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The effects of degradable nitrogen level and slow release urea on nitrogen balance and urea kinetics in Holstein steers

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ABSTRACT

The objective of this study was to compare nitrogen metabolism and urea kinetics between diets containing either rapidly degrading or slow degrading non-protein nitrogen (NPN) at varying levels of degradable intake protein (DIP). Treatments were slow release urea (Optigen®, Alltech, Inc.) fed at 1.01 and 1.14 and feed grade urea (UREA) fed at 0.89 and 1.00 of calculated DIP requirements. Eight Holstein steers (209 ± 15 kg) implanted with 28 mg estradiol + 200 mg trenbolone acetate (Synovex Plus, Fort Dodge Animal Health, Fort Dodge, IA) were used in a replicated 4 × 4 Latin square. Experimental periods were 27 days, with 19 day adaptation followed by 7 day of urine and fecal collection and 1 day of blood sampling. Continuous (78 h) intravenous infusion of $^{15}N^{15}N$-urea allowed the estimation of systemic urea kinetics. Dry matter intake was not different between treatments (7.2 kg/day). Increasing DIP had a tendency to increase dry matter digestibility (DMD) for both Urea and Optigen®. Urea had higher DMD than Optigen®. Increasing DIP increased urinary N output for both UREA and Optigen®, and increased N-retention at 1.14 Optigen®. Increasing DIP increased urea-N entry rate (UER) and urinary urea-N excretion (UUE) for both Optigen® and UREA. Gastrointestinal entry of urea-N, urea-N lost to feces and urea-N apparently used for anabolism were not different between treatments. Plasma urea concentration was greater in higher DIP diets and higher for Urea than Optigen® at 1.00 DIP. Therefore increasing DIP level will increase N-excretion related to higher urea production and excretion in urine but may also increase diet digestibility. Most changes in N metabolism were driven by N intake.

1. Introduction

The efficiency of utilization of dietary N by cattle is generally relatively low under normal production conditions (Castillo et al., 2001) with an estimated global average N-efficiency in cattle estimated at 7.7% (Van der Hoek, 1998). Urea is used rather inefficiently for production of protein products (Broderick et al., 2009) and due to its wide use in ruminant feeds, may be

Abbreviations: CP, crude protein; DIP, degradable intake protein; DM, dry matter; DMI, dry matter intake; GER, gut entry rate of urea N; NPN, non-protein nitrogen; ROC, Urea N returned to the ornithine cycle; UER, urea N entry rate; UFE, urea N excreted in the feces; UUA, urea N apparently used for anabolism; UUE, urinary urea N excretion.

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partially responsible for the overall poor N efficiency in cattle. Low efficiency of utilization of dietary urea has been attributed to the rapid hydrolysis of urea to NH_3 in the rumen by microbial urease which occurs at a higher rate than NH_3 utilization by rumen bacteria, leading to ruminal NH_3 accumulation and the subsequent absorption of ammonia and excretion of urea in the urine (Golombeski et al., 2006; Highstreet et al., 2010). In addition, excretion of urea in the urine has been shown to be particularly sensitive to the concentration of protein, particularly rumen degradable protein (Marini and Van Amburgh, 2005) in the diet. Excessive excretion of urinary urea may be related to high ruminal ammonia concentrations, which result in increased absorption of ammonia from the rumen and subsequent conversion to urea in the liver (Symonds et al., 1981), ultimately leading to increased excretion of urea in the urine. Therefore, attempts have been made to produce a form of urea that would degrade less rapidly in the rumen, potentially resulting in increased incorporation into microbial proteins and consequently lower excretion in the urine. Therefore the objectives of this experiment were to determine the effects of dietary DIP level and slow release urea on N balance and ruminal and systemic urea kinetics in Holstein steers.

