COMPLETE LACTATIONAL PERFORMANCE OF COWS FED WET CORN GLUTEN FEED AND PELLET CONSISTING OF RAW SOYBEAN HULLS AND CORN STEEP LIQUOR

E. E. Ferdinand, J. E. Shirley, E. C. Titgemeyer, J. M. DeFrain, A. F. Park, D. E. Johnson [1], R. T. Ethington [2]

Summary

We evaluated the effect of wet corn gluten feed and a novel product containing raw soybean hulls and corn steep liquor on performance in lactating dairy cows. Forty-six multiparous Holstein cows were used in a randomized incomplete block design. Cows were housed in tie stalls for the first 13 weeks of lactation and moved to group pens for the remainder of the study. Cows were blocked by calving date and assigned to control, wet corn gluten feed (20% of diet DM), or the novel product (20% of diet DM). Diets were administered as total mixed rations at the first feeding postpartum. Control contained (DM basis) 30% alfalfa hay, 15% corn silage, 32% corn, 9.3% whole cottonseed, 4.4% solvent soybean meal (SBM), 3.3% expeller SBM, 1.3% fish meal, 1% wet molasses, and 3.7% vitamins/minerals. Wet corn gluten feed replaced 10% alfalfa hay, 5% corn silage, 5% corn grain, and expeller SBM replaced solvent SBM to maintain diet rumen undegradable protein. The novel product replaced 10% alfalfa hay, 5% corn silage, 3% solvent SBM, and 2% corn. Diet crude protein % and energy density (Mcal/lb, NE_L) for control, wet corn gluen feed, and the novel product were 18.4, 0.73; 18.2, 0.75; 18.5, 0.73; respectively. Milk, energy corrected milk, dry matter intake, and production efficiency (ratio of milk to DM intake) did not differ among diets during the first 91 days of lactation, but there was a diet by week interaction for production efficiency. Cows fed control were more efficient during the first 2 weeks postpartum than cows fed wet corn gluten feed and the novel product, likely due to increased fat mobilization from adipose tissue because intake as a percent of body weight was less for cows fed control. During weeks 3 through 14 postpartum, wet corn gluten feed and the novel product improved milk, energy corrected milk, and milk component yield, and production efficiency. Inclusion of wet corn gluten feed and the novel product at 20% of dietary DM as a partial replacement for alfalfa hay, corn silage, corn grain, and SBM in diets fed to lactating dairy cattle supported performance during early lactation and improved performance during mid and late lactation. In addition, combining wet corn gluten feed or the novel product with corn silage and alfalfa hay maintained milk fat yields, thereby demonstrating that they can serve as effective sources of fiber when fed at 20% of dietary DM. Improved performance attributed to wet corn gluten feed and the novel product is due to factors other than improved digestibility of the diets. These results indicate that wet corn gluten feed and the novel product can serve as alternative feedstuffs in diets fed to lactating dairy cattle.

(Key Words: Wet Corn Gluten Feed, Soybean Hulls, Corn Steep Liquor, By-product.)

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[1]Department of Statistics.
[2]Minnesota Corn Processors, Inc., Marshall, MN.

Introduction

Dairy cattle experience negative energy balance during the first weeks of lactation because they do not consume sufficient dry matter (DM) to offset the demands of the mammary gland. Thus, mammary function during this period is supported by mobilization of stored nutrients, primarily lipids with some protein and carbohydrates, as well as nutrients supplied by the diet. The dietary nutrient supply is a function of nutrient density, dry matter intake, and diet digestibility. Nutrient density of the diet is a formulation issue, digestibility is primarily dependent on diet ingredients and rumen function, and dry matter intake is likely influenced by both ruminal and metabolic factors.

Diets for the early postpartum cows should be formulated to meet the requirements of a transitioning ruminal microbial population and to supply nutrients, especially energy, to a highly metabolically active cow. The form of energy in the diet is an important issue because rapidly fermented starch from concentrates increases ruminal acidity and can lead to decreased fiber digestion and the development of subclinical or acute acidosis. However, excess fibrous carbohydrates reduce the energy density of the diet and decrease productivity.

