# Effects of Rumensin in Lactating Cow Diets with Differing Starch Levels

M.S. Akins[1], K.L. Perfield[2], H. B. Green[2], R.D. Shaver[1]
[1]Department of Dairy Science, University of Wisconsin-Madison
[2]Elanco Animal Health, Greenfield, IN
Email: rdshaver@wisc.edu

## INTRODUCTION

Kaiser and Shaver (2006) and Bucholtz (2006) reported starch concentrations in diets fed to high-producing dairy herds ranged from 25 to 30 % on a dry matter (**DM**) basis. Increased corn prices have heightened the interest in feeding reduced-starch diets. Results from short-term dairy cattle feeding trials suggest that reduced-starch diets formulated by partially replacing corn grain with high-fiber, low-starch byproduct feedstuffs may be economically feasible (Shaver, 2010).

In a 12 wk study with high producing (110 lb milk/d) dairy cows, Gencoglu et al. (2010) reported similar milk yield, greater dry matter intake (**DMI**) and fat-corrected milk (**FCM**) yield, and a trend for reduced actual-milk feed efficiency for cows fed a reduced-starch (**RS**; 21 % starch, DM basis) diet formulated by partially substituting soy hulls for dry ground shelled corn (**DGSC**) contained in the normal-starch (**NS**; 27 % starch, DM basis) diet. Even though feed cost per lb DM was reduced for the RS diet, feed cost per cow per d was greater for RS because DMI was 9 % greater and actual-milk feed efficiency was 7 % lower for RS compared to NS. In a subsequent trial Ferraretto et al. (2011) reported that using a wheat middlings and whole cottonseed mixture rather than soy hulls in the RS diet resulted in an 8 % increase in DMI and a 10 % reduction in actual-milk feed efficiency for cows fed RS compared to NS.

Firkins (1997) suggested that greater digestibility and passage rate for non-forage or by-product neutral detergent fiber (**NDF**) can allow for increased NDF intake and fill; thereby expanding the limitation of dietary NDF content on DMI (Mertens, 1987). Greater DMI for RS versus NS may be related to reduced ruminal propionate concentration (Allen, 1997) leading to increased meal size and consequently greater DMI (Allen et al., 2009). Rumensin® (Elanco Animal Health, Greenfield, IN) has been shown to increase ruminal propionate, reduce DMI, and increase milk production efficiency in dairy cows (Ipharraguerre and Clark, 2003b; Duffield et al., 2008). Rumensin was not fed in the trials of Gencoglu et al. (2010) and Ferraretto et al. (2011). Our hypothesis was that Rumensin would reduce DMI and improve milk production efficiency more with RS than NS diets. This response would expand the economic opportunities for feeding diets of RS content to high-producing dairy cows.

## MATERIALS AND METHODS

The study was conducted under an approved protocol by the Research Animal and Resources Center of the College of Agriculture and Life Sciences at the University of Wisconsin-Madison. One-hundred twenty eight cows (90 ± 33 days in milk; **DIM**) were stratified by breed (Holstein and Holstein x Jersey crossbred), parity (primi- and multiparous), and DIM, and randomly assigned to one of 16 pens with 8 cows per pen in the UW-Madison Emmons-Blaine Arlington free-stall barn. Each pen consisted of three primiparous Holstein, three multiparous Holstein, and two multiparous Holstein x Jersey crossbred cows. Pens were randomly assigned to 1 of 4 treatments in a 2 × 2 factorial design {formulated dietary starch content (RS (21 %) vs. NS (27 %)) and Rumensin (0 g/ton (Control) vs. 18 g/ton (Rumensin)) inclusion as main effects} for a continuous lactation trial. During the 4 wk covariate period all cows were fed the NS diet with 18 g/ton Rumensin (**NSR**) followed by a 12 wk treatment period with cows fed their assigned treatment diets of NSR, NS with 0g/ton Rumensin (**NSC**), RS with 0 g/ton Rumensin (**RSC**), and RS with 18 g/ton Rumensin (**RSR**). All cows were receiving 11 g/ton Rumensin prior to the start of the 4 wk covariate period. Upon moving to the study pens, all animals were fed 18 g/ton Rumensin. On day 1 of the treatment period, the control pens were switched to 0 g/ton while treatment pens continued to receive 18 g/ton Rumensin. All cows were comingled for the first 2 wk of the covariate period and then assigned to their treatment pens for the second 2 wk of the covariate period. Cows remained in those treatment pens for the full 12 wk treatment period. All animals received bovine somatotropin (Posilac®, Elanco Animal Health, Greenfield, IN) every 14 d, starting 57-70 DIM with all cows on Posilac by d 15 of the covariate period.

