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Influence of metabolizable protein and methionine supplementation on growth-performance of Holstein steer calves during the initial 112-d feedlot growing phase

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Abstract

The objective was to examine the effects of metabolizable protein (MP) and ruminal-protected methionine supplementation on growth performance of Holstein steer calves during the initial feedlot growing phase (112 d). One hundred eighty Holstein steer calves (122 ± 7 kg) were blocked by weight and assigned to 30 pens (6 steers per pen). Five treatments were applied: 1) control, a diet based on steam-flaked corn containing urea and dry distillers grains plus solubles as supplemental N sources with no amino acid addition; 2) control diet plus blood meal supplementation; 3) diet from treatment 2, with 0.064% Smartamine M (70% methionine; Adisseo, Alpharetta, GA) supplementation; 4) diet from treatment 2 with 0.096% Smartamine M supplementation; 5) diet from treatment 2 with 0.128% Smartamine M supplementation. All diets were formulated to exceed the estimated MP requirements. The estimated metabolizable lysine, as well as methionine, was deficient in the control diet. Blood meal was added to the control diet to meet estimated lysine requirements (diet 2), the other diets had increasing concentrations of supplemental methionine. Supplemental MP enhanced (10%, $P < 0.02$) interim and overall 112-d average daily gain (ADG). Additional effects of supplemental methionine on ADG were not appreciable ($P > 0.10$). Supplemental MP did not affect ($P > 0.10$) dry matter intake (DMI) during the first 56-d period; however, it tended to increase ($P = 0.08$) DMI during the subsequent 56-d period. Overall, supplemental MP or methionine had no appreciable effect ($P > 0.10$) on DMI. Supplemental MP improved ($P < 0.01$) gain efficiency and estimated dietary net energy (NE) values during the initial 56-d period (11 and 7%, respectively) and overall (7 and 4%, respectively). Supplemental MP did not affect ($P > 0.10$) gain efficiency during the second 56-d period, although it tended to enhance ($P = 0.08$) estimated dietary NE. Supplemental methionine did not appreciably affect ($P > 0.10$) gain efficiency or estimated dietary NE. Therefore, adding MP to cover the estimated limiting amino acid supply in diets may enhance the gain efficiency and dietary energetics of growing Holstein calves. However, amino acid addition supplementation beyond the requirements may not produce extra productive performance of steer calves.

Key words: growth performance, feedlot, Holstein, metabolizable amino acids

Introduction

In a survey of feedlot nutritionists in the United States, Samuelson et al. (2016) reported that Holstein or Holstein crossbred cattle represent close to 19% of the cattle on feed in the United States. Calf-fed Holstein steers represent most of the cattle fed in the southwest desert region of the United States and enter the feedlot at characteristically light weights (115 to 180 kg), where they are fed for long periods, typically over 285 d (Latack et al., 2021; Carvalho et al., 2022). Moreover, because calf-fed Holsteins often arrive at the feedlot at a lighter weight (~130 kg) than traditional native beef cattle breeds, they require a longer initial (growing) phase that extends until calves reach a live weight of about 280 kg or first 112 to 140 d in the feedlot (Zinn et al., 2007). In the feedlot nutritionists survey previously mentioned, authors reported that nutritionists often recommend diets with 10% to 20% distiller grains byproducts (dry matter basis; DM), plus urea as a non-protein nitrogen source (Samuelson et al., 2016). Additionally, receiving and finishing diets included average crude protein (CP) concentrations of 14.5% and 13.4% of DM, respectively (Samuelson et al., 2016). These protein concentrations exceed the overall requirements of growing and finishing cattle based on the metabolizable protein (MP) system (NASEM, 2016).