By-product feedstuffs such as wet corn gluten feed (WCGF) and soybean hulls have been successfully fed to lactating dairy cows and provide a highly digestible source of fibrous carbohydrates without increasing ruminal acidity. On a DM basis, WCGF contains 18 to 22% starch, 42% neutral detergent fiber (NDF), and a highly rumen degradable (65%) protein fraction. Previously, we replaced a portion of alfalfa hay, corn silage, and corn grain with WCGF and reported an increase in DM intake, energy corrected milk (ECM), and production efficiency (ECM/DMI).

Recently scientists at Kansas State University developed a novel pelleted product (SHSL) by combining a digestible source of structural carbohydrates from raw soyhulls with carbohydrates, soluble protein, vitamins, and minerals from corn steep liquor (CSL) in a 75 to 25 ratio, respectively, on a DM basis. They observed that replacing a portion of alfalfa hay, corn silage, ground corn, and solvent SBM with SHSL at a level of 20% of DM improved ECM and protein yields, without depressing milk fat yield. Furthermore, in a subacute ruminal acidosis model, it was observed that SHSL buffered the rumen similarly to alfalfa hay.

Studies that have evaluated production responses to WCGF or SHSL have been relatively short term and did not evaluate early or complete lactation responses. Therefore, the objective of our experiment was to evaluate the effect of WCGF and SHSL on the performance of lactating dairy cows during early lactating as well as over a complete lactation. Our hypothesis was that inclusion of a digestible fibrous carbohydrate source (WCGF or SHSL) as a partial replacement for alfalfa hay, corn silage, and corn grain would not increase ruminal acid load and would improve diet digestibility, thus enhancing nutrient delivery to the cow and improving performance.

Procedures

Forty-six multiparous Holstein cows were used in a randomized incomplete block design, blocked by calving date, and assigned three dietary treatments. Dietary treatments (Table 1) were control, WCGF (20% of diet DM), and SHSL (20% of diet DM). Wet corn gluten feed replaced 10% alfalfa hay, 5% corn silage, and 5% ground corn grain and expeller soybean meal replaced solvent soybean meal to maintain dietary rumen undegradable protein (RUP). Soybean hull-steep liquor pellets replaced 10% alfalfa hay, 5% corn silage, 3% solvent SBM, and 2% ground corn grain. Treatments were initiated at the first feeding postpartum and continued throughout lactation or until cows were removed from the study. Cows were housed and fed individually in a tie-stall facility for the first 13 weeks postpartum and moved to group pens with free stalls for the remainder of the study. Both facilities were located at the Dairy Teaching and Research Center, Kansas State University, Manhattan. Two group pens were used for each treatment, and cows were moved to the pens on day 92 postpartum. Each pen eventually contained eight cows except one SHSL pen that had six cows. The study was terminated when less than four cows constituted a pen. Lactation yields were standardized to 305-2x-ME. Cows fed control, WCGF, and SHSL averaged 248, 283, and 266 days in milk (DIM), respectively, when the study was terminated.

Cows were injected with recombinant bST at 14-day intervals beginning at 66 ± 6 days postpartum. Urine ketones were monitored daily for 14 days postpartum and rectal temperature was measured daily for 7 days postpartum.

Diets were offered as a TMR twice daily (0600 and 1700 hr) for ad libitum consumption. Feed intakes of individual cows were recorded through 13 weeks postpartum, and pen intakes (two pens per treatment) were measured for the remainder of lactation.

Cows were milked daily at 0530 and 1630 hr and individual milk weights were recorded. Milk samples (AM, PM composite) were obtained weekly for analyses of protein, fat, lactose, SCC, and urea nitrogen (MUN).

Body weight was measured on two consecutive days weekly, immediately after the PM milking, and the average used for analysis. Body condition was scored weekly (1 = thin and 5 = fat) using 0.25 increments.

Coccygeal venous blood was collected 2 hr after feeding on days 1, 7, 14, 21, 28, 60, 90, 120, 150, 180, and 210 postpartum to determine plasma concentrations of albumin, glucose, urea nitrogen, total alpha amino nitrogen, triglycerides, and non-esterified fatty acids. Urine and fecal samples were obtained on days 1, 7, 14, 21, 28, 60, and 90 postpartum to determine pH.

