COPING WITH HIGH CORN PRICES: LOW STARCH DIETS AND LACTATION PERFORMANCE BY DAIRY COWS

R. D. Shaver
Department of Dairy Science
266 Animal Sciences Building
1675 Observatory Drive
University of Wisconsin
Madison, WI 53706

Phone: 608-263-3491
FAX: 608-263-9412
Email: rdshaver@wisc.edu

Summary

Lactating dairy cow diets with more than 24% starch (DM basis) are common, but recent high corn prices have fueled a desire to feed lower-starch diets. The potential for using digestible neutral detergent fiber or pectin from byproduct feeds or sugars to partially replace starch from corn grain in diets fed to lactating dairy cows was reviewed. Potential modifying effects of corn silage, starch digestibility and ionophore on lactation performance by dairy cows fed low starch diets was also evaluated. 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. Lactation performance was not reduced for 16%-17% starch diets (DM basis) formulated using soyhulls to partially replace corn grain. Diets containing 21% starch (DM basis) appear to be acceptable when high-fiber, moderate protein byproduct feeds are used to partially replace corn grain and protein supplement. Feeding corn silage at a higher percentage of the forage, high starch corn silage, sugars and ionophore can reduce the percentage of corn needed in high-starch diets or increase the "corn equivalency" of low-starch diets. The cost of using digestible NDF or pectin from byproduct feeds or sugars to partially replace starch from corn grain needs to be evaluated relative to corn and protein supplement prices. The starch in low-starch diets should be highly digestible.

Introduction

The optimum starch content of diets fed to lactating cows is not well defined in the literature, but 24% to 26% starch diets (DM basis) have been suggested as ideal (Staples, 2007). Kaiser and Shaver (2006), from a survey of six high producing (13,500 kg RHA) Wisconsin dairy farms, reported starch concentrations of diets fed to lactating cow groups ranging from 25% to 30% (DM basis). With today's high corn prices, however, there is much interest in feeding diets that are lower in starch content than what has been the norm. Reducing dietary concentrate and starch concentrations via forage substitution below 36% and 21% (DM basis), respectively on average across lactation, reduced ($P < 0.05$) 305-d fat-corrected milk yield (FCM; >1,000 kg) and 305-d cheese yield (>120 kg) for multiparous cows fed alfalfa silage based diets (Tessmann et al., 1991). The purpose of this paper is to evaluate the potential for using digestible neutral detergent fiber (NDF) or pectin from byproduct feeds or sugars to partially replace starch from corn grain in diets fed to lactating dairy cows. Potential modifying effects of corn silage, starch digestibility and ionophore on lactation performance by dairy cows fed low starch diets will also be examined.

Partial replacement of starch from corn grain with digestible NDF or pectin from byproduct feeds

Summarized in Tables 1 and 2 are the results from five trials on the partial replacement of starch from corn grain with digestible NDF or pectin from byproduct feeds.

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, FCM 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 TP 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 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, 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. The cost of using digestible NDF or pectin 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.

Partial replacement of corn starch with sugars

Summarized in Tables 3 and 4 are the results from three dose response trials on partial replacement of corn starch with sugars. Dry matter intake and lactation performance parameters were highest for diets containing 6%, 5% and 8% total sugar (DM basis) in trials using dried molasses, liquid molasses and sucrose supplements, respectively, to partially replace corn starch. Increasing total diet sugar to these concentrations coincided with reductions in dietary starch concentrations of 5%-units on average (DM basis). Thus, sugars can reduce the percentage of corn needed in high-starch diets or increase the “corn equivalency” of low-starch diets by about 7%- units (DM basis). Supplemental sugar

options include dry and liquid molasses, sucrose, whey, bakery waste, citrus pulp and beet pulp. The cost of supplementing sugar to partially replace starch from corn grain needs to be evaluated for these various sugar sources on a local basis relative to corn prices.