Previous research has proposed a feeding system based on metabolizable amino acids requirements instead of crude protein requirements, an approach analyzed by Zinn and Shen (1998) and proposed by NASEM (2016) for the formulation of precision diets to enhance the growth performance of lightweight feedlot calves. The system is based on the estimated

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supply and requirements of essential amino acids. The early feedlot growing phase (first 112 to 140 d) of lightweight calves such as calf-fed Holsteins is particularly sensitive to this approach (Zinn and Shen, 1998), with both lysine and methionine as co-limiting amino acids (Zinn et al., 2000, 2007; Montaño et al., 2016; Torrentera et al., 2017). Montaño et al. (2019) observed greater growth performance of calf-fed Holstein steers fed a steam-flaked corn and distillers dried grains plus solubles (DDGS)-based diet supplemented with 0.4, or 0.8% (DM basis) of rumen-protected methionine and lysine (Smartamine ML). Additionally, Salinas-Chavira et al. (2016) reported similar benefits to adding rumen-protected amino acids when a basal diet was supplemented with a blood meal blend. Therefore, regarding the source of amino acid, increasing the amount of amino acids (i.e., lysine and methionine) reaching the small intestine improves the growth performance of calf-fed Holsteins in the early growing period.

However, no previous research evaluated the combination of DDGS, bloodmeal, and rumen-protected methionine in steam-flaked corn-based diets for feedlot steers to reach metabolizable protein requirements in the growing period of calf-fed Holstein steers. Therefore, the objective of the present study was to examine the effects of MP and ruminal-protected methionine supplementation on steam-flaked corn-based diets containing DDGS and blood meal on the growth performance of calf-fed Holstein steers during the initial growing phase.

MATERIALS AND METHODS

Animal care and handling techniques were approved by the University of California Animal Care and Use Committee (#22271).

Animal Management

One hundred and eighty Holstein steer calves (122 ± 7 kg) were used to evaluate the effects of metabolizable protein and supplemental methionine on growth performance and dietary energetics during the initial 112-d feedlot growing phase. Calves were obtained from a commercial calf ranch (CalfTech, Tulare, CA) and were 119 ± 4 d of age at the beginning of the study. Upon arrival at the University of California Desert Research and Extension Center (El Centro, CA), steer calves were vaccinated against infectious bovine rhinotracheitis and bovine virus diarrhea (type 1 and 2), bovine parainfluenza-3 virus, bovine respiratory syncytial virus (Cattle Master Gold FP 5 L5, Pfizer Animal Health, New York, NY), clostridia (Ultrabac 8, Pfizer Animal Health, New York, NY), treated against internal and external parasites (Dectomax, Pfizer Animal Health, New York, NY), injected with 1,500 IU vitamin E (as D-alpha-tocopherol) 500,000 IU vitamin A (as retinyl-palmitate) and 50,000 IU vitamin D_3 (Vital E-AD, Stuart Products, Bedford, TX), and 300 mg tulathromycin (Draxxin, Pfizer Animal Health, New York, NY).

Steers calves were blocked by initial shrunk (off truck) weight into five groups and randomly assigned within weight groupings to 30 pens (six steers per pen). Pens were 43 m^2 with 22 m^2 overhead shade, automatic waterers, and 2.4 m fence-line feed bunks. Steers were allowed ad libitum access to feed and water. Fresh feed was provided twice daily, at 06:00 and 14:00 h, offering ~40% of daily consumption in the morning and 60% in the afternoon. Diets were prepared weekly and stored in plywood boxes in front of each pen. Feed samples were collected from each batch during diet preparation and composited weekly for DM analysis (oven-drying at 105 °C for 24 hours) to determine DMI. The composition of experimental diets is shown in Table 1. The basal diet utilized DDGS and urea as sources of supplemental nitrogen. Five dietary treatments were evaluated: 1) Control; no rumen-protected amino acid additive, urea, and DDGS as sole sources of supplemental N; 2) urea and blend of DDGS and blood meal (sources of additional metabolizable lysine); 3) same diet as treatment 2 with 0.064% Smartamine M supplementation; 4) same diet as treatment 2 with 0.096% Smartamine M supplementation; 5) same diet as treatment 2 with 0.128% Smartamine M supplementation. The source of supplemental methionine was Smartamine M (contains a minimum of 70% methionine, protected from ruminal degradation via a pH-sensitive copolymer coating; Adisseo, Alpharetta, GA).

Steer full body weight (BW) was recorded every 28 d in the morning until the end of the experiment (day 112) to monitor live weight changes. Steers were permitted full access to feed and water prior to weighing. In determining average daily gain (ADG), interim and final weights were reduced by 4% to account for digestive tract fill. On the same day of cattle weighing, refusals from feed bunks were shoveled back into the plywood boxes, and boxes were weighed for remaining feed to determine feed intake.

