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Effect of Diets Containing a Controlled-Release Urea Product on Milk Yield, Milk Composition, and Milk Component Yields in Commercial Wisconsin Dairy Herds and Economic Implications

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ABSTRACT

The objective of this field trial was to determine the effect of a controlled-release urea product (Optigen, Alltech Inc., Lexington, KY) on milk production in commercial Wisconsin dairy herd diets. Sixteen trial herds were randomly assigned to a treatment sequence, control (CON) to Optigen (OPT) or OPT to CON, in a crossover design with two 30-d periods. Within farm, all lactating cows were fed a single-formulation TMR. The CON diet for each herd was formulated by the herd nutritionist based on the level of milk production, and the OPT diets contained 114 g/d per cow of Optigen, replacing an equivalent amount of supplemental CP, primarily from soybean meal. The partial replacement of soybean meal with Optigen in the OPT diet allowed for an increase in dietary DM from either corn silage or corn grain at the discretion of the herd nutritionist. Records of the weight and composition of bulk tank milk shipments were obtained for each herd over the 60-d trial. Data were analyzed using mixed model procedures, with period, sequence, and treatment as fixed effects and herd as a random effect. Milk yield was 0.5 kg/d per cow greater ($P < 0.01$) when herds were fed OPT compared with when they were fed CON. Under the conditions of this study, Optigen was an effective partial substitute for soybean meal. Economic simulations, using the observed milk yield response, indicated that changes in income over feed cost were more favorable at lower energy supplement and additive prices and higher soybean meal and milk prices.

Key words: controlled-release urea, dairy cow, milk production

INTRODUCTION

Numerous attempts have been made over the years to control the ruminal release of urea by combining urea with starch (Deyoe et al., 1968), molasses (Males et al., 1979), cellulose (Conrad and Hibbs, 1968), or oils (Owens et al., 1980). The development of products that slow the ruminal release of ammonia without limiting the extent of urea degradation in the rumen has been challenging (Males et al., 1979). Owens et al. (1980) reported that ruminal

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ammonia release was slower for an oil-coated prilled urea product than for uncoated prilled urea, thereby increasing diet acceptability and reducing urea toxicity in steers. Broderick and Reynal (2009) reported that DMI and milk yield were 1.3 and 3.3 kg/d per cow lower, respectively, for dairy cows consuming 133 g/d per cow of uncoated prilled urea compared with cows that were not supplemented with urea in isonitrogenous TMR treatments. Galo et al. (2003), however, reported that DMI, milk production, and nitrogen excretion were unaffected in dairy cows when uncoated prilled urea and RUP sources were partially replaced by a polymer-coated prilled urea product in isonitrogenous diets.

In 2005, Alltech Inc. (Lexington, KY) developed and commercialized a controlled-release urea product (Optigen) that involves coating urea prills with vegetable oil. García-González et al. (2007) reported lower ruminal and plasma ammonia concentrations for steers fed Optigen than for steers fed uncoated prilled urea; the in situ rate of nitrogen disappearance for Optigen was 0.237/h. These authors concluded that Optigen is a ruminally protected source of NPN with controlled-release characteristics in the rumen, which is in agreement with the report by Stewart et al. (2008). The greater yield of microbial nitrogen for Optigen than for uncoated prilled urea in ruminal continuous culture has been reported in some (Chalupa, 2007; Tikofsky and Harrison, 2007; Harrison et al., 2008b), but not all, trials (Harrison et al., 2008a,c). There have also been reports of trends for increased milk yield when Optigen partially replaced either uncoated prilled urea (Tikofsky and Harrison, 2007) or an oilseed meal mixture (G. Varga and V. Ishler, The Pennsylvania State University, State College, personal communication) in dairy cattle diets. However, dos Santos et al. (2008) reported that milk yield was unaffected by treatment when soybean meal (**SBM**) in dairy cattle diets was partially replaced by either Optigen or uncoated prilled urea.

The primary objective of this trial was to determine the effect of Optigen, as a source of NPN in commercial Wisconsin dairy herd diets, on milk yield, milk composition, and milk component yields. An additional objective was to evaluate the impact of Optigen use on feed costs and income over feed costs (**IOFC**).

