Current Concepts in Fiber Digestion: Focus on Source of Forage and Trace Mineral

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Introduction

Corn silage is a common source of digestible fiber for lactating dairy cows. In New York State in 2018, 445,000 acres of corn silage were harvested to produce 8,455,000 tons (USDA/NASS, 2019). There are differences between hybrids in the quantity and quality of digestible fiber provided. Corn silage having the brown midrib gene mutation, either BM1 or BM3, had increased neutral detergent fiber digestibility (NDFd) and lower lignin content compared to conventional corn silage (Oba and Allen, 1999a; Hassanat et al., 2017).

Historically, fiber has been measured as crude fiber or NDF, but in the last decade, new analyses have allowed for better fractionation of NDF (Raffrenato et al., 2018). The new analyses are an in vitro fermentation at various time points (30, 120, and 240 h) and are called undigested NDF (uNDF; Raffrenato et al., 2018). The uNDF at 240 h is a measure of the indigestible NDF (iNDF) and allows for an accurate estimation of potentially digestible NDF (pdNDF) which is the fiber that the cow has the opportunity to digest (Cotanch et al., 2014).

Recently we conducted a corn silage hybrid study over three years (2015 - 2017) comparing BM1, BM3, and non-BMR hybrids in quantity and quality (Miller et al., 2018). Using the newly defined fiber fractions, we found that BM3 hybrids had higher NDFd, lower uNDF at 240 h, and higher pdNDF (% of NDF) than BM1 and non-BMR hybrids (Miller et al., 2018). Oba and Allen (2000a) reported that cows fed BM3 corn silage-based diets had higher dry matter intake (DMI) and milk production compared to cows fed CON corn silage-based diets. They also reported faster passage rates of NDF and iNDF in cows fed BM3 corn silage-based diets compared to CON corn silage-based diets (Oba and Allen, 2000a, 2000b, and 2000c).

Some trace minerals are required in small amounts for proper rumen microbe function; however, requirements of rumen microorganisms appear to be very low relative to requirements of the animal. The source of trace mineral affects the solubility in the rumen and could have negative effects on cellulolytic bacteria or bind to undigested fractions (e.g., fiber fractions) that pass from the rumen (Torre et al., 1991; Genther and Hansen, 2015; Faulkner et al., 2017). A recent study showed that feeding hydroxy Cu, Mn, and Zn minerals increased total tract NDF digestibility compared to sulfate sources in forage- and by-product-based dairy cattle diets (Faulkner and Weiss, 2017). A greater difference in total tract NDF digestibility in the forage-based diets between the sulfate

(STM) and hydroxy trace minerals (HTM) suggests that the source of NDF potentially influences the effect of source of trace mineral on NDF digestibility.

Based on those findings, we investigated the effect of source of corn silage and trace mineral on lactation performance and fiber digestibility. We expected that the increased fiber digestibility of BM3 corn silage would allow for higher DMI and milk production, and the decreased solubility in the rumen of HTM in the rumen would allow for higher total tract digestibility of NDF.

Miner Institute Study: Source of Corn Silage and Trace Mineral

Dietary Treatments

To test the effect of source of corn silage and trace mineral, we conducted a study in 2018 using four diets with either conventional or brown midrib-3 corn silage and either a sulfate source of Cu, Zn, and Mn or hydroxy trace minerals (IntelliBond Cu, Zn, and Mn; Micronutrients LLC USA, Indianapolis, IN). The diets contained approximately 54.6% corn silage, 2.3% chopped wheat straw, 43.1% concentrate mix, and either 0.033% STM or 0.022% HTM (Table 1). The objective for the substitution of the corn silage on a 1:1 DM basis was to allow differences in fiber fractions of the diet to be determined by the source of corn silage and their respective fiber content and digestibility.

Table 1. Ingredient composition (% of DM) of diets containing either CON corn silage or BM3 corn silage with either STM or HTM fed to lactating Holstein cows.

	Diets			
	CON		BM3	
Item	STM	HTM	STM	HTM
Conventional corn silage (CON)	54.6	54.6	.	.
Brown mid-rib corn silage (BM3)	.	.	54.6	54.6
Straw	2.3	2.3	2.3	2.3
Concentrate mix				
Other	43.1	43.1	43.1	43.1
Premix				
Cu sulfate	0.004	.	0.004	.
Mn sulfate	0.012	.	0.012	.
Zn sulfate	0.017	.	0.017	.
Hydroxy Cu	.	0.002	.	0.002
Hydroxy Mn	.	0.011	.	0.011
Hydroxy Zn	.	0.009	.	0.009

The amylase-modified NDF on an organic matter basis (aNDFom) content of the CON diets was higher than BM3 diets due to differences in corn silage (36.2 vs. 32.1% of DM; Table 2). The BM3 diets had higher NDFd 30-h and lower uNDF at 240 h than the CON diets (62 vs. 55.7% of aNDFom; 6.9 vs. 8.6% of DM, respectively). The starch content of the CON diets was lower than BM3 diets, and this was due to a decrease in the starch content of the CON corn silage during the study (21.9 vs. 26.2% of DM). The trace mineral concentrations were similar across diets and were chosen to be similar to on-farm diets typically formulated for high-producing dairy cows.

Table 2. Calculated diet composition based on chemical analysis of ingredients fed to lactating Holstein cows.