Estimation of dietary net energy

Energy gain (**EG**, Mcal/d) was calculated by the equation: $EG = 0.0557 W^{0.75} \times ADG^{1.097}$; where EG is the daily deposited energy, and W is the body weight (NASEM, 2000). Maintenance energy (**EM**, Mcal/d) was calculated by the equation: $EM = 0.084 W^{0.75}$ (Garrett, 1971). From the derived estimates of energy required for maintenance and gain, the NEm and NEg values of the diet were obtained using the quadratic formula: $x = (-b - \sqrt{b^2 - 4ac})/2c$, where $a = -0.41\text{EM}$, $b = 0.877\text{EM} + 0.41\text{DMI} + \text{EG}$, and $c = -0.877\text{DMI}$, and $\text{NEg} = 0.877\ \text{NEm} - 0.41$ (Zinn and Shen, 1998).

Statistical design and analysis

Data for growth performance variables were analyzed in a randomized complete block design, considering initial shrunk weight groupings for blocks and pen as experimental units (SAS, Version9, Inst. Inc., Cary, NC). In determining average daily gain (ADG), interim and final weights were reduced by 4% to account for digestive tract fill. The effects of increasing the concentration of methionine in the diet were tested for linear and quadratic components by means of orthogonal polynomials. Data were analyzed using the Proc MIXED procedure (SAS, Version9, Inst. Inc.).

Results and Discussion

Treatment effects on growth performance and dietary NE are shown in Table 2. Supplemental MP had a positive effect ($P < 0.02$) on interim and overall 112-d ADG. Additional effects of supplemental methionine on ADG were not appreciable ($P > 0.10$). Supplemental MP did not affect ($P > 0.10$) DMI during the first 56-d period. However, it tended to increase (4%, $P = 0.08$) DMI during the subsequent 56-d period (56 to 112 d on feed). Overall, supplemental MP or methionine had no appreciable effect ($P > 0.10$) on cattle DMI. Supplemental MP had a positive effect ($P < 0.01$) on

Table 1. Diet composition

		MP + Smartamine M, % (DM basis)			
Item	Control	0	0.064	0.096	0.128
Ingredient composition, % DM					
Sorghum sudan hay	8.00	8.00	8.00	8.00	8.00
Alfalfa hay	4.00	4.00	4.00	4.00	4.00
Tallow	2.50	2.50	2.50	2.50	2.50
Molasses, cane	4.00	4.00	4.00	4.00	4.00
Dry distillers grains with solubles	7.00	7.00	7.00	7.00	7.00
Blood meal	0.00	3.00	3.00	3.00	3.00
Steam flaked corn	70.99	67.99	67.93	67.90	67.87
Urea	1.15	1.15	1.15	1.15	1.15
Limestone	1.68	1.68	1.68	1.68	1.68
Dicalcium phosphate	0.10	0.10	0.10	0.10	0.10
Magnesium oxide	0.15	0.15	0.15	0.15	0.15
Smartamine[a]	0.00	0.00	0.064	0.096	0.128
TM salt[b]	0.40	0.40	0.40	0.40	0.40
Nutrient composition, DM basis[c]					
Dry matter, %	87.9	87.9	87.9	87.9	87.9
NEm, Mcal/kg	2.21	2.18	2.18	2.18	2.18
NEg, Mcal/kg	1.54	1.52	1.52	1.52	1.52
Crude protein, %	13.7	16.2	16.3	16.3	16.3
Rumen degradable protein, % CP	63.6	57.2	57.3	57.3	57.3
Rumen undegradable protein, % CP	36.4	42.8	42.7	42.7	42.7
Ether extract, %	6.5	6.4	6.4	6.4	6.4
Ash, %	5.8	5.9	5.9	5.9	5.9
Nonstructural carbohydrates, %	58	57.5	57.5	57.5	57.5
NDF, %	16.6	16.3	16.3	16.3	16.3
Calcium, %	0.8	0.81	0.81	0.81	0.81
Phosphorus, %	0.34	0.34	0.34	0.34	0.34
Potassium, %	0.75	0.75	0.75	0.75	0.75
Magnesium, %	0.28	0.28	0.28	0.28	0.28
Sulfur, %	0.17	0.19	0.19	0.19	0.19

