Feedlot Performance and Carcass Characteristics of Holstein Steers as Affected by Source of Dietary Protein and Level of Ruminally Protected Lysine and Methionine

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ABSTRACT: The objective of this study was to determine the effects of source of dietary CP and level of ruminally protected lysine and methionine (RPLM) on feedlot performance and carcass characteristics of Holstein steers during a growing-finishing trial (266 d). A total of 168 Holstein steers (182.7 ± 27.5 kg) were used in a completely randomized design experiment (eight treatments; three pens of seven steers/treatment). Steers were given ad libitum access to high-concentrate diets (13% CP) containing 71% whole shelled corn, 10% corn silage, 4% condensed distillers solubles, and 15% protein supplements (DM basis). Treatments were arranged as a 2 × 4 factorial. The main factors were two sources of dietary CP and four levels of RPLM. The sources of dietary CP were soybean meal (SBM) or SBM and urea (SBM-U). Urea-N replaced 50% of SBM-N in the SBM-U diet. The levels of RPLM were 0, 5, 10, and 15 g per steer daily. No interactions (P > .10) between source of dietary CP and level of RPLM were observed for feedlot performance or carcass characteristics. Feedlot performance showed an advantage (P < .10) to feeding SBM during the first 84 d of the trial and an advantage to feeding SBM-U during the last 98 d of the trial. However, feedlot performance for the whole trial and carcass characteristics (except for fat thickness) were not affected (P > .10) by the source of dietary CP. Steers fed diets containing SBM-U had 12% less (P < .10) fat thickness than those fed diets containing SBM. Supplementation of diets with increasing levels of RPLM did not affect (P > .10) ADG or carcass characteristics. However, DMI and gain:feed showed cubic (P < .10) responses to increasing dietary level of RPLM. Supplementation of RPLM at the 10 g/d level improved gain:feed by 12% during the last 98 d of the trial, and this was a direct response to the cubic effects of RPLM on DMI. Results suggest a cost advantage for replacing 50% of SBM-N with that from urea in high-corn diets without negative effects on feedlot performance or carcass characteristics of growing-finishing Holstein steers with extended feeding periods (266 d). These types of diets seem to meet the amino acid requirements and are not limiting in lysine and methionine.

Key Words: Holstein-Friesian, Protein Sources, Amino Acids, Performance, Carcass Quality, Steers

Introduction

Results of estimating amino acid (AA) supply and requirements (Komarek et al., 1983) and N retention (Chalupa and Chandler, 1975; Richardson and Hatfield, 1978) indicated that methionine and lysine are usually the first- and second-limiting AA (respectively) for growing cattle. Understanding of these limitations in requirements can be assessed by feeding AA that are protected from ruminal microbial degradation and are available for digestion and absorption in the small intestine. Such ruminally protected AA (RPAA) can complement AA (from microbial protein and undegraded feed protein) leaving the ruminal fermentation (Titgemeyer et al., 1988) and, therefore, may improve performance of growing cattle. However, results of growth studies have been generally disappointing. Strasia et al. (1986) detected no response in performance when growing steers were supplemented with as much as 20 g/d of ruminally protected methionine. Some improvements in gain or feed efficiency were detected when ruminally protected lysine and methionine (RPLM) were supplemented (Deetz et al., 1985; Oke et al., 1986; Wright and Loerch, 1988), but these results demonstrated neither consistent responses to graded levels of supplementation nor large improvements in performance. Merchen and Titgemeyer (1992) suggested that source of supplemental CP can influence response of growing cattle to RPLM supplementation. Therefore, in this
trial, performance of Holstein steers during growing and finishing was evaluated when graded levels of RPLM were added to high-concentrate diets containing CP from preformed AA (soybean meal; SBM) or from preformed AA (SBM) and urea (SBM-U).

**Experimental Procedures**

Steers and Diets. One hundred sixty-eight Holstein steers were used in a completely randomized design experiment. Treatments were arranged as a $2 \times 4$ factorial. The main factors were two sources of dietary CP and four levels of RPLM. The sources of dietary CP were SBM or SBM-U. The levels of RPLM were 0, 5, 10, and 15 g·steer$^{-1}$·d$^{-1}$. Steers were subjected to the eight dietary treatments for a 266-d growing-finishing trial. There were three replications (pens)/treatment.

