The *sfe* Corn Mutant: A New Approach to Improve Fiber Digestibility & Milk Production

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Corn silage is the single most important forage source used for dairy production in the U.S. While the grain portion of corn silage is highly digestible, stover typically comprises half of the silage dry matter (DM) and contains high concentrations of fiber which is of limited digestibility. For this reason, extensive effort has been directed towards identifying corn hybrids with higher fiber digestibility. Corn hybrid variety trials in Minnesota and Wisconsin include a laboratory measurement of fiber digestibility in their ranking of silage hybrids.

Earlier research led to the development of brown midrib (*bm3*) corn which is now widely used in the U.S. due to its improved fiber digestibility. More recent research has discovered another corn mutation (*sfe*) that improves corn silage digestibility in a different way. Because these are separate mutations, in the future it should be possible to incorporate both the *sfe* and *bm3* mutations in the same hybrid and potentially result in even greater improvements in fiber digestibility and cow response than observed for either mutation alone.

The *bm3* Mutation . . .

In the absence of gene mutations, most of the differences among corn hybrids for fiber digestibility are the result of quantitative genetic variation involving multiple unidentified genes. However, there are a set of four single-gene brown midrib (*bm*) corn mutations that result in greater fiber digestibility due to altered lignin biosynthesis. The *bm3* mutation results in the greatest decrease in lignin concentration and the largest increase in fiber digestibility of the four *bm* mutations. Incorporation of the *bm3* mutation into any corn hybrid enhances fiber digestibility compared with the identical hybrid lacking the *bm3* gene. Unfortunately, the *bm3* mutation is associated with a yield loss of generally 8-12% and is more susceptible to lodging, although these negative impacts are variable among different corn genetic backgrounds.

Role of Cross Linking . . .

While lignin concentration has long been known to be strongly and negatively related with fiber digestibility in forages when viewed across maturity stages, this relationship is much weaker when only forages of similar maturity are considered. Because all corn silage is of similar advanced maturity, other factors beyond simply lignin concentration are believed to contribute to the observed variation in fiber digestibility among hybrids. Extensive research over the past 25 years has demonstrated that cross linking of lignin to hemicellulose by ferulate molecules has a significant negative impact on fiber digestibility independent of lignin concentration.

All grasses, including corn, have these ferulate cross links. When corn cells grown in the laboratory are prevented from adding ferulates to hemicellulose, then the digestibility of the hemicellulose is greater even though the same amount of lignin is present. And negative relationships between the amount of ferulate ether cross links and fiber digestibility in the laboratory have been observed in several cool season perennial grasses. The reason cross linking is important is that the ferulates hold the lignin in very tight physical proximity to the hemicellulose which ensures that lignin blocks access to the hemicellulose by rumen enzymes which can digest hemicellulose.

Ferulates accomplish this cross linking because the ferulates are first attached to hemicellulose by ester bonds and then some of these ferulate esters react with lignin precursors to form additional ether and other bond types to create cross links between hemicellulose and lignin, with ferulate molecules in the middle. Interestingly, only lignin precursors and not preformed lignin polymers react with ferulates, which means that ferulates are the site where lignin deposition begins.

The *sfe* Mutation . . .

Although the importance of ferulate cross links to fiber digestibility has been shown in the laboratory, their impact on fiber digestibility of grasses fed to animals has not been examined previously. A new corn mutation was recently discovered that results in less ferulate ester addition to hemicellulose, fewer ferulate ether cross links at silage maturity, and improved laboratory fiber digestibility of corn stover. The seedling ferulate ester (*sfe*) corn mutant provides the first opportunity to test if reducing cross linking will improve performance of livestock.

Five inbred corn lines were compared: W23, two W23*sfe* lines (M04-4 and M04-21), B73, and B73*bm3*. The B73*bm3* line was included as a positive control to compare the relative impact of the *sfe* mutation vs. the *bm3* mutation. The corn lines were grown at the U.S. Dairy Forage Research Center farm at Prairie du Sac, WI and ensiled in silo bags.

Fourteen Holstein cows were assigned to each of the five corn silage treatments and fed TMRs balanced for 86 lbs milk/day with 70% of dietary NDF from corn silage. The diets included ~40% corn silage, 10% alfalfa haylage, 12% high moisture corn, 6% roasted soybeans, 5% molasses, and 27% of a premix (protein, starch, protected fat, vitamins, minerals, and Rumensin®). Cows were fed once and milked twice daily. The experiment was conducted for four weeks and fecal grab samples were collected during the last week of the experiment to estimate digestibility of the diets.