[a] Smartamine M (contains a minimum of 70% methionine, protected from ruminal degradation via a pH-sensitive copolymer coating; Adisseo, Alpharetta, GA).
[b] Trace mineral salt contained: $CoSO_4$,0.068%; $CuSO_4$, 1.04%; $FeSO_4$, 3.57%; ZnO, 1.24%; $MnSO_4$, 1.07%, KI,0.052%; and NaCl, 92.96%.
[c] Based on tabular values for individual feed ingredients (NASEM, 2016).

gain efficiency and estimated dietary NE during the initial 56-d period (11% and 7%, respectively) and overall (7% and 4%, respectively). Although supplemental MP tended to increase (3%, $P = 0.08$) estimated dietary NE, supplemental MP did not affect ($P > 0.10$) gain efficiency during the second 56-d period. Supplemental rumen-protected methionine did not appreciably affect ($P > 0.10$) gain efficiency or estimated dietary NE.

In the current study, when diets were supplemented with blood meal, regardless of the supplemental rumen-protected amino acid, all amino acid requirements were met (Table 3), particularly the most limiting amino acids such as methionine, lysine, and histidine. Previous research has reported that when diets are formulated to meet metabolizable amino acid requirements, the efficiency of dietary energy utilization is increased (Torrentera et al., 2017; Montaño et al., 2019). Torrentera et al. (2017) observed greater gain efficiency and dietary energetics of calf-fed Holstein steer fed a steam-flaked corn-based diet (urea as a sole N) supplemented with rumen-protected methionine and lysine. Moreover, Montaño et al. (2019) observed greater ADG, gain efficiency, and efficiency of energy utilization of Holstein's calves fed a steam-flaked corn-based diet containing DDGS as the source of supplemental metabolizable protein when supplemented with rumen-protected methionine and lysine. However, increasing the concentration of DDGS to the detriment of steam-flaked corn and urea did not improve the growth performance of calf-fed Holstein steers when histidine, methionine, and lysine were co-limiting amino acids in their diets (Montano et al., 2023).

Previous research from Zinn et al. (2000, 2007) observed that supplementing a basal steam-flaked corn diet supplemented with fish meal improved gain efficiency and estimated dietary NE in calf-fed Holstein steers during the initial growing phase. Salinas-Chavira et al. (2016) and Carvalho et al. (2022) have reported that during the initial 112-d feeding period, calf-fed Holstein steers had improved ADG, gain efficiency, and estimated dietary NE when the dietary metabolizable amino acids were included along with a

