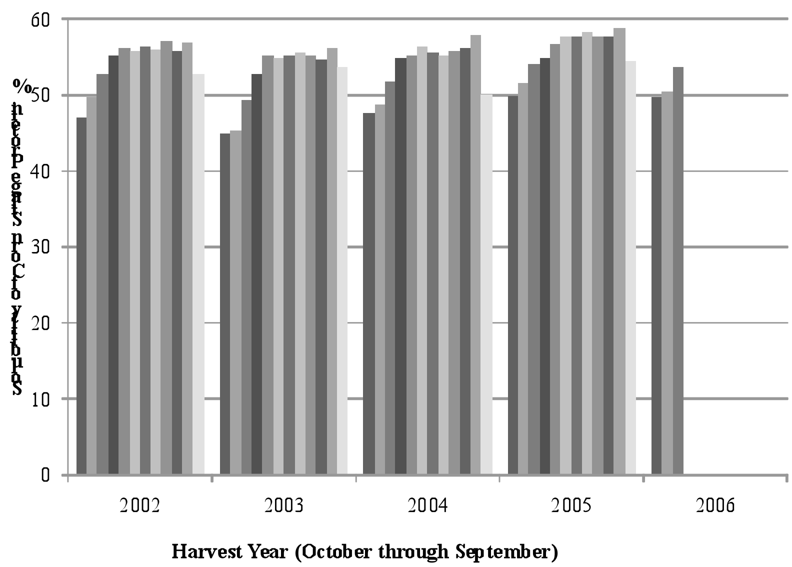


Figure 4. Solubility of protein in high moisture corn samples from New York analyzed each month at Dairy One (Dairy One Forage Lab, 2007).

STARCH TYPE AND STRUCTURE

Two primary starch polymers are found in corn. Amylose, a straight chain polymer of glucose units, usually comprises between 24 to 30% of the total starch in yellow dent corn while amylopectin, a branched polymer makes up the remaining 70 to 76% of the total starch (Owens, 2005). The amylose:amylopectin ratio generally increases with increasing maturity and may be greater in floury than vitreous starch (Owens, 2005). Due to the high degree of branching, amylopectin is more susceptible to enzyme hydrolysis than amylose; thus corn hybrids having higher proportion of amylopectin may have greater ruminal starch digestion. However, steer feeding trials evaluating waxy corn; which typically contains 98% amylopectin, have shown inconsistent response in improving animal performance. Waxy corn has generally shown a positive response in ADG and feed efficiency when fed in dry rolled or whole corn diets but shown no advantage when fed in steam flaked diets (Owens and Zinn, 2005).

Several research studies have shown that corn grain samples containing a greater proportion of vitreous to floury endosperm has lower *in situ* starch digestion when dry rolled (Correa et al., 2002, Philippeau 1997). Greater *in situ* disappearance of floury hybrids has led to the suggestion that extent of ruminal digestion will be greater for a floury than a vitreous hybrid when the grain is fed dry rolled. This concept was verified with dry rolled corn fed to steers by Jaeger et al., 2004; they observed that hybrids with more floury starch produced the best gain efficiency (r = 0.83).

