Increasing Silage Levels in Dairy Diets Using Starch and NDF Digestibility Data

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INTRODUCTION

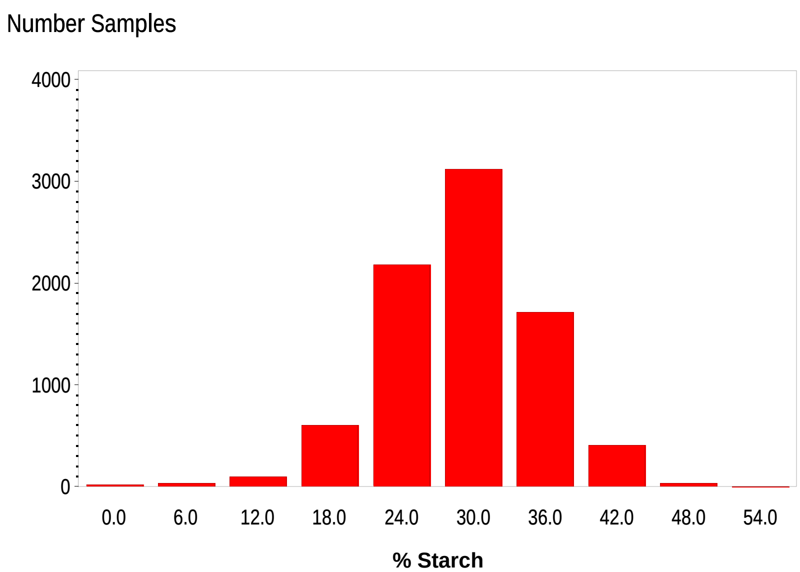
As economic challenges evolve in the dairy industry, improvements are required in how cows are fed to maintain profitability. One strategy to reduce feed costs is to increase corn silage levels in diets and remove corn grain. This is particularly effective when corn is expensive relative to corn silage. However, high corn silage diets can produce variable results due to potential variation in the ruminal digestion of starch and fiber, which can negatively impact dry matter intake (**DMI**) and resulting performance (Allen, 2000; Allen et al., 2009).

Most on-farm formulation systems are used to control dietary variation by optimizing crude nutrient profiles in the diet. While these approaches provide convenient and precise recommendations to the nutritionist, the results may not always be directly relevant to the dairy cow. Rather than responding directly to crude nutrient inputs, the cow is reacting to the digestibility of these nutrients in various parts of the digestive tract. Furthermore, ingredient nutrient content and digestibility change over time. To better adjust to these changes, and provide diet solutions that are more optimized for cow performance, a method is needed for more rapid, accurate monitoring of nutrient digestibility and supply; particularly when high levels of a variable ingredient, like corn silage, are being fed.

CONSEQUENCES FROM VARIATION IN RUMINAL STARCH DIGESTION

Corn silage samples collected from across the United States from October 2007 until June 2010 contained from 12 to 42 % starch (Figure 1, Calibrate™ Technology Lab, 2010), with *in vitro* ruminal starch digestion ranging from 69 to 93 % of starch (Calibrate™ Technology Lab, 2010, Gray Summit, MO).

Figure 1. Distribution of crude starch values from corn silage samples tested in the Calibrate™ Technology Lab (Gray Summit, MO) from October 2007 until June 2010.



Furthermore, the distribution of this variation can vary across years due to differences caused by hybrid effects, growing conditions, and harvest management. This variation in ruminal starch digestion can cause differences in ruminal propionate production, which can affect energy metabolism and DMI in lactating dairy cows through mechanisms described by the Hepatic Oxidation Theory (**HOT**; Allen et al., 2009). A variation of this theory is demonstrated by a summary of studies conducted at the Longview Animal Nutrition Center (**LANC**; Gray Summit, MO) involving 4750 observations of cows in early and mid-lactation (Figure 2). From these data, the relationship between DMI and percent dietary starch in the diet was determined, taking into account days in milk (**DIM**) and cow parity. As observed in Figure 2, DMI was unaffected by dietary starch level in very early lactation with either primiparous or multiparous cows. From 30 to approximately 180 DIM, however, intake was depressed by feeding 25 vs. 15 % diets in either parity.