Results and Discussion

General observations. The ingredient and chemical composition of experimental diets are reported in Table 1. Diets were formulated to be isonitrogenous (18.4% CP, DM basis) and to contain similar amounts of RUP, NE_L, calcium, phosphorus, and sulfur. Expeller SBM and solvent SBM were varied across diets to balance dietary RUP. Diet RUP was lower for the control diet, but was surplus in all diets. Dietary forage NDF (% of diet DM) was 18, 12, and 12% for C, WCGF, and SHSL, respectively. Total NDF was 29.6% of diet DM in the WCGF and SHSL diets compared to 27% in the control diet, which follows the general recommendation that total dietary NDF should be greater when high NDF by-product feedstuffs are substituted for a portion of the forage. Dietary nonfiber carbohydrate (NFC) decreased as NDF increased, but NE_L remained constant. Diets were formulated to contain 1% calcium and 0.5% phosphorus (DM basis) using standard ingredient values. Sulfur content of the diets is reported because it can be excessive in diets containing steep liquor.

Several health issues are problematic in fresh cows and were of particular interest in our study because of the decrease in forage NDF when WCGF and SHSL were included in the diet. Incidences of disease did not differ among diets, and cows that experienced disorders were treated and remained in the study.

Cows fed WCGF and SHSL attained higher peak milk yield (108.7 and 107.6 lb/day, respectively) than cows fed the control diet (100.1 lb/day) and peaked later in lactation (day 75 and 73, respectively) than control (day 39). Furthermore, cows fed WCGF and SHSL had greater peak DM intake and peaked later in lactation (64.2 lb on day 71; 65.7 lb on day 73; respectively) than cows fed the control diet (61.3 lb, day 62).

Cow performance during weeks 1 to 13. Production responses to dietary treatment for weeks 1 through 13 are reported in Table 2. Total DM intake was numerically higher for cows fed WCGF and SHSL than those fed control. A graphical representation of daily DM intake (data not shown) indicated that cows adjusted to all diets similarly and did not suggest that ruminal acidosis was problematic.

Cows fed WCGF and SHSL produced 9.0 and 6.5% more milk, respectively, than cows fed control but this increase was not statistically different, likely due to the number of cows available for study. Wet corn gluten feed and SHSL were reported to improve milk yield by cows fed diets similar to those used in our study, but cows in those studies were in mid lactation. In our study, production efficiencies were not different among treatments during weeks 1 to 13 of lactation.

The numerical differences in ECM were less than observed for actual milk yield because fat concentration was lower in milk from cows consuming WCGF and SHSL. The decrease in milk fat percentage was significant, but not sufficient to decrease milk fat yield below control and thus can be attributed to dilution. The ability of diets to maintain milk fat has been used as an indicator of effective fiber content. Diets with the byproducts contained 20% alfalfa hay (DM basis) and a forage NDF of 12.1% of DM. They did depress milk fat percentage but maintained fat yield. Thus, WCGF and SHSL contribute to the effective fiber content when included at 20% of the diet DM. Milk protein percentage and yield were similar across treatments, but WCGF increased lactose percentage over control and SHSL. Milk urea N concentrations did not differ across diets.

Changes in bodyweight and body condition score during the first 13 weeks postpartum were similar across diets and failed to support the hypothesis that cows fed control were more efficient because they mobilized more body fat. However, subtle changes in bodyweight may be masked by rumen fill and the subjective nature of body condition scoring.

Urine and fecal pH were not different among dietary treatments. Urine pH was used to evaluate differences in DCAD balance. Fecal pH was used as a gross measurement of shifts in site of digestion by diets.

Cow performance during weeks 14 to 30. All cows utilized in this study were fed a common diet and managed similarly during the dry period in order to remove prepartum events as a confounding factor. Our justification for a complete lactation study was based on the premise that cow performance response to diets in the immediate (first 60 days) postpartum period is confounded by nutritional support from tissue mobilization, metabolic instability, and metabolic adaptations by the mammary gland. Thus, performance response to diets following peak milk production should provide a more accurate representation of nutrient delivery by experimental diets. Further, if a diet failed to meet the lactational demands of the cow, short-term production could be supported by fat mobilization, but future performance would be impaired.

