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PERFORMANCE OF DAIRY CATTLE FED SPECIALTY CORN HYBRIDS

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Corn silage represents a mixture of highly digestible, energy-dense grain and a poor quality forage (stover). The value of altering the grain to stover ratio through agronomic and harvesting strategies has been recognized for some time, however many of these practices have been applied to hybrids selected primarily for grain yield and adapted for harvest as silage. Although the feeding value of specific corn hybrids for silage production, such as brown midrib corn, has also been recognized the earlier available hybrids were lower yielding and therefore, less acceptable than conventional hybrids. Recently there is increased awareness of the potential to improve milk production, and milk per acre, through improved selection and use of specialty corn hybrids for silage production. These hybrids include selection for reduced lignin content, increased leaf to stem ratio, high starch content, high oil content and increased protein content. Performance of livestock fed corn hybrids that carry genes for insect resistance (Bt-gene) or herbicide tolerance (Roundup Ready), although not unique for silage production, are also of interest.

There is little information available on feeding value of either Bt or Roundup Ready (RR) corn hybrids despite considerable debate in the public arena on the application of these technologies to food production. Uncertainty regarding the effects of genetically modified corn hybrids on feed intake, rumen function, and milk production led us (Donkin et al, unpublished; Donkin et al., 2000) to test the effects of feeding corn grain and silage produced from these hybrids or their isogenic counterparts to lactating dairy cattle. These issues are particularly important as agriculture evolves a heightened awareness and adoption of integrated systems approaches to plant and animal production. A summary from two feeding studies conducted at Purdue University are presented here. In addition, a synopsis of recent published information for other specialty corn hybrids is included as an indication of their potential for improving animal health and productivity. While corn silage produced using specialty corn hybrids shows some specific advantages it should be noted that their inclusion is part of a total feeding program that should optimize milk production, while maximizing profitability and cow health.

What makes corn silage an attractive feed for dairy cattle

Corn silage is included in dairy cattle diets primarily as an economical source of fermentable carbohydrate. The amount of corn silage that can be used in a diet for lactating cows is limited by the protein content, profile of amino acids, rumen undergradable protein, effective neutral detergent fiber (NDF), calcium and phosphorus. Despite these shortcomings, corn silage is one of the most desirable ration components for profitable milk production due to its ease of handling and palatability.

The carbohydrate portion of corn provides energy for the growth of bacteria in the rumen and results in the formation of volatile fatty acids that serve as an energy source for the cow. The carbohydrate in corn silage is contained in either the fiber portion or in the nonstructural carbohydrate (NSC) fraction of the plant. The fibrous portion is typically measured as NDF whereas NFC which is estimated by difference as NSC = 100 - %NDF - %fat - %CP - %ash and represents the readily available carbohydrates in the feed such starch and sugars. The NSC portion of feeds is broken down more rapidly in the rumen, however, for efficient fermentation a balance of fiber and NSC is required. Typical dairy cattle diets contain 35-42% NSC but the optimum level is dependent on level of production, feeding practices and effectiveness of the fiber in the ration. Excessive NSC can lead to ruminal acidosis and depressed intake whereas too little NSC can depress microbial protein synthesis and milk protein production.

Corn silage contains a desirable balance of NDF and NSC and typical values for each, depending on the grain content of the silage, are 40 to 50% NSC and 42 to 44% NDF. The potential problems with feeding corn silage to dairy cattle are all too familiar. Methods of harvesting corn as silage that retains physically effective fiber as well as the digestibility of the crop have been sought in order minimize some of the digestive disorders that can result when feeding corn silage. The advent of kernel/crop processors on-board the forage harvester has increased the capability of using corn silage in dairy rations while avoiding the ruminal digestive disorders that are inherent to excessive corn silage feeding. These innovations have led to reexamination of the guidelines for using corn silage in diets for lactating cows and, in some cases, has increased the inclusion rate of corn silage in diets fed in the Midwest US.

