Getting the Most from Dietary Starch

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▪ Take Home Messages

- Reduced starch diets may be acceptable for lactating dairy cows when using digestible or soluble fiber to partially replace starch.
- Type of endosperm, particle size, maturity and moisture content, and conservation and processing methods influence the digestibility of starch from corn grain and corn silage by dairy cows.
- The inclusion of exogenous enzymes with amylolytic activity in reduced-starch diets for dairy cows may play a role in the future to increase feed conversions.

▪ Introduction

The optimum starch content of diets fed to lactating cows is not well defined, but 24% to 26% starch (DM basis) has been suggested (Staples, 2007). Kaiser and Shaver (2006) and Bucholtz (2006), from surveys of high producing (>13,650 kg Rolling Herd Average) dairy farms in Wisconsin (n = 9) and Michigan (n = 18), respectively, reported starch concentrations of diets fed to lactating cow groups ranging from 25% to 30% (DM basis). With today's high grain prices, however, there is increased interest in feeding diets that are lower in starch content than what has been the norm. The purpose of this paper is to evaluate the potential for using digestible or soluble neutral detergent fiber (NDF) from byproduct feeds to partially replace starch from corn grain in diets fed to lactating dairy cows. Potential modifying effects of starch digestibility on lactation performance by dairy cows fed reduced starch diets will also be examined.

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▪ Partial Replacement of Dietary Starch with Digestible or Soluble NDF

Voelker and Allen (2003) fed mid-lactation cows diets containing 35, 31, 27 and 18% starch (DM basis); high-moisture corn was replaced by 6, 12 and 24% pelleted beet pulp (DM basis) to formulate diets with decreasing starch content. Effects of decreasing dietary starch content were linear ($P < 0.05$) for dry matter intake (DMI) and quadratic ($P < 0.07$ and 0.03, respectively) for FCM and fat yields. Relative to the average for the 27 and 31% starch diets, feeding the 18% starch diet reduced DMI, fat-corrected milk yield and fat yield by 9%, 4% and 5%, respectively; true protein (TP) content and yield were numerically reduced by 4% and 5%, respectively.

Broderick et al. (2002) fed mid lactation cows diets containing 31 or 20% starch (DM basis); dry cracked corn was replaced by 19% dried citrus pulp (DM basis) to formulate the low-starch diet. Feeding the low starch diet reduced DMI ($P < 0.02$), milk yield ($P < 0.02$), fat yield ($P < 0.03$), TP content ($P < 0.01$) and yield ($P < 0.01$) by 8%, 11%, 14%, 4% and 20%, respectively.

Ipharraguerre et al. (2002) fed mid-lactation cows diets containing 28, 23, 17, 13 and 7% starch (DM basis); dry ground corn was replaced by 10, 20, 30 and 40% pelleted soyhulls (DM basis) to formulate diets with decreasing starch content. Decreasing dietary starch content decreased linearly DMI ($P < 0.06$) by 7% and increased linearly milk fat content ($P < 0.004$) and fat yield ($P < 0.001$) by 8% and 10%, respectively. Yield of TP tended ($P < 0.09$) to be reduced by 5% for the lowest starch diet relative to the 28% starch diet. There were no differences between the 17% and 23% starch diets. Comparing the average of the 7% and 13% starch diets to the average of the 17%, 23% and 28% starch diets, feeding the low starch diets numerically reduced DMI, milk yield and TP yield by 6%, 3% and 3%, respectively; milk fat content and yield were each numerically increased by 8%. Stone (1996) reported no differences between 25% and 16% starch diets fed to early lactation cows with high-moisture corn being replaced by 19% soyhulls (DM basis) to formulate the low-starch diet.

Batajoo and Shaver (1994) fed mid-lactation cows diets containing 30, 26, 21, and 15% starch (DM basis); dry ground corn was replaced by 0-10% wheat midds, 3-20% brewers dried grains and 0-9% soyhulls (DM basis) to formulate diets with decreasing starch content. Decreasing dietary starch content decreased ($P < 0.05$) linearly DMI, milk TP content and TP yield by 7%, 4% and 6%, respectively, and increased ($P < 0.05$) linearly fat content by 3%. Adverse effects of low starch diets on DMI, TP content and TP yield were more apparent for the 15% starch diet than the 21% starch diet. Staples (2007), from a review of 14 trials with lactating dairy cows where corn gluten feed partially replaced grains, protein meals or forages with dietary starch concentrations ranging across the trials from 15% to 40% (DM basis), concluded that 21% starch diets may be acceptable.

Results from these relatively short-term dairy cattle feeding trials suggest that reduced-starch diets formulated by partially replacing corn grain in diets with high-fiber, low-starch byproduct feedstuffs may be feasible, but longer-term lactation trials and trials with higher producing cows are warranted. Further, the cost of using digestible or soluble NDF from byproduct feeds to partially replace starch from corn grain needs to be evaluated for the various high-fiber byproduct sources on a local basis relative to corn and protein supplement prices.

■ Starch Digestibility

Total tract digestibility of starch by dairy cows is variable ranging from 70% to 100% (Firkins et al., 2001). Various factors including particle size (fine vs. coarse grind), grain processing (steam flaked vs. dry rolled), storage method (dry vs. high-moisture corn), moisture content of high-moisture corn, type of corn endosperm, and corn silage maturity and processing, influence the digestibility of starch by dairy cows (Nocek and Tamminga, 1991; Johnson et al., 1999; Firkins et al., 2001).

