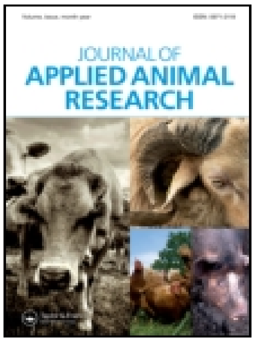

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Effects of a combining feed grade urea and a slow-release product on performance, dietary energetics and carcass characteristics of steers fed finishing diets

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Recent findings have shown that microbial nitrogen flow and digestible energy of diet are increased when urea (U) is combined with a slow-release urea product (SRU) in diets with a starch:acid detergent fibre (S:ADF) ratio of 4.5, while feed grade U has shown greater effects on growth performance or dietary energy utilization when the diet contains a S:ADF ratio of greater than 5.0. These results can be partially explained by the better synchronization of ruminal degradation rates between those U sources with the carbohydrates of the diets. Therefore, 60 crossbreed steers (372.4 ± 15 kg) were used to evaluate the effects of combining U and SRU in a diet with a S:ADF ratio of 4.5 vs. U that was supplemented in diets with different S:ADF ratios (3.5, 4.5 and 5.5) on growth performance, dietary energetics and carcass characteristics. U combination did not affect average daily gain (ADG), but reduced dry matter intake [DMI, as % of body weight (BW)] enough to increase feed efficiency (G:F) and dietary net energy (NE). As the S:ADF ratio increased, the DMI, ADG, G:F and NE of diet increased linearly. Irrespective of the S:ADF ratio, U diets did not modify neither the observed-to-expected NE ratio nor the apparent retention per unit DMI, while U combination increased by 7.2% and 8.4%, respectively, the observed-to-expected dietary ratio and the apparent retention per unit DMI. U combination had no effect on carcass characteristics. As the S:ADF ratio increased, carcass weight and LM area were increased linearly. Combining feed grade U and SRU in diets with a 4.5 starch:fibre ratio resulted in positive effects on the efficiency of utilization of dietary energetics.

Keywords: slow-release urea; finishing diets; steers; Optigen; dietary energetics; growth performance

1. Introduction

Because of its low cost per unit of nitrogen (N) compared with most sources of natural protein, urea (U) is typically the primary source of supplemental N in conventional steam-flaked corn-based finishing feedlot diets (Vasconcelos et al. 2009). Previous reports (Milton et al. 1997; Zinn et al. 2003) have shown that supplemental U has more positive effects on growth performance or dietary energy utilization when the diet contains a starch:acid detergent fibre (S:ADF) ratio of greater than 5.0. However, as a result of the cost of grains, the replacement of grains by co-products (i.e., dried distillers grain with solubles) in feedlot diets is a common practice (Klopfenstein et al. 2008). This change produces diets that contain a lower amount of starch and a greater amount of fibre (Carrasco et al. 2013). Thus, the S:ADF ratio in finishing diets can be reduced (i.e., from 5.0 to 3.0). Hypothetically, combining feed grade U with slow-release urea (SRU) in this type of diet should elicit a better synchrony between starch (high rate of digestion) and fibre (low rate of digestion). Recent findings (López-Soto et al. 2014) indicate that the combination of U and SRU when there is a certain proportion (4.5 to 1) of S:ADF in the diet results in greater improvements in the microbial nitrogen flow and digestible energy of the diet. Because no information is available related to the growth performance and dietary energetics of finishing cattle to verify the findings of López-Soto et al. (2014), the aim of this experiment was to examine the effects of the supplementation of U and SRU in a diet with a S:ADF ratio of 4.5 vs. U supplementation in diets with different S:ADF ratios (3.5, 4.5 and 5.5) on growth performance, dietary energetics and carcass characteristics.

2. Material and methods

All animal management procedures were conducted within the guidelines of locally-approved techniques for animal use and care (NOM-051-ZOO-1995, NOM-062-ZOO-1995 and NOM-024-ZOO-1995).