A further example of the effects of dietary starch levels and ruminal digestibility on performance can be seen in a study conducted at the LANC with early lactation cows (DC #479). From wk 4 through 12 of lactation, 66 cows (22/ treatment) were fed diets differing in starch level and ruminal digestibility. After 3 wk on a common diet, cows were changed over to either a low (20 %) or one of two high (28 %) starch diets. The high starch diets had either all the supplemental starch in the form of fine ground corn or a 50 % replacement with fine ground milo (which had a lower rate of ruminal starch fermentation). When half the corn in treatment 3 was replaced with milo in treatment 4, DMI was improved by 1.0 kg/d (2.2 lb/d; $P < 0.01$; Figure 3) and 3.5 % fat corrected milk (**FCM**) production was significantly improved by 2.6 kg/d (5.7 lb/d; $P < 0.01$; Figure 4). Oba and Allen (2003) observed an 8 % reduction in feed intake when providing corn in the diet in a more fermentable form as high moisture vs. dry grain, but only on a higher starch diet. These studies support the potential for DMI and milk production depression when replacing dry corn in the diet with starch from more ruminally available sources, like high moisture corn or corn silage. Furthermore, it is apparent that controlling the consequences of variation in ruminal starch digestion by using *crude* starch formulation standards is inadequate. Rather, formulation standards for *ruminal digestion* of starch are needed.

Figure 2. Summary of studies conducted at the Longview Animal Nutrition Center (LANC; Gray Summit, MO) involving 4750 observations of cows in early and mid-lactation. From these data, the relationship between DMI and percent dietary starch in the diet was determined, taking into account days in milk (DIM) and cow parity.

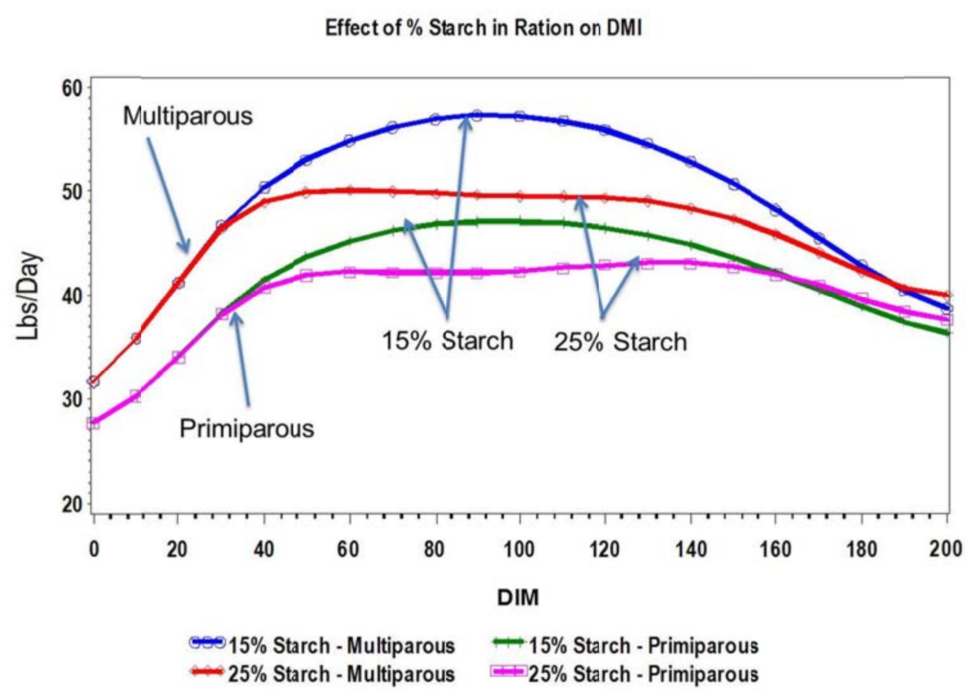


Figure 3. After 3 wk on a common diet, cows were changed over to either a low (20 %; treatment 2) or one of two high (28 %) starch diets. The high starch diets had either all the supplemental starch in the form of fine ground corn (treatment 3) or a 50 % replacement with fine ground milo (which had a lower rate of ruminal starch fermentation; treatment 4). When half the fine ground corn in treatment 3 was replaced with fine ground milo in treatment 4, DMI was improved by 1.0 kg/d (P < 0.01).