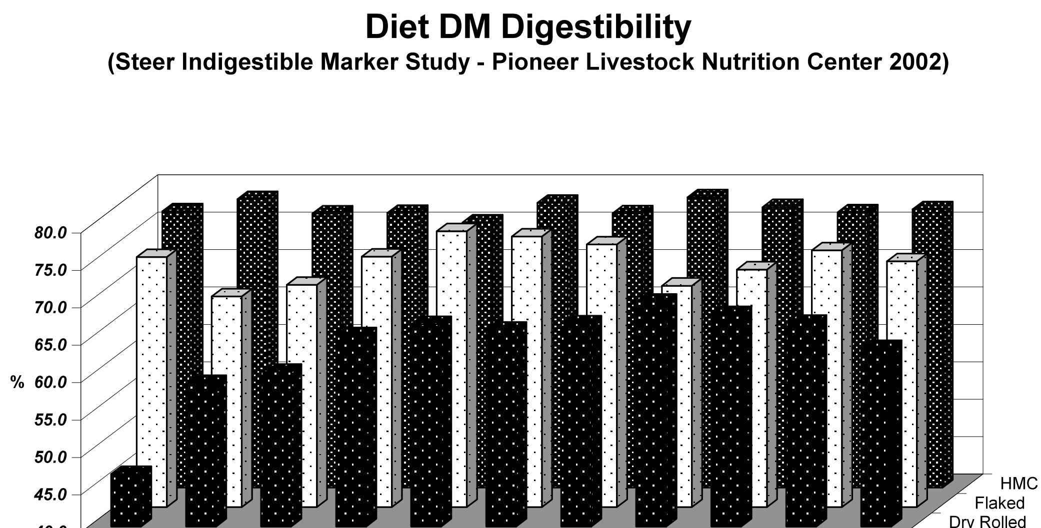
However, close examination of Dacron bag disappearance curves from in situ studies reveals that virtually all of the increased in situ loss for the floury hybrids is lost even before fermentation begins (wash loss). Indeed, floury hybrids when dry and ground, generate more fine particles during grinding, and fine particles readily escape through pores in Dacron bags. The nutritional merit of fine particles may vary depending on the diet. Higher total tract digestibility of small versus large particles should be beneficial, and some fine and dense particles will be flushed rapidly through the rumen with fluids to increase the starch supply to the intestines. However, because small particles are fermented very rapidly in the rumen, fine particles from the floury endosperm may also increase the risk of acidosis. Unfortunately, particle size alone, without knowledge of composition, can prove misleading. Fine particles generated during steam flaking, originating from selective removal of the germ, are likely to be rich in oil and protein. In contrast, fine particles generated during dry milling or over mixing of grain are more likely to be rich in starch and would have greater potential to cause acidosis.

KERNEL PHYSICAL CHARACTERISTICS

Kernels from corn hybrids that differ genetically will vary considerably in their kernel size, density, shape and texture. Test weight (bulk density) of commercial hybrids typically ranges from 53 to 63 lb per bushel, absolute density as measured by a pycnometer will range from 1.2 to 1.4 g/cc and kernel weight will range from 250 to 450 mg. Several studies have assessed the relationship of physical properties of kernels to digestibility of these same corn grain samples. It is not appropriate to consider such measurements as being representative of a specific hybrid because numerous environmental and harvest factors also can influence these physical measurements except to appraise differences associated with types of grain that have extreme differences (flinty, floury, waxy, etc.). Philippeau et al., (1999) reported that ruminal starch degradability of dry rolled grain was highly correlated to the degree of vitreousness (r^2 =0.89) and vitreousness could be predicted by combining absolute density with 1000 kernel weight (r^2=0.91). Owens (2002) noted that absolute density of the whole kernel was highly correlated (r^2=0.79) to 18 hr in situ DM disappearance for dry rolled corn. Jaeger et al. (2004) also found that 1000 kernel weight, Stenvert time to grind, and Stenvert proportion of soft to coarse particle all were highly correlated to feed efficiency when evaluating samples of seven different dry rolled corn hybrids. However, in more recent study conducted by Harrelson et al., (2006) who evaluated seventy-two commercial corn hybrids, test weight was the only kernel trait that related to in situ DM disappearance (P = 0.07) and even there, the relationship was weak (r = 0.04). Contrary to previous results reported by Jaeger et al. (2004), the relationship between the percent Stenvert soft particles in the kernels and in situ DM disappearance was weak and not significant (P = 0.27).

PROCESSING INTERACTIONS

Although hybrid texture and density have been shown to be negatively correlated to in situ digestibility and cattle performance when fed as dry rolled corn, this relationship does not hold true for grain that is processed more extensively, e.g., steam flaked and high moisture corn. Owens (2002) evaluated samples of 10 different commercial Pioneer hybrids all having a large sales volume fed as either dry rolled, steam flaked, or high moisture corn to steers in a digestion trial (Figure 5). Diet DM digestion was significantly ($P < 0.05$) altered by processing methods with a significant ($P < 0.01$) processing by hybrid interaction noted. Across hybrids, diet digestibility was slightly greater for high moisture than flaked corn, and much greater for flaked than dry rolled corn. However, the advantage to processing differed among hybrids. Hybrids with a softer texture tended to have higher digestibility than more vitreous hybrids when fed dry rolled whereas compared with softer hybrids, harder textured hybrids tended to have the greatest digestibility when the grain was steam flaked. No single hybrid was best for all processing methods. A similar hybrid by processing interaction was reported by Harrelson et al. (2006) who compared 12 Golden Harvest corn hybrids that were either dry rolled or steam flaked.