Table 2. Treatment effects on measures of growth performance and dietary NE

		MP + Smartamine M[a], % (DM basis)					*P*-value		
Item	Control	0	0.064	0.096	0.128	SEM	Control vs MP 0% Smartamine	Smartamine	
								Linear	Quadratic
Days on test	112	112	112	112	112				
Pen replicates	6	6	6	6	6				
Shrunk weight[b]									
Initial	122	122	122	122	122	0.33	0.19	0.83	0.56
56 d	184	192	193	193	192	1.23	<0.01	0.92	0.15
Final	250	260	264	264	262	2.19	<0.01	0.59	0.11
Average daily gain, kg									
1-56 d	1.12	1.25	1.27	1.27	1.24	0.02	<0.01	0.86	0.15
56-112 d	1.17	1.21	1.27	1.26	1.25	0.03	0.02	0.45	0.32
1-112 d	1.14	1.23	1.27	1.26	1.25	0.02	<0.01	0.60	0.12
Dry matter intake, kg/d									
1-56 d	4.66	4.72	4.7	4.71	4.66	0.07	0.62	0.61	0.8
56-112 d	5.70	5.90	5.96	6.05	5.85	0.13	0.08	0.91	0.27
1-112 d	5.18	5.31	5.33	5.38	5.26	0.09	0.16	0.79	0.40
Gain–to-feed ratio									
1-56 d	0.24	0.26	0.27	0.27	0.27	0.003	<0.01	0.69	0.19
56-112 d	0.20	0.21	0.21	0.21	0.21	0.005	0.25	0.27	0.98
1-112 d	0.22	0.23	0.24	0.23	0.24	0.003	<0.01	0.32	0.59
Dietary net energy, Mcal/kg									
Maintenance, NEm									
1-56 d	1.81	1.92	1.96	1.95	1.94	0.02	<0.01	0.53	0.26
56-112 d	1.83	1.86	1.91	1.87	1.92	0.03	0.08	0.30	0.93
1-112 d	1.78	1.84	1.88	1.86	1.88	0.02	<0.01	0.34	0.69
Gain, NEg									
1-56 d	1.18	1.27	1.31	1.3	1.29	0.02	<0.01	0.53	0.26
56-112 d	1.20	1.23	1.26	1.23	1.27	0.03	0.08	0.30	0.93
1-112 d	1.15	1.21	1.24	1.22	1.24	0.02	<0.01	0.34	0.69
Observed/expected dietary net energy									
Maintenance									
1-56 d	0.82	0.88	0.89	0.89	0.89	0.01	<0.01	0.53	0.26
56-112 d	0.83	0.84	0.86	0.85	0.87	0.01	0.08	0.30	0.93
1-112 d	0.81	0.84	0.86	0.85	0.86	0.01	<0.01	0.34	0.69
Gain									
1-56 d	0.77	0.85	0.87	0.87	0.86	0.01	<0.01	0.53	0.26
56-112 d	0.78	0.80	0.83	0.81	0.83	0.02	0.08	0.3	0.93
1-112 d	0.76	0.80	0.82	0.81	0.82	0.01	<0.01	0.34	0.69

[a] Smartamine M (contains a minimum of 70% methionine, protected from ruminal degradation via a pH-sensitive copolymer coating; Adisseo, Alpharetta, GA)
[b] Live weight reduced by 4% to account for gut fill.

blend of blood meal and corn distillers replacing urea as sole N source.

Although variable in composition, the low lysine concentration in DDGS (NASEM, 2016) may limit its usefulness as a primary source of metabolizable protein for lightweight calves. This deficiency can be offset by supplementing with blood meal as the main source of supplemented lysine (NASEM, 2016). As previously mentioned, in the current study, the growth performance of Holstein calves fed a steam-flaked corn-based diet in combination with DDGS and blood meal was not further enhanced by including additional metabolizable methionine. Likewise, Carvalho et al. (2022) observed that supplementing steam steam-flaked corn-based diet with DDGS plus blood meal had greater growth performance and NE utilization of calf-fed Holstein steers during the initial 112-d period. However, Latack et al. (2021) did not observe enhancements in the initial 168-d growth performance of calf-fed Holstein steers fed steam-flaked corn and DDGS-based diet supplemented with rumen-protected methionine and lysine.

Although diet formulation to meet metabolizable amino acid requirements has consistently enhanced gain efficiency and dietary NE, the effect on DMI has been variable. Similarly to the current study, previous research has reported that

Table 3. Treatment effects on estimated metabolizable amino acid supply vs requirement

		MP + Smartamine M[a], % (DM basis)				
Item	Control	0	0.064	0.096	0.128	Requirement (NASEM, 2000)
Initial 56-d						
DMI, kg/d	4.66	4.72	4.70	4.71	4.66	
Metabolizable protein, g/d	512	588	586	589	581	490
Methionine, g/d	9.0	9.9	10.6	11.0	11.2	9.8
Lysine, g/d	24.9	32.3	32.1	32.2	31.8	31.3
Arginine, g/d	17.7	21.6	21.5	21.6	21.3	16.2
Threonine, g/d	20.5	24.2	24.1	24.2	23.9	19.1
Leucine, g/d	38.6	48.9	48.6	48.8	48.2	32.8
Isoleucine, g/d	20.1	20.7	20.6	20.6	20.4	13.7
Valine, g/d	23.8	30.9	30.7	30.9	30.5	19.6
Histidine, g/d	8.9	14.0	13.9	14.0	13.8	12.2
Phenylalanine, g/d	20.5	26.7	26.5	26.6	26.3	17.1
Tryptophan, g/d	5.7	7.2	7.2	7.2	7.1	2.9
Final 56-d						
DMI, kg/d	5.70	5.90	5.96	6.05	5.85	
Metabolizable protein, g/d	626	735	743	755	730	535
Methionine, g/d	11.1	12.3	13.4	14.1	14.1	10.7
Lysine, g/d	30.4	40.3	40.7	41.3	39.9	34.3
Arginine, g/d	21.7	27.0	27.3	27.7	26.8	17.7
Threonine, g/d	25.1	30.3	30.5	31.0	30.0	20.9
Leucine, g/d	47.2	61.1	61.7	62.6	60.5	35.9
Isoleucine, g/d	24.6	25.8	26.1	26.5	25.6	15.0
Valine, g/d	29.1	38.6	39.0	39.5	38.2	21.4
Histidine, g/d	10.9	17.5	17.7	17.9	17.3	13.4