Diets (Table 1) were fed as a total mixed ration (**TMR**) mixed and fed once daily. Targeted formulation of starch and NDF concentrations were 21 and 35 % and 27 and 27 % for RS and NS diets, respectively. The Rumensin or Control premixes (Vita Plus Corp., Madison, WI) were added to the TMR at an average rate of 0.5 lb/cow/d separately from the concentrate mixtures. The pens were supplied with TMR to allow for 10 % refusal with daily DMI determined on a pen basis throughout the trial. Control pens received their daily feed allotment first followed by the Rumensin pens. The TMR mixer was flushed with corn silage in between feeding the control and Rumensin pens. Daily pen refusals were recorded each morning prior to new feed delivery using the Feed Supervisor® software (Supervisor Systems, Dresser, WI). Daily pen DMI was measured by the difference of as-fed feed offered and as-is feed refused multiplied by TMR DM.

Body weight (**BW**) and condition score (**BCS**, 1 to 5 in 0.25 increments; Wildman et al., 1982) were recorded on a pen basis on 3 consecutive days at the end of both the covariate and treatment periods. The average BW of the cows in the pen was used for analysis. Body weight change was calculated on a pen basis as the difference between the average BW at the end of the trial and the end of the covariate period. Individual cows from each pen were assigned a BCS and then a pen average was used for analysis.

Cows were milked twice daily and milk yield was recorded daily on individual cows throughout the entire trial. Covariate milk samples were taken the last 3 d of the 4th wk of the covariate period to allow maximum time for adjustment to Rumensin. Individual milk samples were obtained weekly from a.m. and p.m. milkings during the treatment period from all cows on the same two consecutive days and composited by pen by wk with 55 % of the composite from the a.m. milkings and 45 % from the p.m. milkings. Milk composites were analyzed for fat, true protein, lactose and MUN concentrations by infrared analysis

**Table 1.** Dietary ingredients and nutrient composition

| Item | Diet RSC | RSR | NSC | NSR |
|---|---|---|---|---|
| Ingredient | ---------------------- % of DM | | | ---------------------- |
| Corn silage | 25.0 | 25.0 | 25.0 | 25.0 |
| Alfalfa silage | 25.0 | 25.0 | 25.0 | 25.0 |
| Dry ground shelled corn | 15.0 | 15.0 | 23.9 | 23.9 |
| Soyhull pellets | 15.5 | 15.5 | 5.5 | 5.5 |
| Soybean meal-48 % | 10.2 | 10.2 | 11.3 | 11.3 |
| Dried distillers grain | 4.5 | 4.5 | 4.5 | 4.5 |
| Energy Booster 100[1] | 1.8 | 1.8 | 1.8 | 1.8 |
| Calcium carbonate | 0.7 | 0.7 | 0.7 | 0.7 |
| Sodium bicarbonate | 0.5 | 0.5 | 0.5 | 0.5 |
| Iodized salt | 0.4 | 0.4 | 0.4 | 0.4 |
| Magnesium oxide | 0.3 | 0.3 | 0.3 | 0.3 |
| Monocalcium phosphate | 0.1 | 0.1 | 0.1 | 0.1 |
| Magnesium-potassium-sulfate[2] | 0.1 | 0.1 | 0.1 | 0.1 |
| Control premix | 0.9 | 0.0 | 0.9 | 0.0 |
| Rumensin premix | 0.0 | 0.9 | 0.0 | 0.9 |
| Nutrient | | | | |
| CP | 18.1 ± 0.5 | 18.0 ± 0.6 | 18.2 ± 0.7 | 18.3 ± 0.6 |
| NDF | 34.7 ± 1.0 | 35.0 ± 1.3 | 28.3 ± 0.8 | 28.6 ± 1.2 |
| Ether extract | 6.1 ± 0.9 | 5.7 ± 0.4 | 6.0 ± 0.5 | 5.8 ± 0.5 |
| Ash | 8.0 ± 0.3 | 8.0 ± 0.1 | 7.8 ± 0.2 | 7.8 ± 0.1 |
| NFC | 34.0 ± 1.8 | 34.2 ± 1.5 | 40.5 ± 1.1 | 40.4 ± 1.7 |
| Starch | 20.6 ± 1.9 | 20.2 ± 0.7 | 27.3 ± 0.9 | 26.5 ± 1.5 |
| Diet $TDN_{1x}$ | 68.9 ± 3.7 | 68.9 ± 3.7 | 74.5 ± 1.0 | 74.5 ± 1.0 |