	A	B	C	D	E	F	G	H	I	J	Mean
Dry Rolled	47.0	59.2	60.7	65.6	67.0	66.3	67.1	70.0	68.4	67.2	63.8[c]
Flaked	73.4	68.2	69.7	73.5	76.9	76.2	75.1	69.6	71.7	74.3	72.8[b]
HMC	76.9	78.5	76.6	76.7	75.4	78.1	76.7	78.8	77.5	76.8	77.2[a]

Hybrid

Figure 5. Diet DM Digestibility.

Owens (2002) also noted that when being flaked, hybrids that were floury generated fragile flakes, more fine particles, and tended to flake less rapidly at the same flaker settings than more vitreous hybrids. He noted with dry rolled corn diets, most of the difference in digestibility between samples of hybrids could be explained by the differences in total tract starch digestion. In contrast, most of the difference in diet DM digestion noted when hybrid samples were either steam flaked or HM ensiled was due to differences in protein or fiber digestion because starch digestibility with flaked and HM samples all exceeded 98%.

Using in situ and in vitro methods Owens (2002) observed processing method altered in situ and enzymatic disappearance of dry matter and that samples of different corn hybrids also differed in their site of digestion (Figure 6). Most of the difference in starch digestion between dry rolled and corn flaked at 28 lb per bushel could be attributed to an increase in enzymatic (presumably post-ruminal) digestion. Flaking corn to a lower density (25 lbs per bushel) tended to increase ruminal starch digestion beyond that observed with either dry rolled or corn flaked at 28 lb per bushel. These data suggest using in situ DMD alone to predict total tract DM digestion or animal performance can be misleading with dry rolled corn.

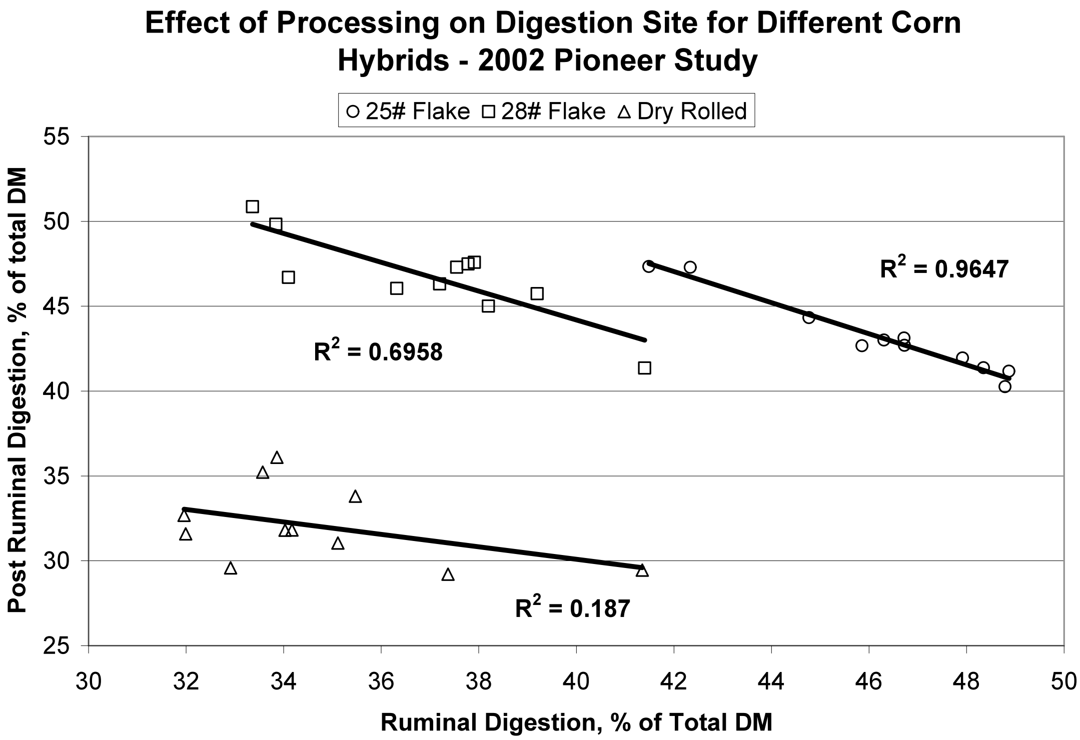


Figure 6. Effect of processing on digestion site for different corn hybrids. 2002 Pioneer study.