MATERIALS AND METHODS

The experiment was conducted from April through June of 2008. Eight collaborating nutritionists from 2 feed companies identified 30 commercial dairy farms in Wisconsin with owner-operators that were willing to participate in a feeding trial. Sixteen of these herds were selected for the study by the investigators, based on the ability of the farm to carry out the experimental protocol. Across the 16 trial herds, the number of lactating Holstein dairy cows within a herd averaged 148 cows, ranging from 58 to 550 cows. The 16 herds were randomly assigned to a TMR treatment sequence (8 herds per sequence), a control (**CON**) to Optigen (**OPT**; Alltech Inc.) sequence, or an OPT to CON sequence, in a crossover design with two 30-d periods.

Within farm, all lactating cows were fed a single-formulation TMR. The CON TMR for each herd was formulated by the herd nutritionist based on level of milk production. The OPT TMR for each herd contained 114 g/d per cow of Optigen, replacing an equivalent amount of supplemental CP, primarily from SBM, to provide isonitrogenous control and treatment diets. The partial replacement of soybean meal with Optigen in the OPT diet allowed for an increase in dietary DM from either corn silage or corn grain at the discretion of the herd nutritionist to the same DMI as used in the formulation of the CON diet.

Milk yield and milk composition [fat, protein, and milk urea nitrogen (**MUN**)] data for each bulk tank shipment from each farm were collected from the milk processing plant. The number of cows that contributed to each bulk tank shipment from each farm was recorded by the herd manager. Average daily per-cow milk yield and milk component yields were then calculated.

Diet formulations and the nutrient analyses of feed ingredients used by the nutritionists for diet formulation were obtained from each farm during each period of the trial. The TMR was sampled at the beginning of the trial and every 30 d thereafter. Samples of TMR were composited by farm by period and sent to Dairy One Laboratories (Ithaca, NY) for wet chemistry analysis for DM, CP, soluble protein, NDF, ADF, starch, fat, TDN (calculated using summative energy equations; NRC, 2001), $NE_{l3\times}$ (i.e., NE_l at 3× maintenance level of energy intake, calculated according to NRC, 2001), calcium, and phosphorus.

Daily milk production data were condensed to a monthly mean for each herd for each 30-d period for statistical analysis. Data were analyzed using the mixed model procedure of SAS (SAS Institute, 2008), with period, sequence, and treatment as fixed effects and herd as a random effect. A significant treatment effect was declared at $P < 0.05$, and a trend was declared at $P \geq 0.05$ to $P < 0.10$.

An economic simulation analysis was performed using the Optigen feeding rate (114 g/d per cow), the milk yield response from our field trial, and the following feed and milk price scenarios: SBM ($0.220, $0.403, and $0.587/kg DM), corn grain ($0.079, $0.157, and $0.236/kg DM), corn silage ($0.050, $0.101, and $0.151/kg DM), Optigen ($1.63 and $2.01/kg), and milk ($0.22, $0.33, and $0.44/kg). An economic evaluation of Optigen compared with uncoated prilled urea was not performed because this treatment comparison was not part of our lactation field trial. Corn silage prices were determined by multiplying corn grain prices per bushel times a factor of 8 (Lauer et al., 2009) to determine prices per ton of 35% DM corn silage. The formulation space created by the use of Optigen to partially replace SBM in isonitrogenous supplements was filled

Table 1. Ingredient composition (% of DM) of the control (CON) and Optigen (OPT) TMR, as formulated by nutritionists for the herds[1]

Ingredient	CON	OPT
Forage	55.5	56.0
Corn silage	23.1	24.2
Alfalfa silage	28.0	27.3
Other forage	4.4	4.5
Concentrate	44.5	44.0
Dry-ground shelled corn	9.0	8.5
High-moisture corn	13.3	14.6
Soybean meal (48% CP)	3.5	1.7
Other plant proteins	3.5	3.5
Animal proteins	0.8	0.8
High-fiber by-products	9.4	9.2
Mineral-vitamin-additive mixes	5.0	5.7

[1]Values are means of the 16 treatment diets formulated during the trial. The OPT diet contained 114 g/d per cow of Optigen (Alltech Inc., Lexington, KY) added to the TMR.