2. Materials and methods

2.1. Experimental design

The experiment was conducted using eight growing Holstein steers with an average initial body weight of 209 ± 15 kg to evaluate N balance and urea kinetics. The experimental design was a replicated 4 × 4 Latin square with a 2 × 2 factorial treatment structure. Treatment factors were NPN source (slow release urea, OPTIGEN®–Alltech, Inc.; or regular feed grade urea, UREA) and dietary DIP level (1.00 and 0.89 of NRC requirements (NRC, 2000). Degradable intake protein of all dietary ingredients was characterized as 13% of TDN according to level 1 of the NRC for beef cattle (NRC, 2000). Diets were formulated for UREA, and OPTIGEN® diets were subsequently formulated by isonitrogenous substitution of urea for Optigen® assuming 100% DIP for each. However, the DIP level in experimental diets containing Optigen® were higher in DIP than formulated, resulting in the following four treatment combinations: 1.14 DIP, OPTIGEN®; 1.01 DIP, OPTIGEN®; 1.00 DIP, UREA; 0.89 DIP, UREA (Table 1). Dry matter intakes were set to 0.0258 of body weight and were offered twice daily (08:00 and 17:00). Intakes were updated weekly throughout the study; however, DMI was not adjusted the week prior to each N balance period. Each period consisted of a 19 day adaptation period followed by 7 days of N balance and a single day of blood sampling.

All animals were implanted with Synovex®Plus (200 mg trenbolone actetate, 28 mg estradiol benzoate, Fort Dodge Animal Health, Fort Dodge, IA) in order to increase muscle deposition and the animals' N requirement. Animals were implanted at the beginning of the first adaptation period and were then re-implanted at the start of the adaptation of the 3rd period (56 days later).

2.2. Nitrogen balance

At the beginning of each N balance period, steers were moved from holding pens (3 m × 3 m) into individual metabolism tie stalls (1.2 m × 2.4 m), each with its own feed bunk and water supply. During the N balance period, total fecal and urine output were quantified before each morning feeding. Feces were weighed, sub-sampled (0.05), and immediately frozen

Table 1
Diet ingredients and chemical composition of diets in steers fed 0.89, 1.00 and 1.14 DIP diets with UREA or OPTIGEN®.

	1.14 DIP, OPTIGEN® (g/kg DM)	1.01 DIP, OPTIGEN® (g/kg DM)	1.00 DIP, UREA (g/kg DM)	0.89 DIP, UREA (g/kg DM)
Feedstuff				
Cracked corn	470.3	489.2	472.7	491.4
Fescue hay	237.0	237.6	238.2	238.6
Cottonseed hulls	222.2	222.7	223.3	223.7
Soybean meal	18.5	0.00	18.6	0.00
Urea[a]	0.00	0.00	10.4	9.5
OPTIGEN®[b]	15.4	13.9	0.00	0.00
Molasses	19.3	19.3	19.4	19.4
Limestone	8.0	8.0	8.0	8.1
Dicalcium phosphate	1.9	1.9	1.9	1.9
Calcium sulfate	1.1	1.1	1.1	1.1
Vitamin premix[c]	0.4	0.4	0.4	0.4
Trace mineral premix[d]	5.9	5.9	6.0	6.0
Chemical composition				
Crude protein	147.5	130.8	132.3	120.4
NDF	419.1	419.6	421.2	421.4
NFC	415.0	424.4	417.1	426.3

[a] Urea nitrogen content: 450 g/kg N.
[b] Optigen® nitrogen content: 410 g/kg N.
[c] Vitamin premix composition: 8811 IU vitamin A, 1762 IU vitamin D, 1100 IU vitamin E.
[d] Trace mineral premix composition: 6.6 g/kg Ca, 563.4 g/kg Cl, 365.3 g/kg Na, 12.0 g/kg S, 68.9 ppm Co, 1837.7 ppm Cu, 119.9 ppm I, 9290.2 ppm Fe, 4792.3 ppm Mn, 18.5 ppm Se, 5520.2 ppm Zn.