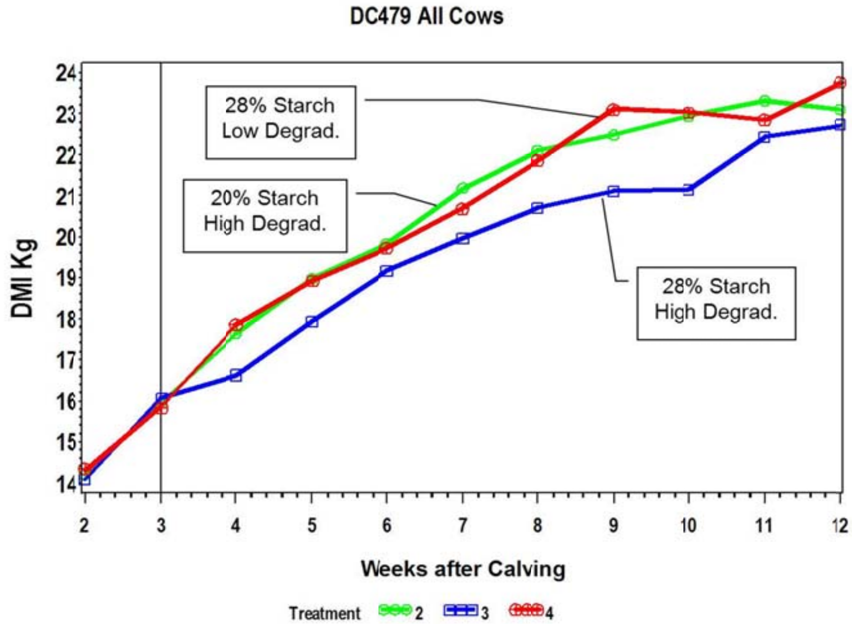


Figure 4. After 3 wk on a common diet, cows were changed over to either a low (20 %; treatment 2) or one of two high (28 %) starch diets. The high starch diets had either all the supplemental starch in the form of fine ground corn (treatment 3) or a 50 % replacement with fine ground milo (which had a lower rate of ruminal starch fermentation; treatment 4). When half the corn in treatment 3 was replaced with milo in treatment 4, fat corrected milk (FCM) production was significantly improved by 2.6 kg/d (P < 0.01).

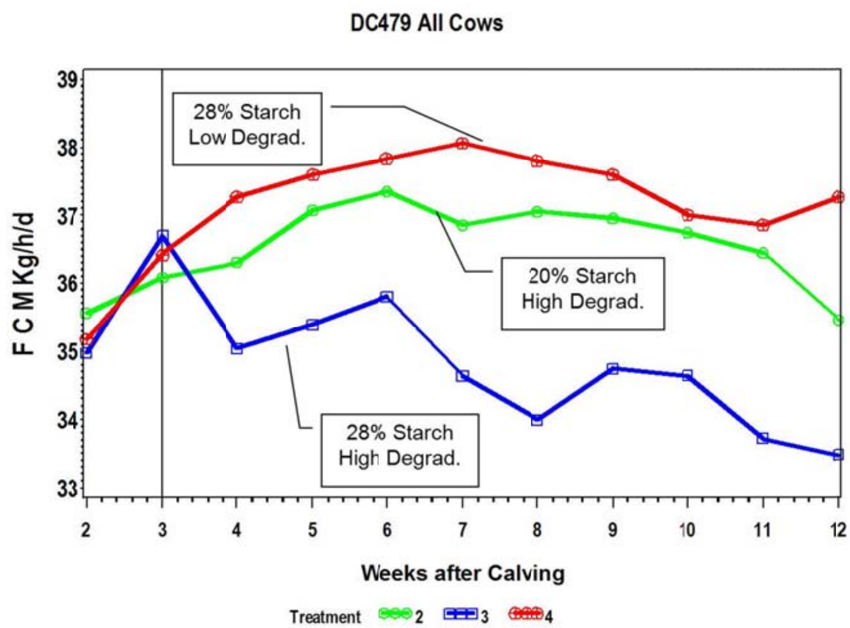


Table 1. Three corn silage hybrids were fed to lactating cows in diets containing 40 % corn silage with and without 3 % wheat straw. While adding wheat straw reduced the formulated diet energy density, subsequent measures of in vivo digestibility of DM were increased by 3 % across all three hybrids (P < 0.05; DCM #145).