2.1. Animal processing, housing and feeding

Sixty crossbreed yearling steers (live weight average 372.4 ± 15 kg) approximately 20% Zebú breeding with

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the remainder represented by Hereford, Angus and Charolais breeds in various proportions, were used to evaluate the treatments effects on characteristics of growth-performance, dietary energetic and carcass characteristics. The trial was conducted at the Feedlot facilities located in Sinaloa, México (25°33′ N and 108°25′ W). The site is about 120 m above sea level, and has a tropical climate.The experiment lasted 70 days (November to January). Six weeks before initiation of the experiment steers were vaccinated for bovine rhinotracheitis and parainfluenza 3 (TSV-27, Pfizer Animal Health, México), clostridials (Fortress 7, Pfizer Animal Health, Mexico) and Pasteurella haemolytica (One Shot, Pfizer Animal Health, México), and treated for parasites (CYDECTIN® NF, Pfizer Animal Health, México; Trodax, Merial, México). Steers were injected with 1×10^6 IU vitamin A (Vita-Jec A& D "500", Synt-ADE®, Fort Dodge, Animal Health, México) and were implanted with 200 mg of trenbolone acetate and 20 mg of estradiol 17β (Revalor H®, Intervet, México). Steers were blocked by weight into five blocks and assigned within blocks to 20 pens (3 steers/pen). Pens were 4.00 × 8.20 m with 19 m^2 of shade, and were equipped with automatic waterers and fence-line feed bunks (2.37 m in length). Cattle were weighed at the start of experiment, at day 35 and before the steers were harvested (day 73). Based that the better responses on microbial duodenal flows and digestible energy of diet was observed only when U and SRU was combined at same proportion (0.80% of each) in diets which proportion of S:ADF is about 4.5 (López-Soto et al. 2014) and that previous reports (Milton et al. 1997; Zinn et al. 2003) have shown that supplemental U has more positive effects on growth performance or dietary energy utilization when the diet contains a ADF ratio of greater than 5.0, thus, to test our hypothesis, four treatments were formulated as follows. The treatment 1 (SRU) consisted in combining U and SRU product (Optigen II; a polymer-coated urea, Optigen, Alltech Mexico, Guadalajara, Jalisco). Accordingly to the results obtained by López-Soto et al. (2014), the U combination used was at 0.80% of each one on DM basis and supplemented in a diet with 4.5 S:ADF ratio. The treatments 2, 3 and 4 were formulated by the supplementation of 0.80% of U solely in diets with 3.5, 4.5 or 5.5 S:ADF ratio. The S:ADF ratio in the diet was manipulated by partially replacing the corn grain by sudangrass hay (Table 1). Diets were prepared at weekly intervals. Daily feed allotments to each pen were adjusted to allow minimal (<5%) feed refusals in the feed bunk. The amounts of feed offered and of feed refused were weighed daily. Steers were provided fresh feed twice daily at 0800 and 1400 hours. Feed bunks were visually assessed between 0700 and 0730 hours each morning, refusals were collected and weighed and feed intake was determined. Adjustments to, either increase or decrease daily feed delivery, were provided at the afternoon feeding.

Table 1. Ingredients and composition of experimental diets.

	Treatments			
Item	SRU + U-4.5	U-3.5	U-4.5	U-5.5
Ingredient composition, % DMB				
flaked sorghum	61.00	56.00	61.00	66.00
DDGS	11.00	11.00	11.00	11.00
Sudangrass hay	12.00	18.00	12.00	8.00
U	0.80	0.80	0.80	0.80
Optigen II[a]	0.80	–	–	–
Cane molasses	9.83	9.63	10.63	9.63
Yellow grease	2.50	2.50	2.50	2.50
Trace mineral salt[b]	0.40	0.40	0.40	0.40
Limestone	1.67	1.67	1.67	1.67
NE concentration[c], Mcal/kg of DM basis				
EN_m, Mcal/kg	2.03	1.98	2.03	2.09
EN_g, Mcal/kg	1.38	1.34	1.38	1.43
Nutrient composition, % of DM[d]				
Crude protein (N × 6.25)	15.90	13.57	13.71	13.84
Starch	42.36	39.56	42.40	46.38
ADF	9.31	11.36	9.24	8.36
S:ADF ratio	4.55	3.48	4.59	5.55