Macken et al. (2003) fed feedlot steer diets based on floury or vitreous corn with corn endosperm type factorialized across processing method (i.e., dry-rolled or high moisture ensiled). When the corn was fed dry rolled, steer fed the floury endosperm corn, as compared with steers fed more vitreous endosperm corn had a superior feed to gain ratio (5.55 vs. 5.88). However; when the corn was fed as high moisture ensiled, feed:gain ratios were identical (5.36 vs. 5.37) for steers fed floury or vitreous corn. In a recent study conducted by Szasz et al. (2006) using high moisture corn (28% moisture) prepared from either a vitreous or a floury corn hybrid, digestibility of starch both in the rumen and the total digestive tract surprisingly tended to be superior for the vitreous hybrid. The authors noted that, contrary to previous findings with dry rolled corn, the more vitreous corn when rolled wet had a smaller geometric mean particle size and 15.8% greater calculated surface area than the floury corn did. The researchers postulated that the floury corn kernels when moist were more pliable and thereby were less damaged by the rolling process. In contrast, vitreous corn kernels when moist were more brittle and shattered into finer particles when rolled with a high moisture content.

In summary, compared with more vitreous or flint hybrids, floury dent hybrids are more extensively digested by ruminants when fed after simply being coarsely rolled. However, this starch digestibility advantage for more floury hybrids is NOT apparent for corn grain that is processed for ruminants by other methods (steam rolled or flaked or fermented alone or in corn silage).

FUTURE IMPLICATIONS

Commercial corn hybrids differ both chemically and physically and hybrid selection can alter nutritional characteristics and economic value for cattle feeders. However, evaluating the feeding value of different corn hybrids for ruminants is a daunting and an expensive proposition because of interactions between grain characteristics and processing method. No single trait can fully explain the differences observed in digestibility and in subsequent animal performance. Therefore, nutritionists and cattle feeders must consider the dynamics between the kernel characteristic, processing methods, and ration formulation in order to fully exploit the differences between corn hybrids. Consequently, in the immediate future, hybrid selection for cattle must still be based primarily on grain production economics, specifically obtaining maximum yields obtained through reliable genetics, good agronomics, and disease and insect resistance. In the future as the nutritional factors that contribute to the feeding value of corn hybrids are defined, more reliable and rapid assay technologies will be developed to predict the metabolizable or net energy value of corn grain based on physical and chemical characteristics of hybrids and the responses to grain processing. Such knowledge will permit corn producers to select hybrids based on nutritional traits and corn breeders to develop hybrids most useful for those cattle producers that use a specific grain processing method.

LITERATURE CITED

Benton, J. R., T. J. Klopfenstein, and G. E. Erickson. 2004. Effects of corn moisture and length of ensiling on dry matter digestibility and rumen degradable protein. Nebraska Beef Report p. 28-30.Correa, C. E. S., R. D, Shaver, M. N. Pereira, J. G. Lauer, and K. Kohn. 2002. Relationship between corn vitreousness and ruminal in situ starch degradability. J. Dairy Sci. 85:3008-3012.

Dairy One Forage Lab. 2007. Data base on feed compositions. http://www.dairyone.com/Forage/FeedComp/disclaimer.asp

Harrelson, F.W., G. E. Erickson, T. J. Klopfenstein, W. A. Fithian, P. M Clark and D. S. Jackson. 2006. The influence of corn hybrid, kernel traits, and dry rolling or steam flaking on digestibility. Nebraska Beef Report pp. 45-47.

Jaeger, S. L., C. N. Macken, G. E. Erickson, T. J. Klopfenstein, W. A. Fithian, and D. S. Jackson. 2004. The influence of corn kernel traits on feedlot cattle performance. Nebraska Beef Report pp. 54-57.

Haefele, D., F. Owens, K. O'Bryan, and D. Sevenich. 2004. Selection and optimization of Corn Hybrids for Fuel Ethanol Production. Am. Seed Trade Assn. http://www.grainsa.co.za/documents/15%20Nov%20Haefele_ASTA_Paper.pdf

Longuski, R. A., K. C. Fanning, M. S. Allen, R. J. Grant, and J. F. Beck. 2002. Endosperm type and kernel processing of corn silage: Effect on short-term lactational performance in dairy cows. J. Dairy Sci. 85(Suppl. 1):204.