The role of corn silage

Corn silage (CS) contains about 25%-units more starch (DM basis) than alfalfa silage (AS; Dairyland Labs, 2007; NRC, 2001). Thus, increasing the forage mixture from $1/3^{rd}$:$2/3^{rd}$ to $2/3^{rd}$:$1/3^{rd}$ CS:AS in a diet with 50% forage will increase the dietary starch content by about 4%-units in low-starch diets or can reduce the percentage of corn needed in high-starch diets by about 6%-units (DM basis). Data on corn silage starch concentrations (Dairyland Labs, 2007) for 2002-2006 are presented in Table 5. Across the five years, corn silage starch content averaged 29.3% (DM basis) with an average within year standard deviation of 7.1% (DM basis). Thus, for $2/3^{rd}$ of corn silage samples the starch content fell between 22% and 36% (DM basis). Feeding the high-starch corn silage versus the low-starch corn silage in diets containing 34% corn silage (DM basis; 50% forage diet with $2/3^{rd}$:$1/3^{rd}$ CS:AS) will increase the dietary starch content by about 5%-units in low-starch diets or can reduce the percentage of corn needed in high-starch diets by about 7%-units (DM basis).

Starch digestibility

If low starch diets are fed, then it seems logical that the starch should be highly digestible. Total tract digestibility of starch by dairy cows is variable ranging from 70% to 100% (Firkins et al., 2001). Various factors, 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 (Firkins et al., 2001; Johnson et al., 1999; Nocek and Tamminga, 1991). The impact of the digestibility of corn grain starch on lactation performance by dairy cows as summarized by Firkins et al. (2001) is presented in Table 6. Based on regressions from the tabular data, 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 not result in reduced milk fat percentage.

Ionophore

The feeding of Rumensin® improves feed efficiency in lactating dairy cows and has been approved for use by the FDA. Calculations by Thomas (2006) suggest that feeding Rumensin increases diet energy density enough to provide a "corn equivalency" of 0.45 to 0.91 kg. The cost of feeding Rumensin at 300 mg/cow/d is \$0.03-\$0.04/cow/d versus the savings in reduced corn feeding of \$0.07-\$0.14/cow/d. Issues with milk fat test depression when feeding Rumensin appear to be less of a concern with low-starch than high-starch diets (Thomas, 2006).

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. Lactation performance was not reduced for 16%-17% starch diets (DM basis) formulated using soyhulls to partially replace corn grain. Diets containing 21% starch (DM basis) appear to be acceptable when high-fiber, moderate protein byproduct feeds are used to partially replace corn grain and protein supplement. Feeding corn silage at a higher percentage of the forage, high starch corn silage, sugars and ionophore can reduce the percentage of corn needed in high-starch diets or increase the "corn equivalency" of low-starch diets. The starch in low-starch diets should be highly digestible.

References

Batajoo, K.K., and R.D. Shaver. 1994. Impact of nonfiber carbohydrate on intake, digestion, and milk production by dairy cows. J. Dairy Sci. 77:1580:1588.

Broderick, G.A., and W. J. Radloff. 2004. Effect of molasses supplementation on the production of lactating dairy cows fed diets based on alfalfa and corn silage. J. Dairy Sci. 87:2997-3009.

Broderick, G.A., D.R. Mertens, and R. Simons. 2002. Efficacy of carbohydrate sources for milk production by cows fed diets based on alfalfa silage. J. Dairy Sci. 85:1767-1776.

Broderick, G.A., N.D. Luchini, W.J. Smith, S. Reynal, G.A. Varga, and V.A. Ishler. 2000. Effect of replacing dietary starch with sucrose on milk production in lactating dairy cows. J. Dairy Sci. 83(Suppl. 1): 248(Abstr.).

Dairyland Laboratories, Inc. 2007. Forage Summaries: 2002-2006. http://www.dairylandlabs.com/pages/interpretations/summaries.php. Accessed Dec. 14, 2007.

Firkins, J.L., M.L. Eastridge, N.R. St-Pierre, and S.M. Noftsger. 2001. Effects of grain variability and processing on starch utilization by lactating dairy cattle. J. Anim. Sci. 79(E. Suppl.): E218-E238.