The advent of new specialty hybrids and data indicating that the highest-yielding grain hybrids are not necessarily the highest silage yielding hybrids are also causing us to reexamine the possibilities for corn silage use in diets for lactating cows. Standard breeding techniques and new biotechnological capabilities provide opportunities to dramatically alter the composition of corn silage. Determining which characteristics to alter and evaluating the consequences of these changes may be the biggest challenge facing corn seed companies, dairy producers and nutritionists.

Hybrids that alter nutrient composition

Brown midrib

The brown midrib mutation was one of the first described for corn. Plants exhibit a reddish brown pigmentation of the leaf midrib, known as a brown midrib, starting when there are four to six leaves. The mutation is associated with a lower lignin content and therefore greater digestibility of plants and is a prime candidate in breeding corn for silage production. There are two independent brown midrib3 mutations that are found for the gene that encodes the enzyme O-methyltransferase which is involved in lignin biosynthesis. Both of these mutations have the same phenotypic effect of reducing lignin content of the plant.

Fiber can be described as is the component of the cell walls of plants. These wall provide the structural elements of the plant and the ability of the microbes in the rumen to digest the fiber in plants give ruminants a unique place in the food chain. A portion of these cell walls is a rigid material that is a complex of carbohydrates and tannins known as lignin. The amount of fiber, or bulkiness of a plant material, will limit how much a cow can consume and, therefore, milk production. As plants mature they accumulate NDF and become less digestible in part because lignin also accumulates. Neutral detergent fiber (NDF) is a laboratory test that is used to meaure the fiber content of plant material and includes cellulose, which is highly digestible, hemicellulose, which is partially digestible, and lignin, which is completely indigestible.

Most plants that are harvested for silage contain 40-55% NDF of which most is hemicellulose and lignin. Therefore reducing the amount of lignin relative to hemicellulose or cellulose acts to increase the digestibility of the plant at the same % NDF (i.e. more cellulose and hemicellulose relative to lignin). Brown midrib corn has a lignin content that is approximately 25-35% lower than of the content of normal corn silage (1.7 vs 2.5 %DM). Because lignin is totally indigestible this difference leads to approximately 20% greater NDF digestibility for brown midrib corn silage (Oba and Allen, 1999) which would provide approximately 400 lbs more digestible NDF per acre at the same DM yield.

Brown midrib corn silage was extensively evaluated during the 1970's and responses ranged from 1.8 to 3.6 lbs additional milk per day (Frenchick et al., 1976; Keith et al., 1979). In these early studies, milk production was less than 75 lb./day and production may not have been limited by feed intake and digestibility. Recent studies using higher producing cows (85 lb./day) indicate a 6 lb./day increase in milk production and a 4.6 lb./day increase in feed consumption when brown midrib corn silage is fed (Oba and Allen, 1999).

Digestibility of any feed in the rumen is a function of the properties of the feed (ie chemical composition) and the amount of time that it is retained in the rumen. In

general as the rate of passage increases the digestibility of a feed decreases. One of the common concerns when feeding reduced lignin corn silage is that an increase in the rate of passage that results from greater intake of brown mid-rib corn silage may offset the inherent characteristics of the plant material (reduced lignin and increased digestibility) to result in little change in nutrient capture by the animal. On the other hand, an increase in passage rate of a feed increases the efficiency of microbial protein synthesis in the rumen. Feeding studies indicate that brown midrib corn increases the rate of passage through the rumen by approximately 10% which results in a decrease in ruminal NDF digestibility of 25% but a 26% increase in microbial protein production (Oba and Allen, 2000). The net effect is a 7 lb increase in milk production and 0.24 lb./day increase in milk protein (Oba and Allen, 2000).