[1]Minimum 98 % total fatty acids (MSC Company, Dundee, IL)
[2]Contains 11 % Mg, 18 % K, and 22 % S (Dynamate; The Mosaic Company, Plymouth, MN)
[3]RSC = Reduced starch without Rumensin; RSR = Reduced starch with Rumensin; NSC = Normal starch without Rumensin; and NSR = Normal starch with Rumensin

(AgSource Milk Analysis Laboratory, Menomonie, WI) using a Foss FT6000 (Foss Electric, Hillerød, Denmark) with average daily yields of fat, protein, and lactose calculated from those data for each week. Yields of 3.5 % FCM, solids corrected milk (**SCM**), and energy corrected milk (**ECM**) were calculated according to NRC (2001) equations. Actual-milk, 3.5 % FCM, SCM, and ECM efficiencies were calculated by pen by week using average daily pen-based yield and DMI data.

Estimated dietary energy concentrations were calculated by summing the Mcal of net energy for lactation (**NE$_L$**) from milk production, required for maintenance, and BW change (NRC, 2001), and dividing the sum by DMI. Samples of TMR, corn silage, alfalfa silage, and concentrate mixes were obtained weekly and composited by 2-wk periods for analysis. Samples of dry ground shelled corn and soy hull pellets were obtained at the beginning and end of the study. Samples for determination of nutrient composition were dried at 60 ºC for 48 h in a forced-air oven to determine DM content, ground to pass a 1-mm Wiley mill (Arthur H. Thomas, Philadelphia, PA) screen, and composited prior to sending to Dairyland Laboratories Inc., Arcadia, WI for analysis of: organic matter (**OM)** (ashing at 600 ºC for 2 h), crude protein (**CP)**, ether extract (AOAC, 1995), NDF using α-amylase and sodium sulfite (Van Soest et al., 1991), and starch (Bach Knudsen, 1997; YSI Biochemistry Analyzer, YSI Incorporated, Yellow Springs, OH). Particle size of TMR, corn silage, and alfalfa silage samples were determined as described by Kononoff et al. (2003). Particle size of the concentrate mixtures, DGSC, and soy hulls were determined by dry sieving using Tyler Ro-Tap Shaker Model RX-29 (Mentor, OH) and sieves with 4760, 2380, 1190, 595, 297, 149 and 63 µm apertures plus bottom pan with mean particle size calculated using a log normal distribution (Baker and Herrman, 2002).

Fecal samples were collected during the last 2 d at 0600 and 1600 of wk 4 of the covariate period and wk 6 and 12 of the treatment period. Fecal samples were collected from each cow in each pen by rectal grab and composited by pen. Fecal samples were analyzed for starch concentration to determine total tract starch digestibility calculated as: (-0.0125 * fecal starch, % DM) + 0.9997) * 100. This equation was developed using data from a database of 506 fecal composites analyzed for starch content and associated total tract starch digestibility of the diets (R. D. Shaver, personal communication).

## STATISTICS

Three cows were removed from the study with one cow having a dilated cecum, another having digestive upset, and another having chronic mastitis. Outlier analysis was performed on all data using PROC UNIVARIATE of SAS (SAS Institute, 2004) and the milk fat percentage data from wk 6 of the treatment period was found to be an outlier. Data affected included milk fat yield, 3.5 % FCM, ECM, SCM, and their associated feed efficiencies. The data were removed before analysis and no treatment comparisons were made for that week. In addition, MUN data from wk 12 of the treatment period was considered an outlier, removed before analysis, and no treatment comparisons made for that week.

