Alternatives to Corn for Dairy Rations

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Introduction

A two- to four-fold increase in corn prices in recent years over historical trends has prompted many questions about alternatives to corn for dairy rations. As corn is a low protein - high energy feedstuff, its continued use even with high prices or concern over its partial replacement is mainly confined to rations for lactating cows where meeting the energy requirements of milk production is important. Thus, rations for lactating cows will be the focus of this paper.

Since about three-fourths of the energy value of corn is provided by its starch content (calculated from NRC, 2001) and starch is thought to be an important carbohydrate fraction of lactating cow rations (Akins et al., 2012a,b; Allen, 2012), the partial replacement of starch from corn grain with alternative strch or other carbohydrate sources will be discussed herein. Because corn price influences the price of corn alternatives, milk prices vary and partial corn replacement can impact lactation performance, it is imperative that the following parameters be closely evaluated when considering or implementing corn replacement strategies: feed cost per unit ration dry matter (**DM**), DM intake (**DMI**), total feed cost per cow, milk yield, composition and component yields, actual and component-corrected feed efficiencies, income over feed costs (**IOFC**), and body condition.

Corn Alternatives

Byproduct Corn Starch

Krause et al. (2003) fed total mixed rations (**TMR**) containing 0, 6, 12 or 18% refined corn starch (**RCS**; DM basis) to mid-lactation Holstein cows. Dry cracked shelled corn was reduced from 39% to 14% and dry corn gluten feed (**DCGF**) increased from 0% to 6% of ration DM for 0% compared to 18% RCS rations. Dietary starch content averaged 31% (DM basis) across the four treatments. Milk yield was unaffected by treatment, but DMI, energy-corrected milk yield (**ECM**), and milk fat and protein percentages were greatest for the 6% RCS treatment. Greatest ECM/DMI was observed for the 18% RCS treatment, and coincident with the greatest ruminal propionate concentration which can influence DMI (Allen et al., 2009; Oba and Allen, 2003). Possibly the reduction in milk fat by 0.29%-units on average observed for the 12% and 18% RCS treatments could have been avoided at reduced dietary starch concentrations.

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Barley and Wheat Grain

A recent meta-analysis addressed the performance of lactating dairy cows fed barley or wheat compared to corn (Ferraretto et al., 2013). Cows fed corn-grain based diets consumed 5.7 lb/d more DM, on average, than cows fed barley- or wheat-grain-based diets. Milk and fat-corrected milk (**FCM**) yields were 7.9 and 9.0 lb/day per cow, respectively, greater, on average, for corn- than barley- or wheat-grain based diets. Actual milk and FCM feed efficiencies were unaffected by treatment. Likewise, milk fat, protein, and urea nitrogen concentrations were unaffected by treatment and averaged 3.51%, 3.13%, and 13.7 mg/dL, respectively.

Ruminal starch digestibility was 17%-units and 25%-units greater for barley and wheat, respectively, than corn. Total tract starch digestibility did not differ among treatments. Ruminal and total tract neutral detergent fiber digestibility (**NDFD**) were similar among treatments. Greater rate and extent of ruminal starch digestion and greater ruminal protein degradability need to be accounted for when formulating rations with barley or wheat as opposed to corn. This is often accomplished by partial rather than full replacement of corn with these alternative cereal grains.

Hominy Feed

Cooke et al. (2009) compared hominy feed (**HF**) to dry ground shelled corn (**DGSC**) and steam-flaked corn (**SFC**) in mid lactation dairy cows fed varying proportions of corn silage and ryegrass silage. Starch and neutral detergent fiber (**NDF**) concentrations of the HF were 47% and 26% (DM basis), respectively, compared to 66% and 14%, on average, for DGSC and SFC. By comparison the national research council (**NRC**, 2001) shows NDF content for HF of 21.1% ± 5.5 (DM basis), which would put starch content at about 52% on average by difference calculation. The HF, DGSC and SFC were each fed at 35%, 33%, 30% and 28% of ration DM as the proportion of corn silage in the forage mixture increased from 0 to 25%, 50% and 75%. Dietary starch concentrations were 2%- to 4%-units lower for HF- compared to DGSC- and SFC-based TMR.

The DMI was greater and milk fat content tended to be greater for DGSC than HF or SFC, while milk yield was similar averaging 31 kg/d per cow across the treatments. Total tract DM and organic matter digestibilities were greater for HF and SFC than DGSC, but NDFD was reduced for HF compared to DGSC and SFC. While starch digestibility was not reported, the above results in concert suggest greater ruminal and total tract starch digestibilities for HF than DGSC which would not be unexpected considering the fine particle size of HF (Larson et al., 1993).

