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Effect of Supplemental Protein and Glucogenic Precursors on Digestibility and Energy Metabolism

Tasha M. King
University of Nebraska - Lincoln

Joslyn K. Beard
University of Nebraska - Lincoln

Mitch M. Norman
University of Nebraska-Lincoln, mnorman2@unl.edu

Hannah C. Wilson
University of Nebraska-Lincoln, hhamilton6@unl.edu

Jim C. MacDonald
West Texas A&M University & University of Nebraska - Lincoln, jmacdonald2@unl.edu

See next page for additional authors

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Summary with Implications

A metabolism study was conducted to evaluate the impact of increasing levels of glucogenic precursors on diet digestibility and acetate clearance. Four supplementation strategies containing 0, 30, 40, and 70 g of supplemental glucogenic potential were supplied to a basal diet of bromegrass hay. Addition of glucogenic potential in the form of rumen undegradable protein improved dry matter, organic matter, and acid detergent fiber digestibility efficiency of acetate utilization in growing lambs fed moderate-quality hay. However, no additive effect of supplementing propionate salts and rumen undegradable protein were observed in this study. This would suggest that rumen undegradable protein requirements must be met to observe effects from increasing levels of glucogenic potential.

Introduction

Supplementation of glucogenic precursors and rumen undegradable protein (RUP) may increase production responses due to improved efficiencies of nutrient utilization. In forage-based production systems, ruminal production of acetate compared to propionate can result in imbalanced acetate:propionate ratio, resulting in negative modifications in energy metabolism. In order to efficiently utilize acetate, animals must have a sufficient supply of glucose coming from propionate or protein serving as glucose precursors. When glucose supply is inefficient, the animal is not able to efficiently utilize acetate causing a decrease in energy utilization. A study isolating the components of modified distillers grains (MDGS; *2019 Nebraska Beef Cattle Report*, p. 29–31), observed that bypass protein contributed greatly to the energy component of distillers improving total digestible nutrients (TDN) in forage-based diets. The hypothesis was that providing increased levels of glucogenic precursors would increase acetate utilization and improve efficiency in growing lambs on a forage-based diet. Therefore, the objective of this study was to determine the effect of supplemental glucogenic potential (GP) on forage digestibility, serum metabolites, and energy utilization of a forage diet.

Materials and Methods

Sixteen crossbred wethers (108 ± 10.3 lb initial BW) were utilized to determine forage digestibility and acetate utilization. Wethers were sorted into 4 blocks based on initial BW in a 4 × 4 replicated Latin Square design. Wethers were randomly assigned within each period to 1 of 4 treatments to provide 0, 30, 40, or 70 g of additional GP: (1) control (**CON**; 0 g of GP), (2) 40 g of NutroCal (**CAP**; Ca-propionate, 30 g of GP; Kemin Industries Inc., Des Moines, IA), (3) 70 g of blood meal and 100 g of feather meal [**BF**; 92.8% crude protein (CP), 61.3% rumen undegradable protein (RUP), 40 g of GP], or (4) combination of CAP and BF (**COMBO**; 70 g of GP). Brome grass hay [8.8% CP, 90.9% organic matter (OM), 71.4% ash-free neutral detergent fiber (NDF_{om}), 44.8% acid detergent fiber (ADF)] was ground with a tub grinder through a 1-inch screen and fed at 2% BW. An ounce of commercial mineral + vitamin premix was offered daily to all wethers.

Periods were 21-d in length allowing for 12 d of diet adaptation, 5 d of total fecal collection, and 4 d for metabolism collections. Wethers were fed brome grass hay twice daily at 0800 and 1700 h, with 50% of daily DM at each feeding. Supplementation occurred at 0730 h daily. Wethers receiving BF supplementation were adapted at levels of 40, 60, and 80% of total supplementation on d 1–3 of each period, respectively. Feed refusals were taken prior to supplementation. On d 12, wethers were placed in metabolism crates at 1700 h for total fecal collection. Fecal bags were emptied and recorded at 0800 and 1700 h daily, fecal samples were composited by period and freeze dried. Feed refusals were taken d 10 to 15 and feed samples taken d 12 and 19 were dried at 60°C for 72 hours to correct for daily dry matter intake. Fecal, feed, and feed refusal samples were ground through a 1-mm screen of a Wiley mill and analyzed for OM, NDF_{om}, and ADF. Digestibilities were calculated using the following equation: (nutrient intake—nutrient output) / nutrient intake.