When the risk of drought is imminent, sorghum provides an alternative drought tolerant forage. The digestibility of sorghum silage is less than typical digestibility of corn silage. Brown midrib sorghum has 1% lower lignin content and a 48% greater rate of digestion of NDF than normal sorghum (Aydin et al., 1999) and the rate of digestion is similar to corn silage. Cows fed brown midrib sorghum produced more milk than cows fed normal sorghum silage and had milk production and composition that was similar to cows fed corn silage (Aydin et al., 1999). Cows fed brown midrib sorghum were slightly (3.5%) more efficient (fat-corrected milk/ DM intake) than cows fed corn silage or normal sorghum (Aydin et al., 1999).

Increased leaf content

Increasing the leaf to stem ratio is a familiar concept when evaluating legumes' forage quality. This same concept has been applied in selection of corn hybrids. The hybrid TMF94 was develop to contain 2-4 extra leaves per plant in an effort to increase the quality of corn silage. Corn leaves contribute approximately 10% of the DM of the plant at silage harvest and is composed of 10 %CP, 56 %NDF, 30 %ADF. Whole plant silage, from the same crop, is 7.0 %CP, 45 %NDF, 24 %ADF. Increasing the leaf content of corn silage by 2.9% increased the in vitro NDF digestibility by 2.4% but did not alter feed intake or milk production (Kuehn et al., 1999).

High oil

In corn, almost all the oil is stored is the germ of the kernel and the oil content of approximately 4 %. High oil (HO) corn has a larger germ than normal corn, and this results in greater oil content and a smaller endosperm which results in less starch in both grain and silage. Because lipids contain 2.25 times more energy than a similar weight of starch, the energy content of HO corn is approximately 4% greater than other varieties. The drawback of high oil corn is that the decreased starch content results in less fermentable energy for microbial growth and protein synthesis. Most of the oil in HO hybrids is contained in grain,

therefore, the impact of HO silage is not as pronounced as feeding HO grain. Only one of 5 studies that examined the effect of feeding HO corn grain or a combination of HO grain and silage indicated an increase in milk production (2 lb./day) and feed intake (2 lb./day) (Dado, 1999).

The lack of positive effect of HO corn on cow performance may not be surprising when we stop to consider that the primary reason for adding corn grain and silage is to boost the non-structural carbohydrate component of dairy cattle diets. Increased oil content at the expense of starch in the diet provides more total energy but less energy (per unit DM) for the rumen microbes. Adding HO corn grain is analogous to the addition of inert fat (tallow) at the expense of corn grain in the diet. In order to improve cow performance the amount of rumen fermentable carbohydrate consumed by the cow must offset the content of inert oil in the diet because decreased fermentable carbohydrate availability leads to decreased microbial protein production in the rumen. Furthermore, ruminal protein synthesis during early lactation limits the productivity of the cow; therefore sources of rumen undegradable protein are usually included in the diet. Rumen undegradable protein content of the diet should be evaluated when considering HO corn or other fat-containing energy sources for early lactation cows.

Genetically modified corn hybrids

Modified for Roundup Ready® tolerance: Roundup Ready® corn

Roundup Ready® (RR) corn hybrids offer an alternative to the targeted weed control commonly practiced by corn growers. The agronomic benefits of Roundup Ready® corn are reduced competition by weeds for soil nutrients, water, or sunlight and enhanced crop yields. Differences in corn yield per acre using Roundup Ready® hybrids are relatively easy to determine. However, differences in digestibility, energy density, and digestibility of the resulting grain and silage that may contribute to efficiency of milk production when fed to lactating dairy cattle are more difficult to measure. It is necessary, therefore, to evaluate the effects of corn that expresses the Roundup resistant gene on production in a whole animal system.

During the 1999/2000 cropping year alternating quarters of a 20.25 ha field were planted with either Roundup Ready® (RR) corn (DK626RR) or the isogenic (ISO) counterpart hybrid line(DK626). Perimeter rows were removed and half of each strip was harvested for whole plant corn silage. The remainder of the crop was allowed to mature and was harvested as grain. Sixteen multiparous Holstein cows were assigned to two groups and fed diets containing 62 % corn silage and 17 % corn grain from either Roundup Ready or from the isogenic counterpart.