Comparing *bm3* and *sfe* Mutations . . .

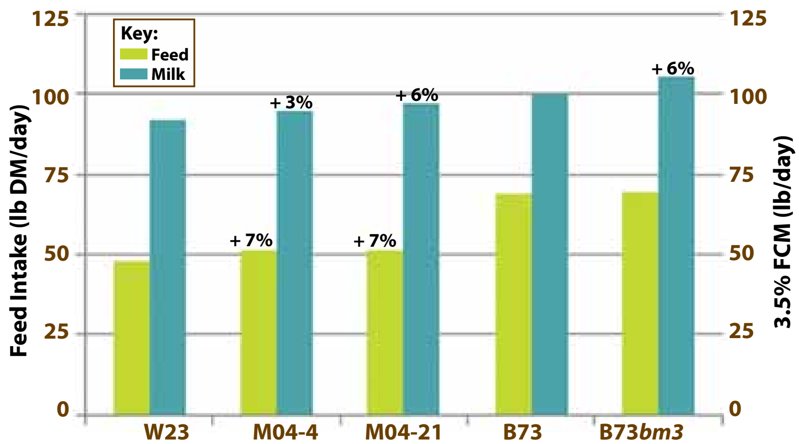
In the W23 corn line, the W23*sfe* silages were wetter and contained less starch and more NDF than the W23 control silage (Table). These differences can be explained based on data from an earlier small-plot experiment which indicated that the W23*sfe* mutants produce more stover, which would dry more slowly than grain and increase the silage NDF concentration. As expected, the W23*sfe* silages contained fewer ferulate ether cross links. In the B73 corn lines, a similar decrease in ferulate cross linking was not seen for the B73*bm3* silage compared to its B73 control; however, the *bm3* mutation caused a large decrease in lignin.

Cows fed the W23*sfe* containing diets consumed more feed and produced more 3.5% fat-corrected milk than cows fed the W23 control silage diet (Figure). Small reductions in protein and lactose concentration in milk were observed with M04-21 feeding; however, yield of protein and lactose per day were greater than with the W23 containing diet. While the B73*bm3* containing diet did not increase feed intake over the B73 diet, milk production was increased. It was also observed that the cows fed W23*sfe* silages were less selective against fiber than W23 silage fed cows. Even though the cows offered W23*sfe* silages consumed a diet richer in fiber, the digestibility of NDF from the M04-21 silage diet was greater than for the W23 diet (65% vs. 58%) and NDF digestibility of the M04-4 diet (56%) was similar to W23. Surprisingly, the B73*bm3* silage containing diet did not improve NDF digestibility compared with B73.

Table. Composition of corn silages from inbreds W23, W23*sfe* lines (M04-4 and M04-21), B73, and B73*bm3* that were fed to lactating Holstein cows as part of total mixed rations.

Component	Corn Lines				
		W23*sfe*	W23*sfe*		
	W23	M04-4	M04-21	B73	B73*bm3*
Dry Matter, %	48.9	42.4	40.4	31.5	32.8
Crude Protein, %DM	8.3	8.1	8.2	7.2	7.5
Starch, %DM	25.7	20.7	21.9	21.5	21.8
NDF, %DM	45.0	48.1	47.3	47.0	47.4
Acid Detergent Lignin, %NDF	4.9	6.7	4.9	5.3	4.0
Ferulate Ethers, %NDF	0.92	0.73	0.71	0.93	0.88

Figure. Feed intake and milk production of dairy cows fed total mixed diets containing silages from inbred corn lines W23, W23*sfe* (M04-4 and M04-21), B73, and B73*bm3*.



Cow performance on the W23*sfe* and B73*bm3* silage diets cannot be compared directly because the two mutations were in different genetic backgrounds (W23 vs. B73), and silages from these two genetic backgrounds differed in their composition and cow response. However, on a relative basis the *sfe* and *bm3* mutations resulted in equivalent increases of 6% in milk production. While the identity of the *sfe* gene is as yet unknown, it is clearly not the same as the *bm3* gene as evidenced by the different impacts of these two mutations on lignin and ferulate cross link concentrations, and the fact that W23*sfe* lines do not exhibit the classical reddish-brown leaf midrib and lower stalk coloration of *bm* mutants. Because these are separate mutations it should be possible to incorporate both mutations into the same corn hybrid. Stacking both the *sfe* and *bm3* mutations in the same hybrid should decrease both lignin concentration and ferulate cross linking, and potentially result in even greater improvements in fiber digestibility and cow response than observed for either mutation alone.

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