Data were analyzed with PROC MIXED of SAS (SAS Institute, 2004) as a completely randomized design with a factorial arrangement of treatments with covariate adjustment. Pen was the experimental unit. The milk and DMI data from the last 2 wk of the covariate period was used as a covariate adjustment in the model. The week of treatment was a repeated measure using the first order autoregressive covariance structure which provided the best fit according to Sawa’s Bayesian information criterion. The model included treatment, week, and treatment by week interactions as fixed effects; and pen within treatment as a random effect. Degrees of freedom were calculated using the Kenward-Roger option. There were no covariate or repeated measures effects included in the analysis of BW, BW change, body condition score, body condition score change, and estimated diet energy concentration data. Least square means were determined and treatment means within weeks compared using the SLICE option. Statistical significance and trends were considered at $P \leq 0.05$ and $P \geq 0.06$ to $P \leq 0.10$, respectively.

## RESULTS AND DISCUSSION

The diets are described in Table 1. Starch and NDF contents averaged 20.4 and 34.9 % for RS and 26.9 and 28.5 % for NS diets, respectively. Non-fiber carbohydrate (**NFC**) was 34.1 and 40.5 % for RS and NS diets, respectively. Differences in starch, NDF, and NFC were due to partial replacement of DGSC with soy hulls. Normal and reduced starch diets had similar CP (18.1 % DM on average) and ether extract (5.9 % DM on average). Forage NDF as a % of DM was 19.5 % for all diets.

Lactation performance data are presented in Table 2. Mean DMI (59.4 lb/d) was not affected by either starch content ($P = 0.53$), Rumensin addition ($P = 0.33$), or their interaction ($P = 0.97$). There were interactions for DMI between week of treatment and starch and week of treatment and Rumensin. The control treatment had higher ($P < 0.05$) DMI during wk 4, 6, and 9 when compared to the Rumensin treatment and the NS treatment had increased DMI during wk 1 and 2 when compared to those fed the RS diet. The Rumensin by week interaction does indicate reduced DMI for Rumensin diets, but it was not consistent throughout the study. The effect was primarily at wk 4, 6, and 9. There was an overall nonsignificant decrease ($P = 0.33$) in DMI of 0.9 lb/d which is similar to a recent meta-analysis on Rumensin, which showed a 0.7 lb/d decrease in DMI (Duffield et al., 2008). Ipharraguerre and Clark (2003b) indicated variable effects of Rumensin on DMI with 2 out of 7 studies reporting a decrease in DMI. A difference between the meta-analysis and the current study is number of animals contributing to the datasets with the meta-analysis reporting data on over 4,000 Rumensin-supplemented animals. Additionally, a decline in DMI may take longer than the current study's treatment period. Studies by Gencoglu et al. (2010) and Ferraretto et al. (2011) reported an increase in DMI for RS diets attributed to a reduction in propionate production and increased NDF digestibility, however, a review by Iphaguerre and Clark (2003a) reported DMI was not affected by partially replacing grain with soy hulls in 13 of 15 studies.

Cows fed the NS diet produced 3.3 lb more milk ($P = 0.01$) per day when compared to those on the RS diet. Rumensin increased ($P = 0.01$) milk yield by 2.9 lb/d compared to control. There was a Rumensin by week interaction ($P = 0.03$) such that Rumensin supplemented cows produced more milk than controls as the treatment period progressed. Gencoglu et al. (2010), which used only multiparious cows starting at an average 50 DIM, found that milk yield was similar between RS and NS using soyhulls to replace corn. In other studies (Batajoo and Shaver, 1994; Beckman and Weiss, 2005), feeding reduced-starch diets with a combination of soy hulls and either wheat middlings or cottonseed hulls did not affect milk yield. The increase in milk yield from Rumensin is well substantiated in the literature with increases of 3.3 lb/d (Ipharraguerre and Clark, 2003) and 1.5 lb/d (Duffield et al., 2008). Rumensin increases milk yield by increasing supply of glucogenic precursors, specifically propionate, from rumen fermentation. Ramanzin et al. (1997) observed increased propionate as a proportion of total volatile fatty acids.

