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Spinning Straw into Milk: Can an All- Byproduct Diet Support Milk Production?

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Abstract

Ruminants are able to consume feeds that are unsuitable for humans and monogastric animals, and thus contribute to increased efficiency of our food systems. This study evaluated the performance of dairy cows consuming a diet comprised almost entirely of byproduct feeds, compared with cows consuming a typical lactation diet. The hypothesis was that the byproduct diet could support 80 lb/day of milk production. Although milk production and crude feed efficiency decreased compared to the typical diet, feed efficiency expressed as human-edible output per human-edible input increased for the byproduct diet. This study highlights the unique and important role played by ruminant agriculture in the quest for improved sustainability of our food systems.

Keywords

nutrition, lactation, sustainability, byproduct

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Summary
Ruminants are able to consume feeds that are unsuitable for humans and monogastric animals, and thus contribute to increased efficiency of our food systems. This study evaluated the performance of dairy cows consuming a diet comprised almost entirely of byproduct feeds, compared with cows consuming a typical lactation diet. The hypothesis was that the byproduct diet could support 80 lb/day of milk production. Although milk production and crude feed efficiency decreased compared to the typical diet, feed efficiency expressed as human-edible output per human-edible input increased for the byproduct diet. This study highlights the unique and important role played by ruminant agriculture in the quest for improved sustainability of our food systems.

Key words: nutrition, lactation, sustainability, byproduct

Introduction
Animal agriculture is perceived by some to be an inefficient use of crops that could instead be used for human consumption. However, the calculations underlying these claims often ignore the fact that some ground is suitable for forages but not row-crop production, and that ruminants often consume a substantial quantity of human-inedible byproducts. The unique ability of ruminants to extract nutrients from fibrous feeds unsuitable for human consumption–including byproducts of food, fuel, and fiber production–provides a substantial efficiency gain to the overall food system. Today, dairy rations typically contain 20 – 30% byproducts, which provides an important avenue for otherwise unusable materials to be turned into nutrient-dense foods for human consumption. Our objective was to compare milk production of cows fed a traditional diet with that of cows fed a diet comprised almost entirely of byproducts of human food/fuel/fiber production, and not grown on arable land that could be used for human food production. We predicted that such a diet could support 80 lb/day of milk production.

Experimental Procedures
Twelve dairy cows were selected from the Kansas State University dairy herd. Cows were all post-peak lactation (154 ± 20 DIM, mean ± SD) and produced on average 94 ± 12 lb of milk per day at the beginning of the study. Cows were housed in

tie stalls and individually fed two different diets in a 2-period crossover design. One diet was a typical lactation total mixed ration and the other was comprised of 95% byproduct feeds (diet composition - Table 1). Each period lasted 20 days, of which the first 17 days allowed for diet adaptation and days 18-20 comprised the sampling period. Milk yield, milk composition, and feed intake were measured and averaged across each sampling period. Feed ingredient and total mixed ration samples were collected, composited, and analyzed for nutrient composition (Dairy One Forage Laboratory, Ithaca, NY). Blood samples were collected immediately before feeding on day 20 of each period and analyzed for plasma glucose and insulin concentrations. Body weights and body condition scores were recorded at the beginning and end of each period; body condition was assessed by three trained individuals and averaged. The study was conducted from March to May 2015 and all animal procedures were approved by the KSU Institutional Animal Care and Use Committee.

Data were analyzed using the mixed procedure of SAS (version 9.3), and included the fixed effects of diet, parity and their interaction, and the random effects of cow and period. Significance was declared at $P \leq 0.05$ and tendencies at $0.05 < P \leq 0.10$.

Results

Some troubleshooting was needed during the first period to improve the palatability of the byproduct diet. Particle size of the wheat straw was decreased, moisture content of the total mixed ration was increased, and molasses was added to mask possible off-flavors or odors. One primiparous cow was removed from the byproduct diet early during the first period due to low feed intake.

Production results are presented in Table 3. Average feed intake during the last three days of each period did not differ by treatment, although there was an effect of parity, with multiparous cows consuming more feed than primiparous cows. Milk production for first parity cows was unaffected by diet; however, the multiparous cows produced an average of 7.9 lb less milk per day on the byproduct diet than on the control diet. Milk fat decreased with the byproduct diet, but milk protein concentration was unaffected. Parity interacted with diet for fat-corrected (FCM) and energy-corrected milk (ECM). Both ECM and FCM decreased more for the multiparous cows on the byproduct diet than for the primiparous cows. Milk urea nitrogen levels were higher for the control diet than for the byproduct diet.

No treatment differences were detected for body condition score or body weight, although a period effect for body weight was observed, with cows on both diets weighing less after the second period. Plasma glucose concentrations were increased for the byproduct diet. Plasma insulin concentrations did not differ between diets.

Discussion

Producers often measure feed efficiency from a milk output per feed input perspective. If we choose to define efficiency as energy-corrected milk per unit of dry matter intake, cows consuming the conventional diet were more efficient, producing 7.5 lb/day more energy-corrected milk per cow than those consuming the byproduct diet.

Despite similar levels of feed intake, cows fed the byproduct diet produced less of all milk components.