Table 2. Nutrient composition (% of DM) of the control (CON) and Optigen (OPT) TMR, as formulated by nutritionists for the herds[1]

Nutrient, %	CON	OPT
DM	53.7 ± 3.9	53.2 ± 5.1
CP	17.1 ± 0.4	17.1 ± 0.4
NDF	30.5 ± 1.3	30.4 ± 2.0
ADF	19.9 ± 0.8	20.0 ± 1.0
Forage NDF	23.1 ± 1.1	23.4 ± 1.2
NFC	39.8 ± 2.2	40.1 ± 2.4
Starch	25.3 ± 2.2	26.2 ± 2.0
Fat	4.8 ± 0.7	4.9 ± 0.8
Calcium	1.0 ± 0.1	1.0 ± 0.1
Phosphorus	0.40 ± 0.02	0.40 ± 0.02

[1]Values are mean ± SD of 16 diets formulated during the trial. The OPT diets contained 114 g/d per cow of Optigen (Alltech Inc., Lexington, KY) added to the TMR.

with DM from either corn grain or corn silage. Feedstuff CP concentrations used for supplement formulations were average tabular values from NRC (2001); a CP equivalence value of 256% (DM basis; Alltech Inc.) was used for Optigen. The simulations were performed using the spreadsheet of Inostroza et al. (2009).

RESULTS AND DISCUSSION

The average ingredient and nutrient composition of the 16 experimental diets, as formulated by the herd nutritionists, are presented in Tables 1 and 2, respectively, whereas analytical results are presented in Table 3. The forage-to-concentrate ratio averaged 55.5:44.5 for CON and 56.0:44.0 for OPT (DM basis). Corn silage constituted a greater percentage of the forage in the OPT formulations. Soybean meal was decreased by 1.8 percentage units and high-moisture corn was increased by 1.3 percentage units, on average, for the OPT formulations (DM basis). Formulated CP concentrations were similar for CON and OPT at 17.1 ± 0.4% (DM basis). However, the analyzed dietary CP concentrations were greater for both CON and OPT, at 18.2 ± 0.9% and 18.4 ± 0.7% (DM basis), respectively. Furthermore, the analyzed diet NDF concentrations were greater than in the formulated diet concentrations for both CON and OPT.

Least squares means for the effect of feeding OPT diets on milk production are presented in Table 4. Milk yield was 0.5 kg/d per cow greater ($P <$ 0.01) for OPT than for CON. Tikofsky and Harrison (2007) and G. Varga and V. Ishler (The Pennsylvania State University, personal communication) reported trends for increased milk yield when diets containing Optigen were fed to dairy cows. However, dos Santos et al. (2008) and Galo et al. (2003) reported that milk yield was unaffected when SBM was partially replaced by Optigen and when uncoated prilled urea plus RUP sources were partially replaced by a polymer-coated prilled urea product, respectively. A greater yield of microbial nitrogen for Optigen than for uncoated prilled urea in ruminal continuous culture has been reported (Chalupa, 2007; Tikofsky and Harrison, 2007; Harrison et al., 2008b), which may partially explain our observed increase in milk yield. In addition, the filling of the diet formulation space created by the use of Optigen with DM from either corn silage or corn grain may have improved the rumen-fermentable carbohydrate and energy status, thereby contributing to the response (NRC, 2001).

In our study, yields of milk fat, milk protein, and milk protein percentage were unaffected ($P > 0.10$) by treatment. A trend ($P = 0.07$), however, was observed for a reduced milk fat percentage for the OPT treatment, in agreement with the results of G. Varga and V. Ishler (The Pennsylvania State University, personal communication). Milk urea nitrogen was greater ($P < 0.01$) for OPT than for CON (13.2 vs. 12.4 mg/dL). These MUN values are within the normally expected range of 10 to 14 mg/dL (Wattiaux et al., 2005), and thus are probably not of consequence. An increase ($P < 0.01$) in MUN from 8.6 mg/dL for the control treatment to 9.8 mg/dL for the Optigen treatment was reported by G. Varga and V. Ishler (The Pennsylvania State University, personal communication).