**Table 2.** Main effects of dietary starch and Rumensin on lactation performance.

| | Starch | | Rumensin | | | P-value | | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Reduced | Normal | 0 g/ton | 18 g/ton | SE | S | R | S x Wk | R x Wk |
| BW, lb | 1520 | 1545 | 1527 | 1537 | 10 | 0.12 | 0.52 | - | - |
| BW change, lb/d | 1.02 | 1.15 | 1.03 | 1.14 | 0.11 | 0.45 | 0.53 | - | - |
| BCS | 3.03 | 3.06 | 3.05 | 3.04 | 0.03 | 0.48 | 0.65 | - | - |
| BCS change | 0.34 | 0.36 | 0.34 | 0.36 | 0.03 | 0.70 | 0.59 | - | - |
| DMI, lb/d | 59.3 | 59.8 | 59.9 | 59.1 | 0.5 | 0.53 | 0.33 | <0.01 | <0.01 |
| Milk, lb/d | 90.4 | 93.7 | 90.6 | 93.5 | 0.7 | 0.01 | 0.01 | 0.51 | 0.03 |
| Milk/DMI, lb/lb | 1.54 | 1.56 | 1.52 | 1.58 | 0.01 | 0.11 | <0.01 | 0.01 | <0.01 |
| 3.5 % FCM[1], lb/d | 96.4 | 97.9 | 96.1 | 97.9 | 1.3 | 0.42 | 0.30 | 0.20 | <0.01 |
| 3.5 % FCM/DMI, | 1.63 | 1.64 | 1.61 | 1.66 | 0.01 | 0.73 | 0.04 | <0.01 | <0.01 |
| ECM, lb/d | 94.8 | 97.0 | 95.0 | 96.8 | 1.1 | 0.25 | 0.29 | 0.32 | 0.02 |
| ECM/DMI, lb/lb | 1.60 | 1.62 | 1.59 | 1.64 | 0.01 | 0.40 | 0.03 | <0.01 | <0.01 |
| SCM, lb/d | 88.9 | 90.6 | 88.9 | 90.6 | 1.1 | 0.28 | 0.31 | 0.26 | 0.02 |
| SCM/DMI, lb/lb | 1.50 | 1.52 | 1.49 | 1.53 | 0.01 | 0.54 | 0.05 | <0.01 | <0.01 |
| Fat, % | 3.88 | 3.81 | 3.87 | 3.82 | 0.05 | 0.36 | 0.52 | 0.08 | 0.31 |
| Fat, lb/d | 3.52 | 3.55 | 3.51 | 3.55 | 0.07 | 0.85 | 0.56 | 0.05 | <0.01 |
| Protein, % | 3.17 | 3.22 | 3.22 | 3.17 | 0.01 | 0.01 | 0.02 | 0.77 | 0.03 |
| Protein, lb/d | 2.87 | 3.00 | 2.91 | 2.95 | 0.03 | <0.01 | 0.37 | 0.60 | 0.05 |
| Lactose, % | 4.94 | 4.94 | 4.93 | 4.94 | 0.01 | 0.71 | 0.60 | 0.04 | 0.27 |
| Lactose, lb/d | 4.48 | 4.63 | 4.48 | 4.61 | 0.04 | 0.02 | 0.02 | 0.15 | 0.02 |
| SNF, % | 9.00 | 9.06 | 9.05 | 9.01 | 0.02 | 0.02 | 0.11 | 0.48 | 0.08 |
| SNF, lb/d | 8.13 | 8.47 | 8.20 | 8.42 | 0.07 | 0.01 | 0.06 | 0.44 | 0.03 |
| SCS[2] | 3.1 | 3.3 | 3.4 | 3.1 | 0.2 | 0.63 | 0.33 | 0.87 | 0.41 |
| MUN, mg/dL | 12.7 | 12.1 | 12.2 | 12.6 | 0.1 | <0.01 | 0.06 | <0.01 | <0.01 |
| Estimated diet energy content, Mcal/lb DM[3] | 0.74 | 0.74 | 0.73 | 0.75 | 0.005 | 0.69 | 0.01 | - | - |

[1]Yield of FCM = 0.432 x milk yield + 16.23 x fat yield, ECM = 12.82 x fat yield + 7.13 x protein yield + 0.323 x milk yield, and SCM = milk yield x ((12.24 x fat% x 0.01) + (7.1 x protein% x 0.01) + (6.35 x lactose% x 0.01) – 0.0345) as according to NRC (2001) equations.