An acetate tolerance test (ATT) was conducted on d 17 to analyze acetate clearance affected by GP of treatments. Serum acetate clearance rate can be used as an indication of glucogenic potential of a diet and reveal energy efficiency. Jugular catheters were inserted the morning of the ATT, through which a 20% acetic acid solution was infused at 2.75 mL/lb of BW. Blood samples were collected (~7 mL) -1, 0, 1, 3, 5, 7, 10, 15, 30, 60, and 90 min relative to infusion. Serum was filtered with a centrifugal filter device and analyzed for acetate concentration via gas chromatography. Half-life of acetate was calculated as the time required for a 50% decrease from peak serum concentration. Serum were analyzed for glucose concentration by the Biomedical and Obesity Research Core (BORC) of the Nebraska Center for Prevention of Obesity Diseases (NPOD).

On d 19, a blood sample was taken preprandial at 0730 h and 4 h post-prandial at 1230 h via jugular venipuncture and saphenous venipuncture into serum separator vacuum tubes. Serum samples were analyzed for glucose, urea N (SUN), and amino acid concentrations. Glucose and SUN were also analyzed by the BORC lab of NPOD.

Total tract digestibility data were analyzed as a Latin Square design using the MIXED procedure of SAS. Data were

Table 1. Total tract digestibilities for wethers supplemented with glucogenic precursors fed a forage-based diet.

	Supplementation Treatment					
	CON[1]	CAP[2]	BF[3]	COMBO[4]	SEM	*P*-value
DM						
Total intake[5], lb/d	2.28[d]	2.32[c]	2.56[b]	2.68[a]	0.05	< 0.01
Digestibility, %	37.4[b]	36.6[b]	43.0[a]	42.9[a]	0.98	< 0.01
OM						
Total intake, lb/d	2.08[d]	2.14[c]	2.44[b]	2.5[a]	0.04	< 0.01
Digestibility, %	42.6[b]	43.6[b]	49.8[a]	49.8[a]	1.11	< 0.01
NDF_{om}[6]						
Total intake, lb/d	1.54	1.54	1.54	1.54	0.04	0.98
Digestibility, %	44.8	45.2	45.8	45.3	1.28	0.93
ADF						
Total intake, lb/d	1.02[b]	1.02[b]	1.09[a]	1.09[a]	0.03	< 0.01
Digestibility, %	35.6[bc]	35.4[c]	39.2[a]	38.5[ab]	1.31	0.03

[a-d]Means within a row with different superscripts differ ($P < 0.05$).

[1]CON: No supplementation.

[2]CAP: Supplementation of 40 g of NutroCal (Kemin Industries Inc., Des Moines, IA).

[3]BF: Supplementation of 70 g of blood meal + 100 g of feather meal.

[4]COMBO: Supplementation of 40 g of NutroCal + 70 g of blood meal + 100 g of feather meal.

[5]Total intake = basal diet + supplementation.

[6]NDF_{om} = ash-free NDF.

Table 2. Impact of glucogenic precursor supplementation on serum metabolites of wethers fed a forage-based diet.

	Supplementation Treatment					*P*-values		
Measurements	CON[1]	CAP[2]	BF[3]	COMBO[4]	SEM	Trt	Time	Trt x Time
Jugular Glucose mg/dL	55.4	54.1	55.8	55.8	1.93	0.87	< 0.01	0.57
Saphenous Glucose mg/dL	56.7	54.8	55.5	58.0	1.84	0.47	< 0.01	0.16
Jugular SUN[5], mg/dL	11.3[b]	10.6[b]	25.9[a]	25.5[a]	1.12	< 0.01	< 0.01	0.23
Saphenous SUN, mg, dL	11.6[b]	11.2[b]	25.7[a]	25.2[a]	1.09	< 0.01	< 0.01	0.13

[a,b]Means with differing superscripts are different ($P < 0.05$).