The response of cows to experimental diets during weeks 14 through 30 is reported in Table 3. All cows consumed similar amounts of total DM, but cows fed WCGF and SHSL produced more (P<0.01) milk and ECM with a lower (P<0.05) than cows fed control. Milk protein concentration was slightly reduced by the two byproduct diets and this effect was significant for SHSL. However, yields of milk fat and protein were increased (P<0.01) by both WCGF and SHSL. Compared to control, milk lactose percentage and yield was greater (P<0.01) for cows fed WCGF and SHSL. During weeks 14 to 30 postpartum, production efficiencies were greater for cows fed WCGF and SHSL than for control cows. This is in contrast to the observation for the first 13 weeks of lactation where production efficiencies were not affected by treatment. Likely, the production efficiencies during the first 13 weeks were misleading because of the contribution of mobilized tissue to mammary gland function. During early lactation, control cows probably mobilized more body tissue (predominantly adipose) to support milk production. However, there are limits to tissue mobilization, and these were likely reached during the initial phase of the trial. Thus, the improved production efficiencies for the WCGF and SHSL diets during the second phase of the experiment (weeks 14 to 30 postpartum) are probably better estimates of the true differences among diets in their ability to support lactation than the production efficiencies of the first 13 weeks. Observed body weight and body condition score changes do not support this concept, but they may not be sufficiently precise to detect subtle changes. However, control cows reached peak milk at 39 days in milk (DIM) compared to 75 and 73 DIM for cows fed WCGF and SHSL respectively, suggesting that control cows mobilized more body tissues than cows fed either of the byproduct containing diets. In a companion study, WCGF did not improve total tract digestibility, which implies that other factor(s) are responsible for the observed improvement in production efficiency.

Cow performance during 305-2x-ME. 305-2x-ME milk, ECM, milk fat yield, and milk CP yields were numerically greater for cows fed WCGF and SHSL, but were not different due to large standard errors and a small number of experimental units (Table 4). The numerically higher 305-2x-ME production responses for cows fed WCGF and SHSL reflect the numerically higher yields of milk from cows fed WCGF and SHSL for the first 13 weeks postpartum and statistically higher yield observed for weeks 14 to 30 postpartum.

Conclusion

Inclusion of WCGF and SHSL at 20% of dietary DM as partial replacements for alfalfa hay, corn silage, corn grain, and SBM in diets fed to lactating dairy cattle supported performance during early lactation and improved performance during mid and late lactation. In addition, combining WCGF or SHSL with corn silage and alfalfa hay maintained milk fat yields, thereby demonstrating that WCGF and SHSL can serve as effective sources of fiber when fed at 20% of dietary DM. Improved performance attributed to WCGF and SHSL is due to factors other than improved digestibility of the diets. These results indicate that WCGF and SHSL can serve as alternative feedstuffs in diets fed to lactating dairy cattle.

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Table 1. Ingredient and Nutrient Composition of Diets (Exp. 1)

Item	Diet[1] Control	WCGF	SHSL
Ingredient	----------------------% of dry matter----------------------		
Alfalfa hay	30.00	20.04	20.12
Corn silage	15.00	10.02	10.06
Corn grain	32.05	27.03	30.17
WCGF	-	20.04	-
SHSL	-	-	20.12
Whole cottonseed	9.30	9.30	9.34
Solvent soybean meal	4.39	-	1.40
Expeller soybean meal	3.30	7.71	3.32
Fish meal	1.30	1.31	1.31
Molasses	1.00	1.00	1.01
Dicalcium phosphate	0.88	0.59	0.18
Limestone	1.36	1.54	1.62
Sodium bicarbonate	0.75	0.75	0.67
Magnesium oxide	0.21	0.21	0.22
Trace mineralized salt[2]	0.32	0.32	0.32
Vitamin ADE premix[3]	0.11	0.11	0.11
Vit E premix	0.02	0.02	0.02
Sodium selenite premix[4]	0.01	0.01	0.01
Nutrient			
Dry matter, %	82.6	74.6	84.5
Crude protein, %	18.4	18.2	18.5
RUP, %	7.09	7.41	7.55
ADF, %	18.2	16.7	20.3
NDF, %	27.0	29.6	29.6
NE_L[5], Mcal/kg	1.62	1.65	1.62
NFC[6] ,%	42.3	40.4	40.3
Calcium, %	1.38	1.43	1.20
Phosphorus, %	0.63	0.69	0.56
Sulfur, %	0.25	0.28	0.28

[1]WCGF= Wet corn gluten feed, SHSL= pellet containing 75% raw soybean hull, 25% corn steep liquor (DM basis).