[2]Somatic cell score. SCS = log base 2 * (SCC/100) + 3

[3]Estimated diet energy content = ((0.08*BW,kg^$^{0.75}$ + BW change * 5.34 + milk yield, kg * (0.0929*fat% + 0.0563*protein% + 0.0395*lactose%)) / DMI,kg)*0.454 (NRC,2001)

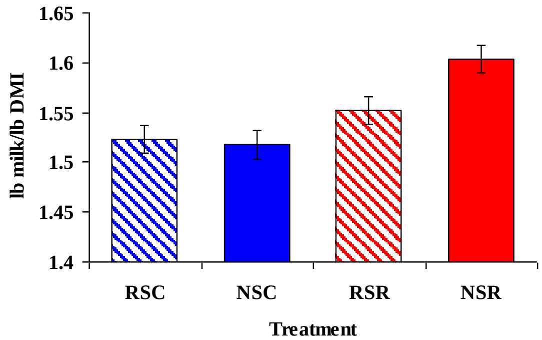


**Figure 1.** Milk/DMI efficiency (lb/lb) of lactating dairy cows fed diets with and without Rumensin and different levels of starch. RSC = reduced starch diet without Rumensin; RSR = reduced starch diet with Rumensin; NSC = normal starch diet without Rumensin; NSR = normal starch diet with Rumensin. Starch x Rumensin, $P = 0.08$; SEM = 0.3.

There was a tendency for a starch by Rumensin interaction for milk production efficiency (**MPE**, Figure 1; $P = 0.08$) such that Rumensin increased MPE more in the NS diet when compared to supplementation in the RS diet. The interaction of Rumensin with starch content may be due to differences in availability of starch for propionate production and the effect of Rumensin on ruminal bacteria. Both starch and Rumensin had interactions with week for MPE. Cows fed Rumensin had increased ($P < 0.05$) MPE during 7 of the 12 wk and cows fed the NS diet had greater ($P < 0.05$) MPE during the last 4 wk of the study, which suggests longer times may be required to observe differences between RS and NS diets. Gencoglu et al. (2010) also observed a treatment by week effect for starch content; however NS had greater efficiency than RS during the first 6 wk of treatment and were not different the remaining 6 wk. Duffield et al. (2008) reported in the meta-analysis that Rumensin increased MPE by 2.5 %. In this study, Rumensin increased MPE by 3.9 %.

There were no Rumensin or starch effects on 3.5 % FCM, ECM, or SCM yields; however, there was a Rumensin by week interaction ($P < 0.02$) for all component-corrected milk yields with Rumensin increasing yields during wk 7 and 8. Gencoglu et al. (2010) observed an average increase of 5.3 lb/d of component-corrected milk yields for NS versus RS diets. The 4 % FCM and ECM were unaffected by feeding RS diets in trials by Batajoo and Shaver (1994) and Beckman and Weiss (2005), respectively. Martinez et al. (2009) reported no effect of Rumensin on 3.5 % FCM yields of cows fed diets with Rumensin at 2 levels of forage inclusion, but used only 4 wk periods in a Latin Square design; which may have not allowed adaptation to Rumensin.

There was a ($P < 0.01$) Rumensin by week, and starch by week interaction for 3.5 % FCM/DMI, ECM/DMI, and SCM/DMI efficiencies. The RS diet had greater efficiency than the NS diet during the first 2 wk of study, were similar from wk 3 to 8, then NS had greater efficiency wk 9 and 10. The Rumensin diet had similar efficiency to Control the first 3 wk of study, then Rumensin had greater efficiency for wk 4, 7, 8, and 9; but were similar the last 3 wk. Similar to previous studies (Duffield et al., 2008), Rumensin increased ($P < 0.05$) 3.5 % FCM/DMI and ECM/DMI efficiencies by an average 0.05 lb yield/lb DMI or 3.1 and 3.4 %, respectively, over control. Previous research has reported increases in efficiencies on average of 3.6 % on low forage diets (< 60 % forage DM) and 11.4 % on high forage diets (> 60 % forage DM; Ipharraguerre and Clark, 2003b).

