Influence of feed intake on nutrient and energy balance in heifers

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The objective of this experiment was to examine the effect of feed intake of a forage-based diet on nutrient and energy metabolism in heifers. Our data indicate that increasing dry matter intake decreases digestive efficiency and increases energy intake and losses. However, the increase in energy intake is greater than the losses associated with decreased digestibility, resulting in increased average daily gain as dietary energy intake increases.

Summary

Eight Angus heifers (approximately 10 months of age; 763 ± 4.0 lb of body weight) were used in a replicated 4 × 4 Latin square design to examine the effect of feed intake of a forage-based diet on nutrient and energy metabolism in heifers. Dietary treatments consisted of feeding a total mixed ration consisting (dry matter basis) containing 48.5% alfalfa hay, 48.5% corn silage and 3% vitamin/mineral supplement offered at 1.0%, 1.4%, 1.8% or 2.2% (dry matter basis) of body weight. Sample collection periods were 15 days, with the first 10 days for adaptation to the feeding level, followed by five days of sample collection. Dry matter, neutral detergent fiber, starch, and crude protein intake, fecal excretion, and lb digested per day increased linearly ($P \leq 0.02$) with increasing intake. Dry matter, neutral detergent fiber, starch, and crude protein digestibility (% of intake) linearly decreased ($P \leq 0.04$) with increasing intake. Gross energy intake, fecal energy, digestible energy, urinary energy, gaseous energy, metabolizable energy, heat production and retained energy increased linearly ($P < 0.001$) with increasing intake. However, the increase in energy intake was greater than the energy losses associated with the decrease in digestibility, resulting in an increase in average daily gain. Retained energy for heifers fed 1.0% and 1.4% of body weight was negative, suggesting these heifers were in negative energy balance. Further analyses will be conducted to calculate estimated maintenance energy requirements and efficiency of energy use and compared to past research. This could provide insights into potential differences between cattle with current genetics as compared to cattle from research conducted 30-plus years ago.

Introduction

There has been considerable recent interest in how cow size influences efficiency of weaned calf production. The size of cows, as well as carcass weight of finished cattle, has increased dramatically over the past 30-plus years. This has been driven by the selection for greater growth rate in calves and the demand for heavier finished carcasses by the packers. Dietary energy requirement models (NASEM, 2016) for beef cattle utilize the net energy system for predicting requirements, which accounts for all inputs (intake) and losses (fecal, urinary, gaseous and heat). However, there has been limited research quantifying all inputs and losses over the last 30-plus years, especially for replacement heifers and cows that are typically fed forage-based diets. Therefore, this study was conducted to examine the effects of dry matter intake on diet digestibility and energy balance in nonpregnant replacement Angus heifers.

Procedures

All procedures with animals were approved by the North Dakota State University (NDSU) Animal Care and Use Committee. Eight Angus heifers (approximately 10 months of age; 763 ± 4.0 lb of body weight) were used in a replicated 4 × 4 Latin square design to examine the effect of feed intake of a forage-based diet on nutrient and energy metabolism in heifers. Dietary treatments consisted of feeding a total mixed ration (Table 1) consisting (dry matter basis) of 48.5% alfalfa hay, 48.5% corn silage and 3% vitamin/mineral supplement offered at 1.0%, 1.4%, 1.8% or 2.2% of body weight. Periods were 15 days in length, with the first 10 days for adaptation to the feeding level, followed by five days of sample collection. Offered feed (hay and supplements) and refusals (if present) were weighed and sampled

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Table 1. Nutrient composition of total mixed ration fed to heifers.

Nutrient	% of DM
Organic matter	89.7
Crude protein	13.5
Neutral detergent fiber	49.6
Acid detergent fiber	31.2
Starch	15.1
Ether extract	1.34
Gross energy, kcal/g	4,261

daily during the collection phase. Total feces and urine were collected over four consecutive days (days 11 to 14). Feces were collected using fecal bags, weighed and sampled twice daily. Feed, refusals and fecal samples were composited by steer and period, dried, ground and analyzed for nutrient and energy concentration. Urine was collected via urinary catheters, preserved in HCl and subsampled daily. Total mass was recorded, and aliquots were frozen for nitrogen and energy analysis.

Heat production and methane production were measured using headbox respiration chambers over 24 hours on day 15 of each period. Steers were tethered and had access to the total mixed ration and water. Air samples were collected from the inlet and outlet of the chambers and analyzed with a Siemens Ultramat 23 gas analyzer for oxygen, carbon dioxide and methane concentrations. Total air flow was recorded and corrected for temperature and humidity. Methane energy loss was calculated by multiplying methane volume by 9.45 kcal/L. Energy balance was calculated from gross energy intake and energy losses via feces, urine, methane and heat. Data were analyzed using the MIXED procedure in SAS (SAS Institute Inc., Cary, NC). The model included square, steer within square, period within square and treatment. Linear and quadratic effects were determined using contrast statements. Significance was declared at $P < 0.05$.