The balance of the diet was from protein supplements, vitamins and minerals. Diet composition is given in Table 1. Treatments were applied as switchback design consisting of 3 contiguous 28-d periods consisting of 14-d adaptation

periods followed by 14 days of data collection. Cows were fed, for ad libitum intake and milked twice daily. Milk production, intake and composition data are given in Table 2. There were no differences for any parameter measured and the data demonstrate equivalence of nutritional value and production efficiency for Roundup ReadyÒ corn compared with the isogenic control.

Table 1. Ingredients and nutrient composition of diets.

Item	Roundup Ready®	Isogenic Control
Ingredient[1]		
Corn Silage	59.6[2]	59.6[3]
Cracked Corn	17.9[4]	17.9[5]
SBM	13.5	13.5
Aminoplus[6]	3.9	3.9
Urea	0.18	0.18
Vitamins & minerals	4.85	4.85
Nutrient[7]		
Crude Protein (CP)	16.8	16.9
RUP, % of CP	35.3	35.4
ADF	15.0	16.1
NDF	25.9	28.8
NE_L, Mcal/kg DM	0.75	0.75
Ca	0.65	0.65
P	0.43	0.43

[1] Average composition: 39.3 %DM, 8.5 %CP, 22.0 %ADF. 37.1 %NDF.

[2] Average composition: 39.4 %DM, 8.5 %CP, 24.2 %ADF. 41.2 %NDF.

[3] Average composition: 12.1 %DM, 9.4 %CP, 4.1 %ADF. 7.4 %NDF.

[4] Average composition: 14.0 %DM, 10.0 %CP, 2.8 %ADF. 9.7 %NDF.

[5] Dry basis unless indicated otherwise.

[6] Processed soybean meal, (RUP = 58%); Consolidated Nutrition L. C., trademark.

[7] Based on ingredient analysis

Table 2: Effect of feeding corn silage and corn grain genetically modified to tolerate Roundup® or from the isogenic parent line on feed intake, milk production and composition.				
	RR Corn	Isogenic Line	SE	P-value
DMI, lb/d	48.0	47.3	0.88	0.58
Fat Corrected Milk, lb/d	61.2	60.5	0.88	0.58
Milk Yield, lb/d	64.9	64.7	0.88	0.81
Efficiency (DMI/lb milk)	1.30	1.29	0.02	0.89
Milkfat				
%	3.61	3.55	0.04	0.28
lb/d	2.33	2.29	0.04	0.47
Milk Protein				
%	3.24	3.25	0.01	0.28
lb/d	2.11	2.11	0.02	0.98
Milk lactose				
%	4.72	4.70	0.01	0.37
lb/d	3.08	3.08	0.04	0.77
Milk Solids not-fat				
%	8.75	8.74	0.02	0.66
lb/d	5.70	5.67	0.09	0.87
MUN (mg/dL)	10.9	10.8	0.2	0.89
SCC (x1000)	99	101	10	0.89

Modified for insect resistance: Bt-corn

Bacillus thuringiensis (Bt) is a naturally occurring soil borne bacterium that produces crystal-like proteins, which selectively kill specific groups of insects. The proteins, known as Cry proteins are activated in the digestive tract of the insect by the insect's own digestive enzymes. Bt corn hybrids, are genetically altered to express these proteins in the stalk of the plant and are a weapon for

corn growers against the yield reductions caused by European corn borer infestation. However, as is the case with other specialty corn hybrids, the benefits of Bt corn on animal production have not been fully evaluated. Therefore, to determine the effects of corn that expresses the Bt-gene on production in a whole animal system we assessed performance of dairy cattle fed corn silage and grain produced from Bt-corn.

The corn production and feeding studies were similar to the design described above. Diet composition of the cow experiment is given in Table 3. Milk production, intake and composition data are given in Table 4. There were no differences for any parameter measured and the data demonstrate equivalence of nutritional value and production efficiency for Bt- corn compared with the isogenic control.