Ipharraguerre, I.R., R.R. Ipharraguerre, and J.H. Clark. 2002. Performance of lactating dairy cows fed varying amounts of soyhulls as a replacement for corn grain. J. Dairy Sci. 85:2905-2912.

Johnson, L., J.H. Harrison, C. Hunt, K. Shinners, C.G. Doggett, and D. Sapienza. 1999. Nutritive value of corn silage as affected by maturity and mechanical processing: A contemporary review. J. Dairy Sci. 82:2813-2825.

Kaiser, R., and R. Shaver. 2006. Benchmarking high producing herds. Proc. Western Canadian Dairy Seminar. Red Deer, Alberta, Canada. 18:179-190.

National Research Council. 2001. Nutrient Requirements of Dairy Cattle. 7th rev. ed. Natl. Acad. Sci., Washington, DC.

Nocek, J. E., and S. Tamminga. 1991. Site of digestion of starch in the gastrointestinal tract of dairy cows and its effects on milk yield and composition. J. Dairy Sci. 74:3598-3629.

Staples, C.R. 2007. Feeding dairy cows when corn prices are high. Proc. 44th Florida Dairy Production Conference. Gainesville, FL.

Stone, W.C. 1996. Applied topics in dairy cattle nutrition: Soyhulls as either forage or concentrate replacement. Ph.D. Thesis. Cornell Univ., Ithaca, NY.

Tessmann, N.J., H.D. Radloff, J. Kleinmans, T.R. Dhiman, and L.D. Satter. 1991. Milk production response to dietary forage:grain ratio. J. Dairy Sci. 74:2696-2707.

Thomas, E.E. 2006. Field responses to the feeding of Rumensin®. Proc. Tri-State Nutr. Conf. Fort Wayne, IN. pages 37-42.

Voelker, J.A., and M.S. Allen. 2003. Pelleted beet pulp substituted for high-moisture corn: 1. Effects on feed intake, chewing behavior, and milk production of lactating dairy cows. J. Dairy Sci. 86:3542-3552.

Table 1. Literature review on partial replacement of starch from corn grain with digestible NDF or pectin from byproduct feeds (Test feeds, design, cows, and diet ingredient and nutrient composition).

Trial	Test Feeds	Trial Design	Cows	Diet Ingredient Composition (DM basis)	Diet Nutrient Composition (DM basis)
Voelker & Allen, 2003	Pelleted Beet Pulp	4x4 LS[1] 21-d periods	n=8 >79 DIM[2] Parity>1	40:60 F:C[3] 50:50 CS[4]: AS[5] HM corn 0, 6, 12, & 24% BP[6]	18% CP 17% Forage NDF 24%-32% NDF
Broderick et al., 2002	Dried Citrus Pulp	RCB[7] 12-wk period	n=48 Parity>1 >66 DIM	60:40 F:C 83:17 AS: Grass silage Dry cracked corn 0 & 19% DCP[8]	19% CP 22% Forage NDF 26 & 28% NDF
Ipharraguerre et al., 2002	Pelleted Soyhulls	5x5 LS 21-d periods	n=15 >112 DIM Parity>1	46:54 F:C 50:50 CS: AS Dry ground corn 0, 10, 20, 30, & 40% SH[9]	16% CP 19% Forage NDF 29%-49% NDF
Stone, 1996	Soyhulls	RCB[7] 14-wk period	n=63 Parity>1 10-108 DIM	52:48 F:C 50:50 CS: AS HM corn 0 & 14% SH	18-19% CP 21% Forage NDF 29 & 36% NDF
Batajoo & Shaver, 1994	WM[10] BDG[11] Soyhulls	4x4 LS 28-d periods	n=8 >63 DIM Parity>1	48:52 F:C Alfalfa silage Dry ground corn 0-10% WM 3%-20% BDG 0-9% SH	19-20% CP 21% Forage NDF 28%-43% NDF

[1]Latin square. [2]Days in milk. [3]Forage:concentrate ratio. [4]Corn silage. [5]Alfalfa silage. [6]Beet pulp. [7]Randomized complete block. [8]Dried citrus pulp. [9]Soyhulls. [10]Wheat midds. [11]Brewers dried grains.