	Diet						
	1	2	3	4	5	6	SE
Wheat Straw, %	0	0	0	3	3	3	
Corn Silage Hybrid[1]	6818	6100	6831	6818	6100	6831	SE
DMI, lb/d	46.3	41.6	44.1	44.7	47.8	42.7	2.2
DM Digested, % of intake[2]	64.0[a]	65.5[ab]	65.3[ab]	66.6[ab]	68.0[b]	66.1[ab]	1.2
NDF Digested, % of intake[3]	32.9[a]	38.7[ab]	34.7[a]	38.1[a]	46.5[b]	36.4[a]	2.8

[1] Croplan Genetics, Winfield Solutions, Shoreview, MN.
[2] Dry Matter Digested; significant (P < 0.05) effect by straw level. Means not followed by a common letter differ (P < 0.05) using LSD procedure.
[3] Neutral Detergent Fiber Digested; significant effect by straw level (P <. 0.04) and hybrid (P < 0.03). Means not followed by a common letter differ (P < 0.05) using LSD procedure.

CONSEQUENCES FROM VARIATION IN RUMINAL FIBER DIGESTION

A frequently quoted metric of the relationship between dietary NDF digestibility and performance in dairy cattle comes from the data summary by Oba and Allen (1999). Relating data from 13 sets of forage comparisons reported in the literature, they concluded that a one (1) percentage unit increase in NDF digestibility (measured *in vitro* or *in situ*) resulted in a 0.37 lb increase in DMI and a 0.55 lb increase in fat-corrected milk. The authors further observed that the relationship was confined to animals of high production that were more likely to exhibit intake suppression from reaching bulk fill limits. A more recent further evaluation of this relationship for 11 corn silage comparisons reported in the literature showed a 0.26 lb/d increase in DMI and a 0.47 lb/d increase in 4 % fat corrected milk per one (1) unit increase in *in vitro* NDF digestion (IVNDFD; Oba and Allen, 2005).

However, the increase in DMI resulting from feeding forages of higher IVNDFD can come at the cost of reduced diet digestibility and potential feed efficiency, as a consequence of reduced residence time of feedstuffs in the digestive tract. This relationship was observed in a recent study (DCM #145) conducted at the LANC, where 3 corn silage hybrids were fed in diets containing 40 % corn silage with and without 3 % wheat straw. While adding wheat straw reduced the formulated diet energy density, subsequent measures of *in vivo* digestibility of dry matter (**DM**) were increased by 3 % (P < 0.05) across all 3 hybrids (Table 1). Additionally, NDF digestibility was improved (P < 0.04) on the straw containing diets (Table 1). Both observations were presumably due to increased residence time of the diet in the rumen when straw was included, despite DMI not being significantly affected.

This would suggest that there may be an optimum mass of digesting NDF, above which intake is limited by bulk fill and below which intake can increase; but possibly at the expense of reduce digestion and, subsequently, feed efficiency. This is in line with the NDF-Energy Intake System recently revisited by D.R. Mertens (2009) where he suggests that there is a unique solution for dietary NDF at each milk production level at which the fill limitation and energy demand curves intersect. Each solution defines the NDF level that maximizes both DMI and maximum NDF (and forage) in the diet. Mertens (2010) further mentions that while the optimum NDF level can be fine-tuned for differences in NDF digestibility, the effect from changing crude NDF is 2 to 3 times greater than changing the digestibility of the NDF. However, one could argue that in practical situations where dietary NDF has reached maximum fill potential in high producing cows, the digestibility of the NDF can take on relatively greater importance.