[a] Smartamine M (contains a minimum of 70% methionine, protected from ruminal degradation via a pH-sensitive copolymer coating; Adisseo, Alpharetta, GA).

amino acid supplementation to meet metabolizable amino acid requirements did not affect the DMI of Holstein calves in the early feeding period (Montaño et al., 2016, 2019; Salinas-Chavira et al., 2016; Torrentera et al., 2017). However, Zinn et al. (2000, 2007) and Carvalho et al. (2022) observed that amino acid supplementation to meet metabolizable amino acid requirements increased calf-fed Holstein steers DMI during the growing feedlot phase.

Treatment effects of estimated metabolizable amino acid supply (NASEM, 2000, level 1) vs. requirements (NASEM, 2000) are shown in Table 3. The greater observed growth performance of Holstein steers in the initial phase of the current experiment was consistent with the estimated amino acid supply required for maximal growth. Moreover, only the basal control diet (with DDGS and urea as sole nitrogen sources) was deficient in methionine (8.2%), lysine (20.4%), and histidine (23.0%). Likewise, during the second feeding period (56 to 112 d), all treatments, except for the basal control diet, met or exceeded the estimated metabolizable lysine and methionine requirement. Histidine might also be considered a limiting amino acid in this study. However, prior work (Montaño et al., 2016) reported that gain efficiency and estimated dietary NE were optimized when theoretical methionine and lysine, but not histidine requirements were met. However, little is known about the effect of histidine on the growth performance of steers. Although meeting estimated metabolizable amino acid requirements increased the observed versus expected NEm and NEg based on diet formulation in the current study, the overall improvement was considerably less than expected (81%), perhaps indicating an overestimation of metabolizable amino acid supply, particularly lysine.

This difference may also be attributed to the variable intestinal digestibility of blood meal. Fitzpatrick and Bayley (1977) observed greater apparent amino acids digestibility in pigs, particularly lysine when animals were fed blood meal produced by the freeze-drying process compared to the commercial process. Additionally, Moughan et al. (1999) evaluated 20 different blood meal products that represented a wide range of commercial processing methods and observed similar crude protein among samples; however, there was a large variation in apparent ileal nitrogen digestibility (from 17% to 95%) and lysine bioavailability (60.3% to 100%) among blood meal products. These authors conclude that the processing method of blood meal production influenced the product's nutritional value (Moughan et al., 1999). The variation in lysine's bioavailability from different blood meal sources has also been previously reported. Kerr et al. (2019) observed that pigs had a decrease in standardized ileal digestibility (SID) of lysine values of blood meals when compared to the NASEM (2012) values (82% vs. 93%, SID lysine, respectively). Additionally, El-Haroun and Bureau (2007) reported that the bioavailability of lysine in rainbow trout was also influenced by the source and processing of the blood meal.

Conclusion

Steam-flaked corn and distiller grain-based diets during the initial feeding phase of calf-fed Holstein steers in the feedlot should be formulated considering limiting metabolizable amino acids (lysine and methionine). Blood meal (from non-ruminants) could be an alternative to provide these limiting amino acids. Rumen-protected methionine supplementation beyond the requirements did not improve calf-fed Holstein steers' growth performance in the growing feedlot phase.

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Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

All authors were involved in study design, data collection, data analysis, and manuscript preparation, and approved the submitted version.

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