[2]Composition: not less than 95.5% NaCl, 0.24% Mn, 0.24% Fe, 0.05% Mg, 0.032% Cu, 0.032% Zn, 0.007% I, 0.004% Co.

[3]Contributed 5,733 IU vitamin A, 2,866 IU vitamin D, 17 IU vitamin E per kg of diet DM.

[4]Provided 0.06 mg Se per kg of diet DM.

[5]NE_L, NRC, 2001.

[6]Nonfiber carbohydrate = 100 – (%NDF + %CP + %Ether Extract + %Ash).

Table 2. Effects of Diet on Performance during Weeks 1 to 13 Postpartum

	Diet[1]			
Item	Control	WCGF	SHSL	SEM
DM intake, lb/day	51.6	54.9	53.8	1.7
Milk, lb/day	90.8	99.0	96.8	3.5
ECM[2], lb/day	95.3	99.9	97.2	3.5
ECM/DM intake	1.96	1.86	1.85	0.058
Milk fat, %	4.00[a]	3.68[b]	3.75[b]	0.075
Milk fat, lb/day	3.55	3.59	3.51	0.13
Milk CP, %	2.99	2.99	3.00	0.040
Milk CP, lb/day	2.69	2.91	2.84	0.11
Milk lactose, %	4.87[b]	4.99[a]	4.91[b]	0.030
Milk lactose, lb/day	4.43	4.93	4.74	0.19
MUN, mg/dL	14.7	14.7	14.8	0.36
SCC × 1000	665	209	531	224
Initial BW, lb	1583	1581	1530	139
BW change, lb	152	174	187	34.0
Initial BCS	3.04	3.13	3.03	0.096
BCS change	0.35	0.31	0.24	0.12

[1]WCGF = Wet corn gluten feed, SHSL = pellet containing 75% raw soybean hull, 25% corn steep liquor (DM basis).

[2]Energy corrected milk.

[a,b]Means with dissimilar superscript letters differ ($P<0.01$).

Table 3. Effects of Diet on Performance during Weeks 14 to 30 Postpartum

	Diet[1]			
Item	Control	WCGF	SHSL	SEM
DM intake, lb/day	58.7	56.4	60.4	2.03
Milk, lb/day	77.4^{b}	87.5^{a}	92.8^{a}	1.92
ECM[2], lb/day	80.0^{b}	88.0^{a}	90.2^{a}	1.26
ECM/DM intake	1.37^{d}	1.56^{c}	1.49^{c}	0.037
Milk fat, %	3.74^{c}	3.55^{d}	3.35^{d}	0.063
Milk fat, lb/day	2.89^{d}	3.10^{c}	3.09^{c}	0.05
Milk CP, %	3.12^{c}	3.04^{cd}	3.00^{d}	0.025
Milk CP, lb/day	2.40^{b}	2.67^{a}	2.78^{a}	0.04
Milk lactose, %	4.83^{b}	4.93^{a}	4.92^{a}	0.015
Milk lactose, lb/day	3.75^{b}	4.32^{a}	4.56^{a}	0.10
MUN, mg/dL	14.5	14.8	14.9	0.28
SCC × 1000	392	585	524	210
Initial BW, lb	1372	1431	1323	77.8
BW change, lb	-49	-46	-3	34.2
Initial BCS	2.71	2.95	2.82	0.14
BCS change	0.08	0.11	-0.06	0.04

[1]WCGF = Wet corn gluten feed, SHSL = pellet containing 75% raw soybean hull, 25% corn steep liquor (DM basis).

[2]Energy corrected milk.

[a,b]Means with dissimilar superscript letters differ ($P<0.01$).

[c,d]Means with dissimilar superscript letters differ ($P<0.05$).

Table 4. 305-2x-ME Performance

	Diet[1]			
Item	Control	WCGF	SHSL	SEM
Milk, lb	23,704	25,543	26,162	1,336
ECM[2], lb	24,224	25,816	26,206	1,398
Milk fat, lb	904	913	924	71
Milk protein, lb	717	783	789	33

[1]WCGF= Wet corn gluten feed, SHSL = pellet containing 75% raw soybean hull, 25% corn steep liquor (DM basis).

[2]Energy corrected milk.