Macken, C., G. Erickson, T. Milton, T. Klopfenstein, and H. Block. 2003. Effects of starch endosperm type and corn processing method on feedlot performance, nutrient digestibility, and ruminal fermentation of high-grain diets. Nebraska Beef Cattle Report MP80-A:32-34.

McAllister, T. A., R. C. Phillippe, L. M. Rode, and K. J. Cheng. 1993. Effect of the protein matrix on the digestibility of cereal grains by ruminal microorganisms. J. Anim. Sci. 71:205-212.

Owens, F. N. 2002. Personal communication.

Owens, F. N. 2005. Corn Genetics and Animal Feeding Value. Minn. Nutrition Conf. http://www.ddgs.umn.edu/articles-proc-storage-quality/2005-Owens%20(MNC)%20Corn%20grain%20proc.pdf

Owens, F. N. and R. A. Zinn. 2005. Corn grain for cattle: Influence of processing on site and extent of digestion. Southwest Nutrition and Management Conference, Tempe, AZ. University of Arizona. pp. 86-112. http://animal.cals.arizona.edu/swnmc/papers/2005/Owens_SWNMC%20 Proceedings%202005.pdf

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

Prigge, E. C., R. R. Johnson, F. N. Owens, and D. Williams. 1976. Soluble nitrogen and acid production of high moisture corn. J. Anim. Sci. 42:490-496.

Szasz J., C. Hunt, and F. Owens. 2006. Impact of starch source and processing on feedlot production with emphasis on high-moisture corn. Proc. Pacific NW Nutrition Conference.

Thornton, J. H. 1976. Chemical indices of quality of ensiled high moisture corn grain. In: High Moisture Grains Symposium. Pp. 150-160. Oklahoma State University.

QUESTIONS AND ANSWERS

Q: What is the correlation between the pH of high moisture corn pH and its starch digestibility?

A: Generally, pH is lower with wetter high moisture corn and starch digestibility also will be greater with wetter high moisture corn, so one has an inverse relationship.

Q: For Steve or John, when comparing feeding values of dry and high moisture corn, does the method being used for dry matter determination bias this comparison? Do you have any comparison among various dry matter techniques? How much variation would you expect depending on the method you use to determine dry matter?

A: Certainly we are losing some volatiles with oven drying, probably 1 or 2%.

Additional comment by Owens: We compared various drying procedures for freshly harvested high moisture corn containing from13 to 38% moisture. Note that these samples had NOT been fermented. We compared drying at 62 C for a minimum of 24 hours, 103 C and 130 C and compared values with estimates from an NIR (a Dickey John and another NIR machine) as well as the Karl Fischer dry matter procedure. Certainly, with drying at 62 C, about 4% moisture remained in the freshly harvested whole kernel corn grain. The agreement between 103 C and NIR procedures was quite close. We also compared moisture content of kernels from the tip versus the base of the cob. Compared with kernels at the tip, kernels at the base of the ear had 3 to 5% greater moisture. Though it sounds simple, moisture content is one of the more complex measurements we have. Certainly, loss of organic volatiles, being greater for fermented than fresh grain, presents a problem in data interpretation with all fermented products.

Q: Is kernel size be correlated with endosperm type.

A: About 40 to 50% of endosperm type can be explained by differences in pure density, but test weight is not a particularly good measure of pure density. We use a pycnometer to measure pure density by displacement. Kernel size is important, particularly with dry processing, because it will influence the ideal gap setting and particle separation. Also, wet corn will fracture differently from dry corn. Particle size of rolled corn will vary tremendously with different corn types, particularly with a floury versus a more vitreous product. Being in the seed business, we routinely count kernel size because we sell seed corn in various kernel sizes. Sizing can be done. We have an automated 100 kernel counter so 100 kernel weight could be measured in about the same time it takes to do test weight. The automated kernel counter costs several thousand dollars. But I would rather have 100-kernel weight than test weight because kernel weight provides an index of both kernel size and density.

Q: If we have a huge variability in starch availability among hybrids, do people feeding rolled corn need to be rolling to a finer density?

A: Definitely. If you have small kernels, anything below about 300 mg, and test weights above 60 pounds per bushel, use finer processing. Logistics of fine grinding can get complex in a large lot. But smaller feedlots that roll grain daily and can measure particle size probably can pick up significant improvements in efficiency by adjusting their grinding to obtain a specific small particle size.