A METHOD FOR OPTIMIZING HIGH CORN SILAGE DIETS

Using principles from both the HOT and the NDF-Energy Intake System, along with data from the LANC, a straightforward model was designed to better manage starch and forage fiber containing ingredients in the diet through chemical and *in vitro* testing of the digestibility of those ingredients. One example of the model's use could be to better control variation in lactating dairy cow performance that can arise from the use of high (50 to 60 % of diet DM) corn silage diets.

Two rations were formulated to meet nutrient requirements for 95 lb of milk containing 3.5 % fat and 3.1 % protein (Dynamic Nutrition System, 2008). Both diets contained 60 % forage (DM basis), with one diet containing a lower level (30 %) of corn silage with 30 % alfalfa hay and the other diet containing a higher level (55 %) of corn silage with 5 % alfalfa hay. For demonstration purposes, formulation targets were assumed for fixed daily amounts of starch digested in the rumen and forage NDF passing from the rumen per day. In practice, these amounts can be predicted from *in vitro* or *in situ* digestibility measurements on the total diet or individual constituent ingredients. The level of corn silage (55 %) in the high corn silage diet was chosen as the level required to avoid additional supplementation with ground dry shelled corn.

The rations can be seen in Table 2. Ingredient prices were selected from the central U.S. market on March 1, 2011 (The Jacobsen report, 2011; USDA-IL Department of AG Market News, Springfield, IL, 2011). The higher corn silage diet bears a number of nutritional limitations. The lower dietary starch level is the result of the greater ruminal starch digestion of the corn in corn silage, as compared with the dry shelled corn being replaced. This limits the amount of energy contributed from corn. Therefore, animal fat was incorporated into the diet up to a level of 1 lb/d to make up a portion of the energy deficit. On balance, however, the metabolizable energy (ME) content of the high corn silage diet was 0.03 mcal/lb DM lower than the lower corn silage diet. At a DMI of 51 lb of DM/d, the resulting loss in ME intake was 1.53 mcal/d which could result in a 2.8 lb milk loss if not compensated by a 1.2 lb increase in DMI.

Table 2. Two rations were least cost formulated to meet nutrient requirements for 95 lb of milk containing 3.5 % fat and 3.1 % protein, with a 51 lb DMI.[1] Both diets contained 60 % forage (DM basis), with one diet containing a lower level (30 %) of corn silage with 30 % alfalfa hay and the other diet containing a higher level (55 %) of corn silage with 5 % alfalfa hay. For demonstration purposes, formulation targets were assumed for fixed daily amounts of starch digested in the rumen and forage NDF passing from the rumen per day.

	Cost, $/ton (3/1/2011)	**Low Corn Silage**	**High Corn Silage**
		- -- - Lb “as fed”- - - - -	
Alfalfa hay	180	17	2.8
Corn silage	45	43.7	80.1
Corn, fine ground	270	10.1	0
Soybean hulls	180	4.1	8.9
Soybean meal (SBM)	375	0.4	7.9
Protected SBM	415	6.9	3.4
Animal fat	930	0.4	0.92
Wheat straw	110	0	0
Vit/Mineral mix	900	1.35	1.65
Total, lbs "as fed"		83.95	105.67
Percent of starch dig. target		100	102
Crude starch, % of DMI		24	20
Percent of NDF dig. target		101	99
Forage NDF, % of DMI		23.8	25.5
ME, mcal/lb DM		1.28	1.25
MP, % of DMI		12.3	12.3
TMR cost, $/hd/d		$6.55	$6.21

[1] Dynamic Nutrition System, 2008, Dalex Livestock Solutions, LLC.
[2] The Jacobsen, 2011, Chicago, IL; USDA-IL Dept. of AG Market News, Springfield, IL.
[3] These diets are provided for demonstration purposes only and should not be fed without additional consultation with, and recommendations from, your nutritionist.
[4] Metabolizable Energy
[5] Metabolizable Protein

The apparent feed cost savings of the high corn silage diet was $6.55 - $6.21 = $0.34/cow/d using current ingredient costs (3/1/2011). However, on the high corn silage diet, the savings will be reduced by either lost milk (2.8 lb milk x $0.16/lb milk = $0.45) or higher feed intake (1.2 lb feed x $0.12/lb feed = $0.15), because of starch limits in the diet as a result of the high ruminal fermentability of the corn in corn silage. In an attempt to see if the potential cost savings varies with differently priced ingredient markets, the same diets were compared using lower ingredient costs from a year earlier (3/1/2010). The apparent feed cost savings from the high corn silage diet was $4.94 - $4.50 = $0.44/cow/d, suggesting that the savings are probably similar across differently priced ingredient markets; presumably because ingredient prices tend to move in unison.