Overall means of milk fat percentage and yield were unaffected by Rumensin or starch content (*P* > 0.10) which differs from other studies with Rumensin inclusion in diets (Ipharraguerre and Clark, 2003b) or feeding of diets differing in starch content (Beckman and Weiss, 2005). However, Duffield et al. (2008) reported Rumensin decreased milk fat percentage by 0.13 %, but had no effect on milk fat yield. A linear increase in milk fat percentage was observed by Beckman and Weiss (2005) when diets increasing in NDF to starch ratio from 0.74 to 1.27 were fed. The RS and NS diets in this study had NDF to starch ratios of 1.70 and 1.06, respectively. There was a starch x time interaction for milk fat percentage; such that NS diets had lower milk fat percentage than RS during wk 1 and 2. During the first 2 wk of treatment, cows fed RS diets had lower DMI; and thus reduced energy intake, which likely resulted in cows mobilizing body reserves to meet energy requirements as exhibited in the milk fat content graph. Mean energy balance during wk 1 and 2 as calculated using NRC (2001) equations were -1.7 Mcal/d and 0.1 Mcal/d for RS and NS, respectively. Similar to milk yield results, there was a Rumensin x week interaction (*P* < 0.01) for milk fat yield such that Rumensin increased milk fat yield through the treatment period. Additionally, there was a starch by week interaction (P = 0.05) for milk fat yield such that the NS diet increased milk fat yield slightly over time.

The NS diet increased (*P* = 0.01) milk protein percentage and yield compared to RS, likely due to greater ruminal microbial protein yield. Ferraretto et al. (2011) showed an increase in protein yield for NS compared to RS. Compared to Rumensin, the control group had greater (*P* = 0.02) milk protein percentage; however, no difference in yield was found (*P* = 0.37). There was a Rumensin by week interaction for milk protein yield similar to FCM, ECM, and SCM; with Rumensin increasing (P = 0.05) milk protein yields during wk 7 and 8 of the treatment period. Ipharraguerre and Clark (2003b) and Duffield et al. (2008) also observed a decrease in milk protein percentage with the addition of Rumensin; however, milk protein yield was either unaffected (Ipharraguerre and Clark, 2003b) or increased (Duffield et al., 2008). A decrease in protein percentage may be explained as a possible dilution effect from increased milk yield or a decreased supply of protein because of lower DMI.

Lactose percentage was unaffected by treatment, but lactose yield was increased by Rumensin and NS (*P* = 0.02). The NS diet increased SNF percent (*P* = 0.02) and yield (*P* = 0.01) compared to RS. Rumensin did not affect (*P* > 0.10) SNF percent, but tended (*P* = 0.06) to decrease SNF yields. However, there was a Rumensin by week interaction (*P* = 0.03) similar to that for milk yield, such that Rumensin cows had greater SNF yields throughout the treatment period.

The MUN concentration was higher (P < 0.01) in RS diets compared to NS (12.7 vs. 12.1 mg/dL, respectively). Rumensin-supplemented cows tended to have greater MUN than control (12.6 vs. 12.2 mg/dL, respectively). Milk urea nitrogen was influenced by Rumensin × week (*P* < 0.01) and starch × week (*P* < 0.01) interactions. During the first 3 wk MUN was greater (*P* < 0.05) for Rumensin and RS compared to control and NS, respectively. Increased MUN during the first weeks of feeding a RS diet is consistent with work by Gencoglu et al. (2010) and Ferraretto et al. (2011) where they observed an increase to about 20 mg/dL in the first week of treatment. The greater MUN concentration for RS is likely related to less rumen-available carbohydrate for microbial protein synthesis and thus less milk protein as described previously.

Total tract starch digestibility was influenced by starch concentration in the diet ($P < 0.01$) with NS and RS diets having 96.8 and 98.1 % starch digestibility, respectively. Rumensin inclusion did not affect total tract starch digestibility. Gencoglu et al. (2010) observed a similar effect of starch content with NS and RS diets having 94.9 and 97.2 % total tract starch digestibility, respectively. Firkins (1997) explained the increase in starch digestibility of RS diets being due to reduced negative associative effects of starch on ruminal fermentation.

## CONCLUSIONS

In conclusion, milk yield was reduced for cows fed the RS diet; but DMI, 3.5 % FCM, ECM, and SCM yields and efficiencies were similar for RS compared to NS. Under the conditions of this study, RS diets were feasible for reducing corn inclusion in lactating cow diets. Inclusion of Rumensin at 18 g/ton DM improved lactation performance, specifically milk production efficiency, on both RS and NS diets. There were few significant interactions of starch and Rumensin, supporting the use of Rumensin in both lactation diets tested in this study.

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