Kernel vitreousness, the ratio of vitreous to floury endosperm, has been used to assess the type of corn endosperm (Ngonyamo-Majee et al., 2008a, b). Increased kernel vitreousness reduced ruminal in situ corn starch degradation (Correa et al., 2002; Ngonyamo-Majee et al., 2008b). Kernel vitreousness was lower and ruminal in situ starch degradation was greater for dry corn with floury or opaque endosperm than with normal dent endosperm (Ngonyamo-Majee et al., 2008a, b). Taylor and Allen (2005) reported greater ruminal and total tract starch digestibilities in ruminally and duodenally cannulated lactating dairy cows for floury (3% vitreousness) vs. normal dent (67% vitreousness) endosperm dry corn.

Highly vitreous corn types contain higher concentrations of prolamin proteins than floury or opaque corn types (Hamaker et. al., 1995; Larson and Hoffman, 2008). Starch granules in the corn endosperm are surrounded by hydrophobic prolamin proteins which are slowly degraded (McAllister et al., 1993). Lopes et al. (2009) conducted an experiment to evaluate the effect of type of corn endosperm on nutrient digestibility in lactating dairy cows using near-isogenic variants of a normal dent endosperm hybrid carrying floury-2 or opaque-2 alleles. The percentage vitreous endosperm was zero for floury and opaque endosperm corns and 64% for the vitreous corn. Prolamin protein content of floury and opaque endosperm corns was 30% of the content found in vitreous corn. Starch disappearance after 8-hr ruminal in situ incubation was 32% units on average greater, respectively, for floury and opaque endosperm corns than vitreous corn. Total-tract starch digestibility was 6.3% units, on average, greater for cows fed diets containing floury and opaque endosperm corns than vitreous corn.

The impact of the digestibility of corn grain starch on lactation performance by dairy cows was reviewed by Firkins et al. (2001). Based on regressions from the data of (Firkins et al., 2001), increasing starch digestibility increased milk and protein yields ($R^2 = 0.89$; $P < 0.01$) and reduced milk fat percentage ($R^2 = 0.58$; $P < 0.05$) but not yield. When in concurrence with the feeding of low-starch diets, however, increasing starch digestibility may be less likely to result in reduced milk fat percentage. But, research is limited on the impact of increasing starch digestibility in reduced-starch diets on lactation performance by dairy cows.

■ Reduced Starch Diets and Improving Starch Digestibility

Gencoglu et al. (JDS In press) conducted a lactation trial to determine lactation performance responses in high-producing dairy cows to a reduced-starch versus a normal-starch diet and to the addition of exogenous amylase to the reduced-starch diet. Some exogenous enzymes are resistant to ruminal degradation (Hristov et al., 1998), and thus may offer potential for improving diet digestibility and animal performance. Klingerman et al. (2009) reported that exogenous amylase addition to a normal-starch diet (26% of DM) increased milk yield by dairy cows; positive in vitro and in vivo digestibility responses to exogenous amylase were also observed.

In the trial of Gencoglu et al. (JDS In press), 36 multiparous Holstein cows (51 ± 22 DIM at trial initiation) were randomly assigned to 1 of 3 treatments in a completely randomized design; a 3-wk covariate adjustment period with cows fed the normal-starch diet followed by a 12-wk treatment period with cows fed their assigned treatment diets. The normal-starch TMR did not contain exogenous amylase (NS-). The reduced-starch diets, formulated by partially replacing corn grain with soy hulls, were fed without (RS-) and with (RS+) exogenous amylase addition to the TMR. Starch concentrations averaged 27.1%, 21.8% and 20.7% (DM basis) for the NS-, RS- and RS+ diets, respectively.

Dry matter intake for cows fed RS- was 2.4 and 3.2 kg/d greater than for cows fed NS- and RS+, respectively. Milk yield averaged 50.4 kg/d and was unaffected by treatment. Fat-corrected milk yield was 2.9 kg/d greater for cows fed RS- than for cows fed NS-. Body weight and condition score measurements were unaffected by treatment. Fat-, solids-, and energy-corrected milk feed conversions (kg / kg DMI) were 12% to 13% greater for cows fed RS+ than for cows fed RS-. Dry matter and nutrient digestibilities were lowest for cows fed NS- and greatest for cows fed RS+, and were greater for cows fed RS+ than for cows fed RS- with the exception of starch digestibility which was similar. Greater conversion of feed to milk for dairy cows fed reduced-starch diets with inclusion of exogenous amylase may offer potential for improving economic performance depending on diet and additive costs.

■ Conclusions

Lactation performance was reduced for 18% and 20% starch diets (DM basis) formulated using beet pulp and citrus pulp, respectively, to partially replace corn grain. However, lactation performance was not reduced for diets as low as 16% to 17% starch (DM basis) formulated using soy hulls to partially replace corn grain. Diets containing 21% starch (DM basis) were acceptable when high-fiber, moderate protein byproduct feeds were used to partially replace corn grain and protein supplement. The starch in low-starch diets should be highly digestible. Various factors, including type of endosperm, particle size, maturity and moisture content, and conservation and processing methods, influence the digestibility of starch from corn grain and corn silage by dairy cows. The inclusion of exogenous enzymes with amylolytic activity in reduced-starch diets for dairy cows may play a role in the future.

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