Table 2. Literature review on partial replacement of starch from corn grain with digestible NDF or pectin from byproduct feeds (Lactation performance).

Trial	Diet Starch DM basis	DMI kg/d	Milk kg/d	FCM kg/d	Fat %	Fat kg/d	TP[1] %	TP kg/d	FCM/ DMI
Voelker and Allen, 2003	35%	24.8	36.4	37.4	3.72	1.34	3.21	1.13	1.51
	31%	25.0	36.6	38.4	3.84	1.40	3.21	1.15	1.54
	27%	25.1	35.9	38.0	3.90	1.39	3.22	1.15	1.52
	18%	22.9	35.4	36.8	3.81	1.33	3.10	1.09	1.62
		L[3]		Q[4]		Q			L
P <		0.05		0.07		0.03			0.05
Broderick et al., 2002	31%	20.9	33.6	32.7	3.25	1.11	2.96	1.00	1.57
	20%	19.2	29.9	28.2	3.40	0.98	2.84	0.80	1.47
P <		0.02	0.02	0.03		0.08	0.01	0.01	
Ipharraguerre et al., 2002[2]	28%	23.8	29.5	29.0	3.60	0.99	3.17	0.93	1.24
	23%	24.8	29.3	29.0	3.61	1.00	3.15	0.92	1.18
	17%	24.4	29.9	30.1	3.67	1.06	3.17	0.94	1.23
	13%	22.9	29.3	30.6	3.93	1.11	3.12	0.92	1.28
	7%	22.7	28.3	29.7	3.91	1.08	3.13	0.88	1.25
		L	28 v 7		L 28 v 7	L		28 v 7	
P <		0.06	0.07		0.004 0.02	0.001		0.09	
Stone, 1996[2]	25%	20.7	40.7	41.2	3.58	1.45	2.92	1.19	1.98
	16%	22.6	41.7	41.9	3.56	1.48	2.89	1.20	1.86
P <		0.10							
Batajoo and Shaver, 1994	30%	27.6	40.2	35.5	3.24	1.29	3.07	1.23	1.46
	26%	27.2	39.7	35.6	3.30	1.32	3.02	1.20	1.46
	21%	26.7	39.7	35.9	3.33	1.33	3.02	1.20	1.49
	15%	25.8	39.5	35.6	3.35	1.32	2.95	1.16	1.53
		L			L		L	L	
P <		0.05			0.05		0.05	0.05	

[1]True protein.
[2]Diet starch concentrations calculated using book values for ingredient starch concentrations.
[3]Linear effect.
[4]Quadratic effect.

Table 3. Literature review on partial replacement of corn starch with sugars (Test feeds, design, cows, and diet ingredient and nutrient composition).

Trial	Test Feeds	Trial Design	Cows	Diet Ingredient Composition (DM basis)	Diet Nutrient Composition (DM basis)
Broderick & Radloff, 2004 Trial 1	Dried Molasses	RCB[1] 8-wk period	n=40 >128 DIM[2] Parity>1	60:40 F:C[3] 33:67 CS[4]: AS[5] HM corn 0, 4, 8, & 12% DMO[6]	18% CP 23% Forage NDF 29% NDF
Broderick & Radloff, 2004 Trial 2	Liquid Molasses	RCB 8-wk period	n=48 Parity>1 >85 DIM	52:48 F:C 40:60 CS:AS HM corn 0, 3, 6, & 9% LMO[7]	16% CP 21% Forage NDF 26% NDF
Broderick et al., 2000	Sucrose	RCB 8-wk period	n=48	60:40 F:C 33:67 CS: AS HM corn & starch 0, 2.5, 5.0, 7.5% sucrose	17% CP 23% Forage NDF 29% NDF

[1]Randomized complete block. [2]Days in milk. [3]Forage:concentrate ratio. [4]Corn silage. [5]Alfalfa silage. [6]Dried molasses. [7]Liquid molasses.