[a]Optigen-II. Alltech de México, Guadalajara Jalisco.
[b]Trace mineral salt $CoSO_4$, 0.068%; $CuSO_4$, 1.04%; $FeSO_4$, 3.57%; ZnO, 1.24%; $MnSO_4$, 1.07%; KI, 0.052%; NaCl, 92.96%.
[c]Based on tabular NE values for individual feed ingredients (NRC 1996) with the exception of supplemental fat, which was assigned NE_m and NE_g values of 6.03 and 4.79, respectively (Zinn, 1988).
[d]Dietary composition was determined by analyzing subsamples collected and composited throughout the experiment. Accuracy was ensured by adequate replication with acceptance of mean values that were within 5% of each other.

2.2. Laboratory analyses

Feed and refusal samples were collected daily for DM analysis, which involved oven drying the samples at 105°C until no further weight loss occurred (method 930.15, AOAC 2000). In addition, Kjeldahl N (method 984.13, AOAC 2000), ADF (Van Soest et al. 1991) and starch (Zinn 1990) were determined in feed samples.

2.3. Calculations

The estimations of expected DMI and dietary energetic were performed based on measures of initial and final shrunk body weight (SBW), assuming that SBW is 96% of full weight (NRC 1996). Average daily gains (ADG) were computed by subtracting the initial BW from the final BW and dividing the result by the number of days on feed. The efficiency of BW gain was computed by dividing ADG by the daily DMI. The estimation of expected DMI was performed based on the observed ADG and SBW according to the following equation: expected DMI, kg/day = $(EM/NE_m) + (EG/EN_g)$, where EM (energy required for maintenance, Mcal/day) = $0.077W^{0.75}$ (Garrett 1971), EG $= ADG^{1.097} \times 0.0557W^{0.75}$ (NRC 1984), NE_m and NE_g are

2.22 and 1.55 Mcal/kg, respectively (derived from tabular values based on the ingredient composition of the experimental diet; NRC 1996). The dietary NE_g was derived from NE_m by the equation: $NE_g = 0.877\ NE_m - 0.41$ (Zinn et al. 2008). Dry matter intake (DMI) is related to energy requirements and dietary NE_m according to the equation: DMI = EG/($0.877NE_m - 0.41$), and can be resolved for estimation of dietary NE by means of the quadratic formula: $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2c}$, where $x = NE_m$, $a = -0.41EM$, $b = 0.877\ EM + 0.41\ DMI + EG$, and $c = -0.877\ DMI$ (Zinn & Shen 1998).

2.3. Carcass data

All steers were harvested on the same day. Hot carcass weights (HCW) were obtained from all steers at the time of slaughter. After carcasses were chilled in a cooler at −2°C to 1°C for 48 h, the following measurements were obtained: (1) LM area, taken by direct grid reading at the twelfth rib; (2) subcutaneous fat over the ribeye muscle at the twelfth rib taken at a location three-quarters of the lateral length from the chin bone end; (3) kidney, pelvic and heart fat (KPH) as a percentage of carcass weight; and (4) marbling score (USDA 1997).

2.4. Statistical analyses

Performance (gain, gain efficiency and dietary energetics) and carcass data were analysed as a randomized complete block design. The experimental unit was the pen. The MIXED procedure of SAS (SAS Institute Inc. 2004) was used to analyse the variables. The fixed effect consisted of treatment, and pen as the random component. Three contrasts were defined to answer: (1) the effect of U combination vs. U at same S:ADF ratio (4.5), (2) linear response of the S:ADF ratio in U treatments and (3) quadratic response of the S:ADF ratio in U treatments. *F*-test (numerator = 1 df, denominator = error df) was utilized to test contrasts. The analysis was carried out using SAS (SAS Inst., Inc., Cary, NC; Version 9.1). Contrasts were considered significant when the *P*-value was ≤0.05, and tendencies were identified when the *P*-value was >0.05 and ≤0.10.