Alternatively, feed efficiency could be expressed as human-edible protein output per unit of human-edible protein input. This addresses the concern of many consumers that the resources used as livestock feed could instead contribute directly to the human food supply, and that the conversion of feed protein into animal protein by ruminants actually yields a net loss of nutrients. In this case, human-edible protein is defined as protein that can be digested by humans for nutrients. Corn is considered to be human-edible, even though varieties eaten by livestock are different than eaten by people; hominy feed is considered to be partially edible because of the nutrients (i.e. starch) that could potentially be extracted and incorporated into foods.

Comparing the two diets used in this study, we find that the human-edible protein conversion efficiency was 79% for the conventional diet (net loss) and 131% for the byproduct diet (net gain). Not surprisingly, since byproduct feeds typically aren't suitable for human consumption, the human-edible protein conversion efficiency is higher for this diet. Similarly, if we consider the energy content of human-edible feed between the two diets, we find that the energy conversion efficiency is 85% for the control diet, and 148% for the byproduct diet.

Although this measurement of feed efficiency is not typical for livestock producers, it emphasizes the valuable contribution of ruminants as recyclers in the food system. Ruminant consumption of human-inedible feeds decreases the amount of waste produced by the food industry, and increases the production efficiency of human-edible protein and energy.

Conclusions

Typically, producers partially replace conventional ingredients with byproducts, and observe no negative effects on milk production. The byproduct diet formulated for this study was an extreme case, and although it decreased milk production, the diet was still able to support milk production of 86 lb/day. This study shows that it is possible to support a high level of milk production on a diet largely composed of unconventional feeds that do not compete with production of other human foodstuffs. Expressing feed efficiency in terms of the human food supply highlights the contributions of ruminant livestock production to an efficient and sustainable agricultural sector.

Table 1. Diet composition

Ingredient, % of dry matter	Control diet	Byproduct diet
Corn silage	17.6	--
Alfalfa	22.1	--
Corn gluten feed[1]	26.6	32.0
Cotton seed	4.3	--
Soybean meal[2]	5.9	--
Corn, dry rolled	21.2	--
Wheat straw	--	21.2
Wheat middlings	--	3.4
Hominy feed	--	27.1
Molasses	--	3.9
Blood meal	--	0.7
Algae	--	9.9
Limestone	1.6	1.8
Calcium salts of long-chain fatty acids[3]	0.8	--
Sodium bicarbonate	1.1	--
Vitamin and trace mineral mix	1.3	1.3

[1] Sweet Bran, Cargill, Blair, NE.
[2] Soy Best, Grain States Soya, Inc., West Point, NE.
[3] Megalac-R, Arm & Hammer Animal Nutrition, Princeton, NJ.

Table 2. Nutrient composition of diets

Nutrient, % of dry matter	Control diet	Byproduct diet
Dry matter, % as-fed	50.9	50.3
Crude protein	17.4	17.0
Acid detergent fiber	18.6	18.2
Neutral detergent fiber	30.5	32.9
Non-fiber carbohydrate	37.1	35.6
Crude fat	5.2	4.7
Ash	9.8	8.5

Table 3. Effects of diet on cow performance[1]

	Multiparous		Primiparous			P-value		
Response variable	Control	Byproduct	Control	Byproduct	SEM	Diet	Parity	Diet × parity
Milk yield, lb/day	93.4	85.3	86.9	86.7	4.9	0.04	0.71	0.05
Fat %	3.74	3.42	3.51	3.25	0.17	0.01	0.40	0.63
Fat, lb/day	3.48	2.93	3.02	2.80	0.18	0.001	0.23	0.06
Protein %	3.07	3.04	2.91	2.84	0.07	0.07	0.10	0.39
Protein, lb/day	2.87	2.60	2.51	2.47	0.13	0.02	0.22	0.08
Lactose %	4.76	4.74	4.96	5.01	0.07	0.75	0.02	0.22
Lactose, lb/day	4.45	4.04	4.32	4.34	0.26	0.08	0.82	0.05
Milk urea nitrogen, mg/dL	14.25	11.55	15.18	12.46	0.96	0.001	0.30	0.98
SCLS	3.82	3.62	0.98	0.25	0.89	0.31	0.001	0.56
Energy-corrected milk, lb/day	97.4	85.6	86.7	83.4	4.5	0.01	0.30	0.03
Fat-corrected milk, lb/day	96.7	84.3	86.4	82.8	4.5	0.001	0.34	0.03
Dry matter intake, lb/day	64.0	64.6	57.0	57.9	2.9	0.94	0.001	0.51
BW initial, lb	1570	1563	1341	1343	49	0.52	0.001	0.44
BW final, lb	1568	1592	1354	1341	41	0.49	0.001	0.06
BW change, lb	-2	29	12	3	60	0.28	0.53	0.06
BCS initial	3.44	3.49	3.32	3.35	0.15	0.46	0.54	0.93
BCS final	3.43	3.50	3.36	3.36	0.14	0.39	0.60	0.43
BCS change	-0.01	0.02	0.04	0.02	0.08	0.92	0.63	0.71
Plasma glucose, mg/dL	58.04	61.21	57.43	66.21	2.23	0.01	0.48	0.11
Plasma insulin, ng/mL	0.36	0.51	0.42	0.34	0.08	0.55	0.62	0.11

[1]For response parameters where parity × diet interaction produced a p-value > 0.1, the interaction term was removed from the model to obtain p-values for the main effects. SEM = standard error of the mean; average of the 4 diet/parity combinations. SCLS (somatic cell linear score) = log2(SCC/100)+3.