Feed cost results from the economic simulation analyses are presented in Table 5. For all prices of corn grain, corn silage, and Optigen simulated, feed costs were increased by the use of Optigen with 48% CP SBM priced at \$0.220/kg of DM and were decreased by the use of Optigen with 48% CP SBM priced at \$0.587/kg of DM. With 48% CP SBM priced at \$0.403/kg of DM, the average increases in feed costs from the use of Optigen were \$0.005/d per cow and \$0.034/d per cow for corn silage and corn grain, respectively. Changes in feed costs were more favorable when the formulation space created by the use of Optigen to partially replace 48% CP SBM in isonitrogenous supplements was filled with corn silage rather than corn grain. Income over feed cost results from the economic

Table 3. Chemical composition (% of DM) of the control (CON) and Optigen (OPT) TMR[1]

Nutrient	CON	OPT
DM, %	50.5 ± 3.9	50.8 ± 5.0
CP, %	18.2 ± 0.9	18.4 ± 0.7
Soluble CP, % of CP	49.8 ± 7.0	52.5 ± 5.3
NDF, %	33.6 ± 1.8	35.4 ± 2.8
ADF, %	22.7 ± 2.1	23.6 ± 2.9
Starch, %	23.0 ± 2.9	22.6 ± 4.6
Fat, %	5.6 ± 0.7	6.0 ± 1.0
$TDN_{1\times}$,[2] %	72.6 ± 1.4	71.4 ± 1.9
$NE_{l3\times}$,[3] Mcal/kg	1.72 ± 0.04	1.69 ± 0.06
Calcium, %	1.0 ± 0.1	0.9 ± 0.1
Phosphorus, %	0.4 ± 0.03	0.4 ± 0.04

[1]As analyzed by Dairy One Laboratories (Ithaca, NY). Values are mean ± SD of 16 TMR samples composited by farm by period. Optigen was supplied by Alltech Inc. (Lexington, KY).

[2]Total digestible nutrients at a maintenance level of energy intake, calculated according to the NRC (2001) summative energy equation.

[3]Net energy for lactation at 3× the maintenance level of energy intake, calculated according to NRC (2001).

simulation analyses using the 0.5 kg/d per cow milk yield response from the field trial are presented in Table 6. The IOFC was increased by the use of Optigen for all scenarios simulated, on average, except when milk was priced at $0.22/kg and 48% CP SBM was priced at $0.220/kg of DM, with IOFC averages of −0.040 and −0.007 for corn grain and corn silage, respectively. Changes in IOFC were more favorable when corn grain, corn silage, and Optigen prices were lower and when SBM and milk prices were higher. Although lactation performance and economic evaluations of Optigen compared with uncoated prilled urea were not performed herein, this treatment comparison is of major practical importance and warrants future research.

Table 4. Least squares means for milk yield, milk composition, and milk component yields for the control (CON) and Optigen (OPT) treatments[1]

Item	CON	OPT	SEM	*P*-value
Milk yield, kg/d	35.4	35.9	0.2	<0.01
Fat, %	3.72	3.69	0.02	0.07
Fat, g/d	1,317	1,322	8	NS
Protein, %	2.98	2.97	0.01	NS
Protein, g/d	1,055	1,065	6	0.13
MUN,[2] mg/dL	12.4	13.2	0.3	<0.01

[1]The OPT treatment contained 114 g/d per cow of Optigen (Alltech Inc., Lexington, KY) added to the TMR.

[2]MUN = milk urea nitrogen.

IMPLICATIONS

Milk yield was greater when commercial dairy herds were fed Optigen than when they were not fed Optigen in diets formulated to be isonitrogenous. The crossover design with herd as the experimental unit appears to be a feasible approach for evaluating the efficacy of feed additives on commercial dairy farms. Under the conditions of this study, Optigen fed at 114 g/d per cow was an effective partial substitute for SBM as a source of

Table 5. Influence of feed prices [soybean meal (48% CP): $0.220, $0.403, and $0.587/kg DM] on the change in feed costs when Optigen (114 g/d per cow) partially replaced soybean meal in isonitrogenous supplements[1]