3. Results and discussion

3.1. U combination effects on growth performance and dietary energy of diet

According to the determinations of starch and ADF obtained in the laboratory, the S:ADF ratio reached 101, 99, 102 and 101% of the planned for each treatment (Table 1). Treatment effects on growth performance of feedlot steers are shown in Table 2. U combination did not affect ($P = 0.96$) ADG, but tended to reduce DMI (5.1%, $P = 0.06$), and reduced DMI expressed as a percentage of live weight (5.8%, $P = 0.02$). In a few studies, the absence of effects on feed intake of the combination of U plus SRU products has been observed previously in steers fed a finishing diet (Tedeschi et al. 2002; Pinos-Rodríguez et al. 2010; Castañeda-Serrano et al. 2013). However, a tendency for reduction in DMI has been observed in steers fed diets containing 2.25% of a solution of SRU product based on calcium bond U (Duff et al. 2000). Taylor-Edwards et al. (2009) reported a 4.4% reduction in DMI when 0.8% of Optigen II replaced 0.8% of U, but these responses were noted only in the last 28 days of the 56 days of the experiment. As mentioned previously (materials and methods section) in the present experiment the DM intake was registered daily and DM intake pattern was consistent lower to urea combination treatment (SRU) throughout experiment. The basis for the inconsistencies in DMI responses to SRU supplementation is not certain, but may be related to the taste of SRU products and/or diet composition.

In the present experiment, the decreases in DMI on SRU + U treatment was enough to increase feed efficiency (G:F) by 14.2% ($P = 0.02$) and to increase the dietary net energy (NE) by 7.2%. Duff et al. (2000) reported that the gain-to-feed ratio was improved by 4.4% ($P < 0.01$) when 100% of U (1.21% in the diet) and 100% of soybean meal (2.80% in the diet) were replaced by 2.25% of Ruma Pro (a SRU product) plus 1.76% of corn grain. Changes in the productivity and/or energy efficiency of cattle that have been fed diets containing SRU can be explained by improvements in N retention by decreases in ruminal ammonia concentration and increases in microbial flow to the duodenum (Akay et al. 2004; Alvarez-Almora et al. 2012). López-Soto et al. (2014) showed that steers fed a combination of U and SRU (Optigen) in a diet with a S:ADF ratio of 4.5 had higher ($P = 0.04$) flows of microbial N and digestible energy of diet than those fed U and those fed U plus SRU in diets with a S:ADF ratio of 3 or 6. They explained that the combination of feed grade U with SRU in diets containing a certain ratio of starch:fibre should promote a better synchrony between starch (high rate of digestion) and fibre (low rate of digestion). In contrast, other studies (Tedeschi et al. 2002; Pinos-Rodríguez et al. 2010) showed that SRU supplementation to finishing steers did not have positive effects on neither gain nor feed efficiency. The estimated S:ADF ratio of the experimental diets of studies conducted by Tedeschi et al. (2002) and by Pinos-Rodríguez et al. (2010) was over 5.4; thus, the high S:ADF ratios of the diets used in those studies could be a factor in the absence of effects on the performance and feed efficiency of steers fed a combination of U and SRU.

Compared with the U diets, combining U and SRU at a 4.5 S:ADF ratio increased ($P < 0.01$) by an average of 7.2% the observed-to-expected dietary ratio and reduced

Table 2. Influence of treatments on growth performance and dietary energy of feedlot steers.