Sugar Supplements

Broderick and Radloff (2004) partially replaced starch from high-moisture shelled corn with sugar from either dried (Trial 1) or liquid (Trial 2) molasses. Dietary starch and total sugar concentrations (DM basis) ranged from 31.5% to 23.2% and 2.6% to 7.2%, respectively, in Trial 1, and from 31.4% to 26.1% and 2.6% to 10.0% in Trial 2. The estimated overall optimum for total dietary sugar, based on yields of fat and FCM in Trial 1 and yields of milk and protein in Trial 2, was 5.0% (DM basis); feeding diets with more than 6% total sugar with the added sugar from molasses appeared to depress milk production. Broderick et al. (2008) partially replaced byproduct corn starch with sucrose. Dietary starch and total sugar concentrations (DM basis) ranged from 28.2% to 21.5% and 2.7% to 10.0%, respectively. Milk yield was unaffected by treatment, but milk fat yield was greatest for the diet containing 7.1% total sugar and 24.5% starch (DM basis).

Alternatives for high-sugar ingredients include molasses, whey, whey permeate, liquid feed supplements, and sucrose. For an excellent review on the feeding of whey permeate, readers are referred to Cotanch et al. (2006). Wet sugar additives, such as liquid feed supplements, liquid molasses, whey or whey permeate, may also improve palatability and (or) reduce sorting of the TMR.

Glycerin

Donkin et al. (2009) evaluated glycerin, a byproduct of biodiesel production, as a replacer of corn in rations fed to lactating dairy cows. Refined glycerin (**RG**) was included in TMR at 0, 5, 10 and 15% of ration DM while DGSC was reduced from 20% to 3% of ration DM for zero to the highest level of RG addition. Lactation performance was unaffected by treatment in late lactation cows averaging about 37 kg/d per cow.

Shin et al. (2012) evaluated crude glycerin (**CG**; 0.4% methanol) as a replacer of concentrate ingredients including DGSC in rations fed to mid lactation dairy cows fed two different roughage sources. The CG was included in TMR at 0, 5, and 10% of ration DM while DGSC was reduced from 18% to 8% (corn silage as main roughage source in low total NDF rations) or 32% to 22% (cottonseed hulls as main roughage source in low forage NDF rations) for zero to the highest level of CG addition. Milk fat content and yield and total tract NDFD were reduced by feeding the 10% CG ration for both roughage sources, while feeding the 5% CG ration increased DMI but not milk yield. Feeding CG increased FCM/DMI for the corn silage based rations but decreased FCM/DMI for the cottonseed hulls based rations. Molar proportions of ruminal propionate, butyrate and valerate were increased while acetate was decreased by feeding CG.

High Fiber – Low Starch Byproduct Feeds

There are a myriad of high NDF – Low Starch byproducts (**HFLS**) fed to dairy cows (Shaver, 2005). The HFLS can be used to partially replace corn grain, forage or both depending on ration nutrient needs and ingredient availability and price. Low protein HFLS, such as soy hulls (**SH**) or beet pulp which are high in digestible or soluble fiber, usually get used for a direct pound for pound corn replacement. Whereas, middle protein HFLS, such as CGF, brewers grains or distillers grains, often partially replace both corn grain and oilseed meals on a protein equivalence basis; i.e. one lb. DM of

HFLS replaces about 0.5 lb. corn and 0.5 lb. oilseed meal. Alternatively, these middle protein HFLS can be used to partially replace forage NDF (Bradford and Mullins, 2012). Whole cottonseed (**WCS**) and cottonseed hulls are the classic middle and low protein, respectively, HFLS forage replacers.

We conducted four recent continuous-lactation (12 - 14 weeks on treatment) feeding experiments at UW-Madison (Gencoglu et al., 2010; Ferraretto et al., 2011 and 2012; Akins et al., 2012a, b) to evaluate HFLS as partial corn grain replacers in mid lactation cows. The forage-NDF concentrations were 20% - 21% across all diets with 5% to 10%-units less starch for reduced-starch (**RS**) than normal-starch (**NS**) diets. Milk yield for cows fed the NS diet ranged from 42 to 52 kg/cow/d across the four trials.

Dry matter intake was greater for RS than NS in 3 of 4 trials (unaffected by treatment in Akins et al., 2012). Greater DMI for RS than NS may be related to reduced ruminal propionate concentration (Allen, 1997; Beckman and Weiss, 2005) leading to increased meal size and consequently greater DMI (Allen et al., 2009).

Actual milk yield was similar for cows fed RS and NS in two trials with SH (Gencoglu et al., 2010; Ferraretto et al., 2012), was lower for RS than NS in the SH trial of Akins et al. (2012a, b), and tended to be lower for RS than NS in the trial with WCS and wheat midds (**WM**; Ferraretto et al., 2011). Because WCS and WM are moderate-protein HFLS, they partially replaced both corn grain and soybean meal (**SBM**) in the RS diet (Ferraretto et al., 2011). Greater ruminal protein degradation for these ingredients compared to SBM along with reduced rumen microbial protein production for RS may have decreased metabolizable protein flow, which could partially explain the decrease in milk yield (NRC, 2001).