	Change in feed cost, $/d per cow		
Item, $/kg DM	$0.220	$0.403	$0.587
Corn, Optigen			
0.079, 1.63	0.088	−0.028	−0.144
0.079, 2.01	0.131	0.015	−0.101
0.157, 1.63	0.128	0.012	−0.104
0.157, 2.01	0.171	0.055	−0.061
0.236, 1.63	0.168	0.052	−0.064
0.236, 2.01	0.211	0.095	−0.021
Mean	0.150	0.034	−0.083
SD	0.043	0.043	0.043
Minimum	0.088	−0.028	−0.144
Maximum	0.211	0.095	−0.021
Corn silage, Optigen			
0.050, 1.63	0.073	−0.039	−0.152
0.050, 2.01	0.116	0.004	−0.109
0.101, 1.63	0.095	−0.017	−0.130
0.101, 2.01	0.138	0.026	−0.087
0.151, 1.63	0.117	0.005	−0.108
0.151, 2.01	0.160	0.048	−0.065
Mean	0.117	0.005	−0.109
SD	0.031	0.031	0.031
Minimum	0.073	−0.039	−0.152
Maximum	0.160	0.048	−0.065

[1]Optigen was supplied by Alltech Inc. (Lexington, KY).

Table 6. Influence of feed [soybean meal (48% CP): $0.220, $0.403, and $0.587/kg DM] and milk prices ($0.22, $0.33, and $0.44/kg) on change in income over feed cost (IOFC) when Optigen (114 g/d per cow) partially replaced soybean meal in isonitrogenous supplements using the 0.5 kg/d per cow milk yield response from the field trial[1]

	Change in IOFC, $/cow per day								
	$0.22			$0.33			$0.44		
Item, $/kg DM	$0.220	$0.403	$0.587	$0.220	$0.403	$0.587	$0.220	$0.403	$0.587
Corn, Optigen									
0.079, 1.63	0.022	0.138	0.254	0.077	0.193	0.309	0.132	0.248	0.364
0.079, 2.01	−0.021	0.095	0.211	0.034	0.150	0.266	0.089	0.205	0.321
0.157, 1.63	−0.018	0.098	0.214	0.037	0.153	0.269	0.092	0.208	0.324
0.157, 2.01	−0.061	0.055	0.171	−0.006	0.110	0.226	0.049	0.165	0.281
0.236, 1.63	−0.058	0.058	0.174	−0.003	0.113	0.229	0.052	0.168	0.284
0.236, 2.01	−0.101	0.015	0.131	−0.046	0.070	0.186	0.009	0.125	0.241
Mean	−0.040	0.077	0.193	0.016	0.132	0.248	0.071	0.187	0.303
SD	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
Minimum	−0.101	0.015	0.131	−0.046	0.070	0.186	0.009	0.125	0.241
Maximum	0.022	0.138	0.254	0.077	0.193	0.309	0.132	0.248	0.364
Corn silage, Optigen									
0.050, 1.63	0.037	0.149	0.262	0.092	0.204	0.317	0.147	0.259	0.372
0.050, 2.01	−0.006	0.106	0.219	0.049	0.161	0.274	0.104	0.216	0.329
0.101, 1.63	0.015	0.127	0.240	0.070	0.182	0.295	0.125	0.237	0.350
0.101, 2.01	−0.028	0.084	0.197	0.027	0.139	0.252	0.082	0.194	0.307
0.151, 1.63	−0.007	0.105	0.218	0.048	0.160	0.273	0.103	0.215	0.328
0.151, 2.01	−0.050	0.062	0.175	0.005	0.117	0.230	0.060	0.172	0.285
Mean	−0.007	0.106	0.219	0.049	0.161	0.274	0.104	0.216	0.329
SD	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031
Minimum	−0.050	0.062	0.175	0.005	0.117	0.230	0.060	0.172	0.285
Maximum	0.037	0.149	0.262	0.092	0.204	0.317	0.147	0.259	0.372

[1]Optigen was supplied by Alltech Inc. (Lexington, KY).

RDP. Results from economic simulations, using the 0.5 kg/d per cow milk yield response from the field trial, indicate that improvements in IOFC are more favorable at lower corn grain, corn silage, and Optigen prices and at higher SBM and milk prices. More research is warranted to determine potential interactions between diet ingredients or nutrient composition and Optigen supplementation on milk production and IOFC responses.

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