	Diets			
	CON		BM3	
Item	STM	HTM	STM	HTM
CP, % of DM	15.0	15.3	15.6	15.4
aNDFom, % of DM	36.3	36.0	32.1	32.0
30-h aNDF digestibility, % of aNDFom	56.0	55.3	61.9	62.0
Undigested NDFom at 240-h, % of DM	8.6	8.6	6.9	6.9
Potentially digestible NDF, % of aNDFom	76.3	76.1	78.4	78.2
Starch, % of DM	21.8	21.9	26.2	26.1
Copper, mg/kg of DM	18	17	17	16
Manganese, mg/kg of DM	61	68	60	64
Zinc, mg/kg of DM	101	93	107	88

When feeding these dietary treatments (Table 1 and 2), we expected the cows fed the BM3 diets to have higher DMI and milk production (Oba and Allen, 2000a; Hassanat et al., 2017) and trace minerals to have minimal effect on DMI and milk production (Faulkner and Weiss, 2017). There was a corn silage effect on DMI as the cows fed the BM3 diets had greater DMI than cows fed the CON diets (28.1 vs. 27.5 kg/d; Table 3). The increased fiber digestibility and lower uNDF240 of the BM3 corn silage allowed the cows to have greater intake. There was also a trace mineral effect on DMI as the cows fed the HTM diet had greater DMI than cows fed the STM diets. In contrast to our results, a similarly designed study reported no effect of trace mineral source on DMI (Faulkner and Weiss, 2017).

Cows fed the BM3 diets had higher milk and energy-corrected milk (ECM) yield compared to the cows fed the CON diets (47.0 vs. 44.7 kg/d; 47.6 vs. 46.2 kg/d, respectively). With the greater dietary starch content, lower NDF content, and feed intake of the cows fed the BM3 diets; it is not surprising that they produced more milk than the cows fed the CON diets. There was a corn silage effect on feed efficiency when expressed as milk per DMI, but there was no corn silage effect when feed efficiency was expressed as ECM per DMI.

Table 3. Least squares means of DMI and milk production data from lactating Holstein cows fed diets containing either CON corn silage or BM3 corn silage with either STM or HTM.

	Diets							
	CON		BM3			*P*-value		
Item	STM	HTM	STM	HTM	SE	CS	TM	CS x TM
DMI, kg/d	27.4	27.6	27.5	28.6	0.6	0.02	0.01	0.11
DMI, % of BW/d	4.12	4.16	4.18	4.30	0.1	<0.01	0.01	0.26
Milk, kg/d	44.8	44.6	46.2	47.7	1.1	<0.01	0.21	0.12
ECM, kg/d	46.4	45.9	46.9	48.2	1.2	0.02	0.47	0.17
Milk/DMI, kg/kg	1.63	1.62	1.68	1.67	0.05	<0.01	0.22	0.80
ECM/DMI, kg/kg	1.69	1.66	1.70	1.69	0.03	0.43	0.21	0.76

When we assessed total tract digestibility (TTD), the cows fed the BM3 diets had higher TTD of organic matter (OM) and lower TTD of starch compared to the cows fed the CON diets (74.1 vs. 72.3%; 95.1 vs. 99.1%, respectively; Table 4). The BM3 corn silage has a higher amount of potentially digestible NDF than CON corn silage which could mean that more of the fiber might be digested in the cow (Table 2). However, in similar studies (Hassanat et al., 2017; Oba and Allen, 2000c), they reported no differences in TTD of OM in cows fed either BM3 or CON corn silage. Ferraretto and Shaver (2015) reported lower total tract starch digestibility for cows fed the BM3 diets compared to cows fed CON diets due to greater kernel vitreousness of BM3 corn silage hybrids.

The cows fed the HTM diets had a tendency for higher TTD of aNDFom than the cows fed the STM diets (56.9 vs. 54.9%; Table 4). This was in agreement with Faulkner and Weiss (2017) who reported cows fed diets with HTM had a higher TTD of NDF compared to cows fed diets with STM. Oba and Allen (1999b) reported that a one-unit increase in vivo total tract NDF digestibility of TMR was associated with a 0.42-kg increase in DMI. The 2.8% difference in total tract digestibility of aNDFom between the cows fed the BM3-HTM and BM3-STM diets would equate to a 1.18-kg increase in DMI, which would explain the 1.1-kg difference observed in DMI.

Table 4. Least squares means of total tract digestibility data from lactating Holstein cows fed diets containing either CON corn silage or BM3 corn silage with either STM or HTM.

	Diets							
	CON		BM3			*P*-value		
Item	STM	HTM	STM	HTM	SE	CS	TM	CS x TM
OM, % of OM	72.1	72.5	74.2	74.0	0.7	0.01	0.88	0.71
Starch, % of starch	99.0	99.1	95.0	95.2	0.2	<0.01	0.48	0.90
aNDFom, % of aNDFom	54.4	55.5	55.4	58.2	1.2	0.12	0.10	0.52
pdNDF, % of pdNDF	70.7	71.7	70.4	72.7	1.4	0.80	0.20	0.65

Summary And Perspectives

Minerals Matter

This study evaluated the effect of source of corn silage and trace mineral on fiber digestibility and lactation performance. Cows fed the BM3 diets had higher DMI and ECM than cows fed the CON diets. Source of trace minerals had an effect on DMI with the cows fed the HTM diets having higher DMI than the cows fed the STM diets. This DMI difference between the HTM and STM diets can be accounted for by the difference in total tract digestibility of aNDFom. The effect was greater for the cows fed the BM3 diets compared to the cows fed the CON diets. Source of trace minerals influences DMI and total tract digestibility of aNDFom and should be taken into consideration when formulating diets for high-producing dairy cows.

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