It should be noted that corn silage and grain used in the studies presented here was grown on fields that were maintained as pasture for an extended period before the 1998-99 and 1999-2000 cropping seasons. Therefore, pest pressure was believed to be minimal. While this experiment provide the maximal opportunity to determine differences due to corn hybrids, different results may be observed under more corn borer pressure. These difference are likely to favor Bt-corn if pest resistance benefits the nutritive value or yield of the resulting crop.

The action of the cry proteins contained in Bt-corn on microbial fermentation have not been previously evaluated. There have been some concerns raised that perhaps these proteins may inhibit the growth of rumen bacteria in a manner related to their action in the digestive tract of the European corn borer. In order to test this possibility we determined the rate of digestion of samples of silage and grain from Bt-corn and the isogenic line that were ground, sealed in dacron and placed in the rumen of lactating cows. After 2, 4, 8, 12 ,24 and 48 h thee bags were recovered and the rate of digestion of each feed was determined separately for corn silage and corn grain. Results indicated no differences in rumen digestibility of Bt-corn compared with the isogenic control.

Summary

Corn silage is likely to continue to provide an economical source of fermentable carbohydrate for dairy cattle. Relatively small differences in corn silage fiber content and digestibility translate to large differences in milk production. Some traditionally produced specialty hybrids provide advantages compared with isogenic controls. Currently available genetically modified corn hybrids support similar milk production, composition and do not alter rumen fermentation. The advantages for these hybrids may be realized as milk per acre of corn silage through differences in improved nutritive value of the crop. Future opportunities are likely in the development, evaluation and adaptation of specialty corn hybrids for use in silage production for dairy cattle.

Table 3. Ingredients and nutrient composition of diets.		
Item	Bt-Corn	Isogenic Control
Ingredient[1]		
Corn Silage	59.6[2]	59.6[3]
Cracked Corn	17.9[4]	17.9[5]
SBM	13.5	13.5
Aminoplus[6]	4.0	4.0
Urea	0.18	0.18
Vitamins and minerals	4.82	4.82
Nutrient[7]		
CP	16.2	16.2
RUP, % of CP	35.3	35.4
ADF	15.0	16.1
NDF	25.9	28.8
NE_L, Mcal/kg DM	0.76	0.76
Ca	0.72	0.72
P	0.44	0.44

[1] Average composition: 44.4 %DM, 7.5 %CP, 25.3 %ADF. 40.1 %NDF.

[2] Average composition: 36.0 %DM, 7.9 %CP, 26.6 %ADF. 43.4 %NDF.

[3] Average composition: 11.3 %DM, 8.4 %CP, 2.9 %ADF. 10.2 %NDF.

[4] Average composition: 13.6 %DM, 9.2 %CP, 2.5 %ADF. 9.1 %NDF.

[5] Dry basis unless indicated otherwise.

[6] Processed soybean meal, (RUP = 58%); Consolidated Nutrition L. C., trademark.

[7] Based on ingredient analysis

Table 4: Effect of feeding corn silage and corn grain from Bt-corn or its isogenic parent line on feed intake and milk production.				
	Bt Corn	Isogenic Line	SE	P-value
DMI, lb/d	52.7	55.9	1.12	.06

Milk Yield, lb/d	84.2	86.9	1.20	.15
Efficiency (DMI/lb milk)	.64	.66	.01	.26
Milkfat				
%	3.45	3.42	.07	.76
lb/d	2.86	2.91	.07	.62
Milk protein				
%	2.99	2.99	.02	.88
lb/d	2.52	2.58	.04	.32
Milk lactose				
%	4.68	4.68	.02	.89
lb/d	3.95	4.08	.06	.16
Milk solids				
%	6.70	6.75	.02	.16
lb/d	5.64	5.85	.08	.10
SCC (x1000)	203	258	61	.54

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