Further complicating matters with higher corn silage diets is the increasing percentage of the starch that becomes ruminally digestible with advancing ensiled storage (Allen et al., 2003). This is thought to be due, in part, to increased solubility of the proteins in the endosperm matrix, allowing greater availability of the starch granules to digestion by ruminal microorganisms. If the corn (starch) content of the silage is high at harvest, the resulting increase in ruminal starch fermentability that can evolve by late spring through the summer can result in poorer DMI and lower milk fat. Therefore, high corn yields in corn silage may not be desirable for high corn silage containing feeding programs. Lastly, differences throughout the corn crop at harvest can cause variation in the content and ruminal digestibility of starch and NDF within the corn silage storage structure, which in turn will impact performance. For these reasons, frequent testing of ingredient ruminal starch and fiber digestion should allow for diet formulation adjustments to maintain consistency of diet ruminal digestibility in response to these sources of variation.

CONCLUSION

Dry matter intake and digestibility in dairy cows are influenced in great part by the consequences of digestibility of starch and fiber in the rumen. Formulating to crude starch and fiber dietary standards will not account for the variation in digestibility, potentially leading to differences in dairy cow performance. Rather, a method for rapid testing of the digestibility of ingredients, combined with formulating to known dietary targets, should better optimize ingredient use and animal performance. Formulating diets with high levels of corn silage should benefit from this approach. The relatively large variation that can occur in ruminal starch digestion from corn silage, coupled with potential variation in the digestibility of the NDF, can lead to losses in DMI (brought about by the hepatic oxidation and bulk fill limitations) or diet digestibility (brought on by decreased ruminal retention of ingredients). The high corn silage diet example, provided, suggests that such diets can be limited in their energy content by the level and ruminal digestibility of the starch coming from the corn. However, such diets could provide an opportunity to save on diet cost by reducing amounts of purchased corn.

LITERATURE CITED

Allen, M. S. 2000. Effects of diet on short-term regulation of feed intake by lactating dairy cattle. J. Dairy Sci. 83:1598-1624.

Allen, M. S., R. J. Grant, G. W. Roth, W. P. Weiss, and J. F. Beck. 2003. Effect of endosperm type of corn grain on starch degradability by ruminal microbes in vitro. J. Dairy Sci. 86(Suppl. 1):61.

Allen, M. S., B. J. Bradford, and M. Oba. 2009. The hepatic oxidation theory of the control of feed intake and its application to ruminants. J. Anim. Sci. 87:3317-3334.

Dynamic Nutrition System. 2008. Dalex Livestock Solution, LLC. Bloomington, MN 55437.

Mertens, D. R. 2009. Maximizing forage use by dairy cows. Western Canadian Dairy Seminar, Advances in Dairy Technology 21:303-319.

Mertens, D. R. 2010. NDF and DMI – Has anything changed? *In:* Proc. Cornell Nutr. Conf. Feed Manuf., Ithaca, NY, Pp. 160-174.

Oba, M., and M. S. Allen. 1999. Evaluation of the importance of the digestibility of neutral detergent fiber from forage: Effects on DMI and milk yield of dairy cows. J. Dairy Sci. 82:589-596.

Oba, M., and M. S. Allen. 2003. Effects of corn grain conservation method on feeding behavior and productivity of lactating dairy cows at two dietary starch concentrations. J. Dairy Sci. 86:174-183.

Oba, M., and M. S. Allen. 2005. In vitro digestibility of forages. Pp. 81-91 *In:* Proc. Tri-State Dairy Nutr. Conf., Dept. Dairy Sci., The Ohio State University, Columbus, Ohio 43210.