Responses for milk yield corrected for concentrations of fat, protein and lactose (solids-corrected milk; **SC**M) were inconsistent with either greater (Gencoglu et al., 2010), trend for lower (Ferraretto et al., 2011), or similar (Ferraretto et al., 2012; Akins et al., 2012a,b) SCM observed for RS compared to NS. A recent meta-analysis by Ferraretto et al. (2013) found that milk yield and protein content were increased and fat and urea nitrogen contents decreased with increasing dietary starch concentrations. Body weight gain was not different for cows fed RS compared to cows fed NS across the four UW Madison trials. Ruminal and total tract NDF digestibilities decreased with increasing dietary starch concentrations in the meta-analysis reported by Ferraretto et al. (2013).

Feed efficiencies, across the four trials, were reduced for RS compared to NS by 2% to 12% for Milk/DMI and by 1% to 11% for SCM/DMI. Reduced feed efficiency for dairy cows fed RS diets creates an economic concern for nutritionists desiring to use this formulation strategy to reduce diet cost per unit of DM. Midwest USA market prices for feed ingredients and milk were applied to ration ingredient composition, DMI and milk production data from the four trials to estimate feed costs and IOFC. Feed costs per unit DM were reduced in all four trials by 1% to 8% for RS. Feed costs per cow per day for RS, however, were increased for two trials by 3% to 8% and decreased for two trials by only 1% to 2%. Estimates of IOFC were unaffected in one trial, and decreased in three trials by 4% to 7% for RS.

Feed efficiency and IOFC results indicate that for high producing cows in early- to mid- lactation, partially replacing corn grain with HFLS to formulate RS diets was not beneficial. Reduced market prices for HFLS relative to corn grain and soybean meal would improve the economics of feeding RS compared to NS diets. Furthermore, RS diets formulated by partially replacing starch from corn grain with NDF from HFLS may offer more potential for beneficial responses when fed to lower producing, later lactation cows than evaluated in the trials reviewed herein (Allen, 2012; Bradford and Mullins, 2012). Also, the use of HFLS to partially replace forage NDF may allow for the feeding of RS diets without sacrificing lactation performance (Bradford and Mullins, 2012).

Monensin. Akins et al. (2012a, b) hypothesized that monsensin would reduce DMI and thus improve efficiency (Duffield et al., 2008) more with RS than NS rations. The RS ration was formulated by partially replacing DGSC with SH. Mid-lactation dairy cows (n = 128) were stratified by breed, parity and days in milk, and randomly assigned to one of 16 pens with 8 cows each per pen in the UW-Madison Emmons-Blaine Arlington free-stall, parlor facility. Pens were randomly assigned to 1 of 4 treatments in a 2 × 2 factorial arrangement of treatments (RS vs. NS and Control vs. Monensin) for a continuous-lactation feeding trial. Inclusion of monensin in the TMR at 18 g/ton DM improved lactation performance and measures of feed efficiency for both RS and NS rations. There were few significant interactions between dietary starch content and monensin supplementation, thereby supporting the use of monensin in both normal- and reduced-starch rations. Dietary monensin supplementation increased ration net energy content by 2.8% as calculated from body weight, weight gain, milk energy output and DMI data. Based on trial DMI and an assumed net energy content of DGSC (NRC, 2001), this increase in energy utilization calculated to a corn grain equivalency for monensin of 1.5 lb/day per cow (as fed basis).

Fat Supplements

The energy density of fat supplements can be 2.5 to 3 times the energy density of DGSC depending on the fat source (NRC, 2001). With today's increased corn prices the economics of supplemental fat feeding along ration fat limits should be re-evaluated. Ruminal inertness and fatty acid composition of fat supplements is highly important to minimize milk fat depression (He et al., 2012).

Conclusions

There are numerous nutritional alternatives to corn available for inclusion in dairy cattle rations. The challenge, however, is to determine whether or not they are economical alternatives, which is important since their prices are often closely related to corn price and there can be some lactation performance risks associated with their use. FeedVal 2012 (Cabrera et al., 2012) and Sesame (St-Pierre and Cobanov, 2011) are useful decision tools for assessing the dollar value of feed ingredients on a nutrient basis relative to other available feed ingredients upon which to base feed purchase decisions. Least cost ration formulation to pre-set nutrient specifications with feed ingredients available in inventory and monitoring of lactation performance are highly important for successful implementation of corn replacement strategies.

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