Item	Treatments[a]				SEM	SRU + U-4.5 vs. U-4.5	S:F ratio[b]	
	SRU + U-4.5[c]	U-3.5	U-4.5	U-5.5			Linear	Quadratic
Pen replicates	5	5	5	5				
Number of steers	15	15	15	15				
Days on feed	70	70	70	70				
Weight, kg[d]								
Initial	371.65	372.22	372.74	372.86	3.3	0.81	0.89	0.96
Final	461.18	453.31	462.08	473.85	6.5	0.92	0.05	0.82
ADG, kg	1.279	1.158	1.276	1.443	0.052	0.97	<0.01	0.97
DMI, kg	7.896	8.321	8.548	9.085	0.219	0.06	0.03	0.57
DMI, % LW	1.896	2.012	2.046	2.145	0.037	0.02	0.03	0.49
Gain for feed, kg/kg	0.162	0.139	0.149	0.159	0.003	0.02	<0.01	0.97
Dietary NE, Mcal/kg[e]								
Maintenance	2.14	1.93	2.00	2.05	0.018	<0.01	<0.01	0.71
Gain	1.47	1.28	1.35	1.39	0.016	<0.01	<0.01	0.71
Observed to expected dietary ratio[f]								
Maintenance	1.06	0.98	0.99	0.98	0.009	<0.01	0.59	0.55
Gain	1.06	0.96	0.98	0.97	0.011	<0.01	0.59	0.55
Observe to expected daily DM intake[g]	0.94	1.02	1.02	1.04	0.011	<0.01	0.39	0.50

[a]SRU + U-4.5 = 0.80% U plus 0.80% at 4.5 S:F ratio, U-3.5 = 0.80 U at 3.5 S:F ratio, U-4.50 = .80% U at 4.5 S:F ratio, and U-5.5 = 0.80% U at 5.5 S:F ratio.
[b]Proportion of starch *vs*. fibre acid detergent in diet.
[c]Source of SRU was Optigen II, Alltech Inc., México, Guadalajara México.
[d]The initial and BW was reduced by 4% to adjust for the gastrointestinal fill.
[e]The estimation of dietary NE was performed based on observed ADG, DMI and average shrunk weight (SBW) and was estimated by means of the quadratic formula: $x = \frac{-b \pm \sqrt{b^2-4ac}}{2c}$, where $x = NE_m$, $a = -0.41EM$, $b = 0.877\ EM + 0.41\ DMI + EG$, and $c = -0.877\ DMI$, where EM = maintenance coefficient of 0.077 Mcal/BW$^{0.75}$ (NRC 1984), EG is the daily energy deposited (Mcal/day) estimated by equation: EG = ADG$^{1.097}$ × 0.0557W$^{0.75}$ (NRC 1984), and DMI is the average daily dry matter intake (Zinn et al. 2008).
[f]Observed to expected dietary NE ratio was computed by dividing NE observed between expected diet NE, which was estimated based on tabular values for individual dietary ingredients (NRC 1996).
[g]Expected DMI, kg/day = (EM/NE$_m$) + (EG/EN$_g$); where, NE$_m$ and EN$_g$ is the diet energy concentration.

by 8.4% (P < 0.01) the apparent retention per unit DMI. This corroborates the findings of López-Soto et al. (2014), which reported an energetic advantage (increases in digestible energy) in cannulated steers when the combination of SRU + U was given at a ratio of starch and ADF identical to that used in the present experiment. In practical terms, if we consider that the diet composition of combined U treatment (SRU + U-4.5) and U treatment at the same S:ADF ratio (U-4.5, Table 1) were practically identical, the energy improvement observed for SRU + U-4.5 treatment represents the equivalent of an increase of 6.4% [(2.14 − 2.00)/2.18] of steam-flaked sorghum in the diet.

3.2. U and S:ADF ratio effects on growth performance and dietary energy of diet

The average observed DMI of steers fed U diets was 102% of the expected based on tabular (NRC 1996) estimates of diet energy density and observed SBW and ADG (Table 2), supporting the practicality of the prediction equations proposed by the NRC (1996) for the estimation of DMI in relation to SBW and ADG in feedlot cattle. Similar responses in DMI between diets containing different levels of forage have been observed previously in trials involving steam-flaked corn-based diets (Zinn et al. 1994; Calderon-Cortes and Zinn 1996). As the S:ADF ratio increased, the DMI, ADG, G:F and NE of diet increased ($P \leq 0.03$) linearly. The increases in gain, feed efficiency or both, as a result of increases in energy density in diets are well documented (Zinn et al. 2008).