[1]CON: No supplementation.

[2]CAP: Supplementation of 40 g of NutroCal (Kemin Industries Inc., Des Moines, IA).

[3]BF: Supplementation of 70 g of blood meal + 100 g of feather meal.

[4]COMBO: Supplementation of 40 g of NutroCal + 70 g of blood meal + 100 g of feather meal.

[5]SUN = serum urea N.

analyzed with lamb serving as experimental unit, with supplementation type and period set as fixed effects. Acetate half-lives were estimated for each animal by regressing the logarithmically transformed acetate concentrations over time. Area under the curves (AUC) were determined for acetate and glucose using the trapezoidal summation method. Serum data was analyzed as repeated measures with time of blood collection serving as repeated factor.

Results

Digestibility of DM and OM were greater ($P < 0.01$; Table 1) for wethers receiving BF and COMBO supplementation compared to the CAP and CON treatments. Treatments had no effect ($P = 0.93$) on NDF_{om} digestibility. Total intake of DM andOM increased ($P < 0.01$) with increasing GP supplementation, which was expected as supplementation increased intake above the 2% BW DMI for CON.

Supplementation had no effect on circulating glucose concentration ($P \geq 0.47$, Table 2) in samples taken from both jugular and saphenous veins. Addition of RUP supplementation in BF and COMBO increased SUN compared to CON and CAP ($P < 0.01$). A time effect was observed ($P < 0.01$) with serum concentrations being lower prepprandial compared to serum concentrations taken post-prandial.

Acetate half-life was not different ($P = 0.39$; Table 3) among supplemental treatments. Acetate AUC was influenced ($P = 0.04$) by supplemental treatments. Wethers fed BF and COMBO had decreased ($P \leq 0.04$) acetate AUC compared to CON wethers. Wethers fed CAP had a tendency ($P = 0.08$) to have a decreased AUC compared to CON. However, glucose AUC was not different ($P = 0.80$) among supplemental treatments.

Conclusion

Results from this study suggest supplementing additional glucogenic precursors in the form of RUP improved efficiency of nutrient and acetate utilization in growing lambs fed a moderate-quality hay. However, no additive effect of supplementing propionate salts and RUP (COMBO) were observed in this study. Nutrient quality of hay fed in this study has potential for a more balanced acetate:propionate ratio which could explain the decreased responses observed from supplementation of glucogenic precursors.

Tasha M. King, graduate student

Joslyn K. Beard, graduate student

Mitch M. Norman, research technician

Hannah C. Wilson, research technician

Jim C. MacDonald, professor Animal Science, Lincoln

J. Travis Mulliniks, range nutritionist, West Central Research and Extension Center, North Platte

Table 3. Effect of supplement on acetate tolerance test for wethers consuming a forage- based diet supplemented with glucogenic precursors.

Acetate tolerance test response	Supplementation Treatment				SEM	*P*-value
	CON[1]	CAP[2]	BF[3]	COMBO[4]		
Acetate half-life, min	39	33	26	31	6	0.39
Acetate AUC[5]	298[a]	242[ab]	205[b]	228[b]	24.3	0.04
Glucose AUC	310	310	326	316	15.7	0.80

[a,b]Means with differing superscripts are different ($P < 0.05$).

[1]CON: No supplementation.

[2]CAP: Supplementation of 40 g of NutroCal (Kemin Industries Inc., Des Moines, IA).

[3]BF: Supplementation of 70 g of blood meal + 100 g of feather meal.

[4]COMBO: Supplementation of 40 g of NutroCal + 70 g of blood meal + 100 g of feather meal.

[5]AUC: area under curve.