Table 4. Literature review on partial replacement of corn starch with sugars (Lactation performance).

Trial	Diet Starch, Sugar DM basis	DMI kg/d	Milk kg/d	FCM kg/d	Fat %	Fat kg/d	TP[1] %	TP kg/d	FCM/ DMI
Broderick & Radloff, 2004 Trial 1	32%, 3%	25.3	38.0	41.2	4.00	1.52	3.10	1.19	1.63
	28%, 4%	25.7	37.5	42.2	4.26	1.60	3.09	1.15	1.65
	25%, 6%	26.3	38.9	42.7	4.16	1.61	3.12	1.20	1.63
	23%, 7%	26.0	36.7	40.3	4.07	1.50	3.05	1.11	1.56
		L[2]	C[3]	Q[4]	Q	Q		C	L
P <		0.05	0.04	0.07	0.07	0.02		0.05	0.09
Broderick & Radloff, 2004 Trial 2	31%, 3%	25.4	43.6	46.0	3.67	1.65	2.96	1.32	1.79
	29%, 5%	28.1	45.5	46.7	3.74	1.67	3.21	1.43	1.64
	28%, 7%	26.1	44.0	44.0	3.54	1.55	3.12	1.37	1.70
	26%, 10%	26.8	42.4	42.4	3.72	1.52	3.13	1.29	1.61
		C	Q	L			Q	Q	L
P <		0.01	0.05	0.05			0.01	0.02	0.05
Broderick et al., 2000[5]	32%, 3%	24.5	38.9	40.5	3.81	1.47	3.24	1.24	1.65
	29%, 6%	25.6	40.4	42.2	3.82	1.53	3.22	1.28	1.65
	26%, 8%	26.0	40.0	43.9	4.07	1.65	3.27	1.29	1.69
	23%, 11%	26.0	39.4	43.2	4.16	1.62	3.30	1.28	1.66
		L		L	L	L			
P <		0.01		0.11	0.01	0.05			

[1]True protein. [2]Linear effect. [3]Cubic effect. [4]Quadratic effect.
[5]Diet starch concentrations calculated using book values for ingredient starch concentrations.

Table 5. Corn silage starch data from Dairyland Laboratories, Inc. Arcadia, WI (Dairyland Labs, 2007).

		Starch (% of DM)	
Year	**n**	**Average**	**Standard Deviation**
2006	10,864	29.7	6.3
2005	13,452	29.6	7.3
2004	12,540	28.7	7.1
2003	12,804	28.5	7.2
2002	12,115	30.0	7.8

Table 6. Total tract starch digestibility and lactation performance by dairy cows fed different corn sources (adapted from Firkins et al., 2001).

Corn	**n**[1]	**Starch Digestibility %**	**Milk**[2] **kg/d**	**Fat**[2] **%**	**Fat**[3] **kg/d**	**Protein**[2] **%**	**Protein**[3] **kg/d**
Dry, cracked or rolled	9	85	30.9	3.59	1.11	3.09	0.96
Steam-rolled	10	89	31.9	3.49	1.11	3.10	0.98
Dry, ground	13	91	31.5	3.53	1.11	3.18	1.00
Dry, ground finely	3	91	32.4	3.49	1.13	3.02	0.98
Steam-flaked	10	94	32.5	3.36	1.09	3.10	1.01
High-moisture, rolled	3	94	32.5	3.54	1.15	3.17	1.03
High-moisture, ground	2	99	33.9	3.37	1.14	3.17	1.08

[1]Number of treatment means across studies summarized by Firkins et al., 2001..
[2]Least squares means reported by Firkins et al., 2001.
[3]Calculated from milk yield and composition least squares means reported by Firkins et al., 2001.