Irrespective of the S:ADF ratio, U diets did not modify neither the dietary energy ratio nor the observed-to-expected DMI. It has been observed that in high-grain diets (a starch:ADF ratio of greater than 5.0:1), U can be supplemented at a level 50% higher than the

Table 3. Treatment effects on carcass characteristics.

Item	Treatments[a]				SEM	SRU + U-4.5 vs. U-4.5	S:F ratio[b]	
	SRU+U-4.5	U-3.5	U-4.5	U-5.5			Linear	Quadratic
Pen replicates	5	5	5	5				
Number of steers	15	15	15	15				
HCW, kg	301.7	293.1	302.7	308.6	4.12	0.86	0.02	0.72
Cold carcass weight, kg	298.1	289.6	299.1	305.0	4.07	0.86	0.02	0.72
Drip loss, %	1.20	1.18	1.19	1.19	0.023	0.73	0.87	0.98
Dressing percent	65.40	64.66	65.50	65.10	0.32	0.78	0.81	0.28
Longissimus muscle área, cm^2	78.10	77.18	78.30	80.73	1.079	0.90	0.04	0.62
Backfat thickness, mm	0.62	0.62	0.61	0.67	0.065	0.94	0.61	0.70
Kidney-pelvic fat, %	1.93	2.00	2.00	2.13	0.154	0.76	0.55	0.73
Marbling score	3.27	3.20	3.28	3.33	0.157	0.95	0.55	0.95

[a]SRU + U-4.5 = 0.80% U plus 0.80% at 4.5 S:F ratio, U-3.5 = 0.80 U at 3.5 S:F ratio, U-4.50 = .80% U at 4.5 S:F ratio, and U-5.5 = 0.80% U at 5.5 S:F ratio.
[b]Proportion of starch *vs*. fibre acid detergent in diet.

recommended with positive effects on growth performance or in dietary energy utilization (Milton et al. 1997; Zinn et al. 2003). One possible advantage to higher U levels in finishing diets might be related to the buffering effects of U as a result of its hydrolysis to CO_2 and NH_3 and the potential buffering effects via ammonia (Galyean 1996), and/or because the synchrony of ruminal degradation rates between feed grade U and starch is maybe more favourable in these types of diets. The observed-to-expected dietary energy and intake are an important and practical application of current standards for energetics in nutrition research (Zinn et al. 2008). Based on diet composition and measures of growth performance, there is an expected energy intake and hence an expected of DMI (NRC 1996). The estimation of dietary energy and the ratio of observed-to-expected DMI reveals differences in efficiency independently of ADG, providing important insight into potential treatment effects on the efficiency of energy utilization of the diet itself. In the present experiment, the absence of effects on observed-to-expected DMI and dietary NE of the U treatments at different S:ADF ratios showed that starch and fibre at these proportions did not provide any energetic advantage when they were supplemented with U.

3.2. Treatments effects on carcass characteristics

Treatment effects on carcass characteristics are shown in Table 3. Similar to previous reports (Pinos-Rodríguez et al. 2010; Holland & Jennings 2011), there were no effects of U combination on carcass characteristics. As the S:ADF ratio increased, carcass weight and LM area were increased linearly. The linear increases in HCW and dressing percentage, as a result of increased S:ADF ratio, was likely due to the concomitant linear increase in ADG (Block et al. 2001). In the same manner, an increased LM area has been a consistent response to an increased rate of ADG (Zinn et al. 2007).

4. Conclusions

Under the conditions of the current experiment, it was concluded that combining U with Optigen II in diets containing an approximate S:ADF ratio of 4.5:1 increases by 8% the dietary energy efficiency. This energetic advantage represents the equivalent of a 6% increase of grain in the diet. An additional point is that the use of the combination of U and SRU as an alternative source of non-protein nitrogen for finishing diets in feedlots will depend on its cost and the relative prices of forage and grain.

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