Results and Discussion

Dry matter, neutral detergent fiber, starch, and crude protein intake, fecal excretion, and lb digested increased linearly ($P \leq 0.02$) with increasing intake (Table 2). There were also trends for quadratic effects, which occurred because some of the heifers fed the higher intakes did not consume all of the feed offered. Dry matter, neutral detergent fiber, starch and crude protein digestibility (% of intake) linearly decreased ($P \leq 0.04$) with increasing intake, which is consistent with past research (Tyrrell and Moe, 1975; Van Soest and Fox, 1992). Gross energy intake, fecal energy, digestible energy, urinary energy, gaseous energy, metabolizable energy, heat production and retained energy increased linearly ($P < 0.001$) with increasing intake (Table

Table 2. Influence of dry matter intake of a forage-based diet on nutrient digestibility in Angus heifers.

	DM offered, kg					*P*-value	
Item	1%	1.4%	1.8%	2.2%	SEM	Linear	Quadratic
Dry matter							
Intake, lb/d	7.47	10.43	12.10	12.94	0.542	<0.001	0.06
Feces, lb/d	3.15	4.45	5.11	6.08	0.158	<0.001	0.30
Digested, lb/d	4.32	5.95	6.99	6.86	0.461	<0.001	0.07
Digested, % of intake	57.9	57.1	57.6	51.0	2.08	0.04	0.18
Neutral detergent fiber							
Intake, lb/d	3.86	5.38	6.26	6.66	0.284	<0.001	0.06
Feces, lb/d	1.65	2.34	2.73	3.28	0.086	<0.001	0.42
Digested, lb/d	2.23	3.04	3.53	3.37	0.251	0.002	0.06
Digested, % of intake	57.6	56.6	56.0	48.2	2.45	0.02	0.51
Starch							
Intake, lb/d	1.19	1.65	1.91	2.03	0.091	<0.001	0.08
Feces, lb/d	0.073	0.108	0.123	0.152	0.0055	<0.001	0.47
Digested, lb/d	1.11	1.55	1.78	1.88	0.0880	<0.001	0.07
Digested, % of intake	93.6	93.5	93.4	92.3	0.28	0.005	0.08
Crude protein							
Intake, lb/d	1.05	1.46	1.70	1.82	0.067	<0.001	0.04
Feces, lb/d	0.525	0.734	0.850	1.011	0.021	<0.001	0.25
Digested, lb/d	0.524	0.728	0.850	0.805	0.057	0.002	0.04
Digested, % of intake	50.1	49.7	49.8	41.6	2.15	0.02	0.09

3), which is expected because of increased dry matter intake and thus increased energy intake and losses. However, the increase in energy intake was greater than the energy losses associated with the decrease in digestibility, which resulted in increased average daily gain. Further research is needed to examine if the digestive efficiency losses associated with increased energy intake have changed over time and if the currently used equations to predict net energy supply (NASEM, 2016) are appropriate for cattle with current genetics. Retained energy for heifers fed 1.0% and 1.4% of body weight were negative, suggesting these heifers were in negative energy balance. Further analyses will be conducted to calculate estimated maintenance energy requirements and efficiency of energy use and compared to past research. This could provide insights into potential differences between cattle with current genetics and those from research conducted 30-plus years ago.

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Table 3. Influence of dry matter intake of a forage-based diet on energy balance in Angus heifers.

	DM offered, kg					*P*-value	
Item, Mcal/d	**1%**	**1.4%**	**1.8%**	**2.2%**	**SEM**	**Linear**	**Quadratic**
Gross energy intake	14.8	20.7	24.8	28.6	0.40	<0.001	0.02
Fecal energy	6.2	8.8	10.1	12.0	0.36	<0.001	0.32
Digestible energy	8.7	11.9	14.7	16.6	0.37	<0.001	0.09
Urinary energy	0.87	0.97	1.02	1.11	0.040	<0.001	0.99
Gaseous (methane) energy	1.11	1.38	1.52	1.67	0.048	<0.001	0.26
Metabolizable energy, Mcal	6.7	9.6	12.2	13.8	0.341	<0.001	0.09
Heat production	9.7	11.4	12.0	13.4	0.28	<0.001	0.58
Retained energy	-3.03	-1.86	0.17	0.41	0.315	<0.001	0.15