Before the start of the trial, all steers were ear-tagged, dewormed, vaccinated for protection against infectious bovine rhinotracheitis, parainfluenza, clostridia, malignant edema, Haemophilus somnus, and Pasteurella. Steers were adapted to a high-concentrate diet (90% of DM) for 4 wk by using a series of diets in which the proportion of whole shelled corn in the diet was increased gradually at the expense of corn silage. At the end of this adjustment period, unhealthy and poorly performing steers were eliminated and the remaining steers were weighed. The 168 steers (mean ± SD of initial BW = 182.7 ± 27.5 kg) were selected and allotted to 24 pens (seven steers/pen). Solid-floor pens (250 m$^2$) were bedded and were equipped with automatic waterers and fence-line feed bunks. Steers were implanted with Revalor-S® that contained 120 mg of trenbolone acetate and 24 mg of estradiol (Hoechst Roussel Agri-Vet, North Somerville, NJ) on d 1 and 112 of the trial. Steers were weighed at 28-d intervals during the trial to monitor their performance. Steers were limit-fed to 70% of ad libitum feed intake for 3 d to minimize gut fill before being weighed on d 1, 84, 168, and 266. These weights were used to calculate performance of steers during three periods of growth (the first 84 d, the second 84 d, and the last 98 d of the trial).

The ingredient composition of the diets is presented in Table 1. The two sources of dietary CP (Table 2) were used to evaluate the efficacy of supplemental RPLM when supplemental CP was from preformed AA (SBM) or from preformed AA and nonprotein N (SBM-U). The diets were isonitrogenous (13% CP; DM basis) and SBM or SBM-U provided 40% of total dietary CP. Diets were formulated to contain 1.2% Ca, .5% P, .8% K, .3% trace mineralized salt, and to provide daily intakes of 30,000 IU of vitamin A. These nutrients were balanced to meet or exceed the recommended requirements (NRC, 1984) for large-framed steers. Samples of dietary ingredients and total mixed diets were taken every 28 d and dried at 57°C in a forced-air oven and ground (1-mm screen).

Diets were fed fresh once daily and the amounts (i.e., 0, 5, 10, and 15 g·steer$^{-1}$·d$^{-1}$) of RPLM (Smartamine ML®; Rhône-Poulenc Animal Nutrition, Atlanta, GA) were added to the dietary ingredients while mixing diets for each pen. This product contained 50% L-lysine and 15% DL-methionine that are encapsulated in a pH-sensitive coating (poly-2-vinylpyridine-co-styrene). It is a tasteless, odorless, and amorphous product that is approved by the FDA for its safety in beef cattle nutrition. The pH-sensitive

### Table 1. Ingredient and chemical compositions of diets fed to Holstein steers

<table>
<thead>
<tr>
<th>Item</th>
<th>SBM</th>
<th>SBM-U</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ingredient composition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole shelled corn</td>
<td>71</td>
<td>71</td>
</tr>
<tr>
<td>Protein supplement$^{b}$</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Corn silage</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Condensed distillers solubles</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Chemical composition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OM</td>
<td>94.8</td>
<td>97.7</td>
</tr>
<tr>
<td>CP</td>
<td>13.1</td>
<td>13.2</td>
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<tr>
<td>NDF</td>
<td>14.4</td>
<td>14.1</td>
</tr>
<tr>
<td>ADF</td>
<td>6.3</td>
<td>5.9</td>
</tr>
</tbody>
</table>

$^{a}$Containing soybean meal (SBM) or SBM and urea (SBM-U).

### Table 2. Ingredient composition of protein supplements fed to Holstein steers

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>SBM</th>
<th>SBM-U</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean meal</td>
<td>67.6</td>
<td>33.8</td>
</tr>
<tr>
<td>Urea</td>
<td>—</td>
<td>5.33</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>5.95</td>
<td>6.75</td>
</tr>
<tr>
<td>Limestone</td>
<td>14.57</td>
<td>14.39</td>
</tr>
<tr>
<td>Potassium bicarbonate</td>
<td>1.15</td>
<td>2.62</td>
</tr>
<tr>
<td>Condensed distillers solubles</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Trace mineralized salt$^{b}$</td>
<td>2.67</td>
<td>2.67</td>
</tr>
<tr>
<td>Rumensin-80$^{c}$</td>
<td>.14</td>
<td>.14</td>
</tr>
<tr>
<td>Tylan-40$^{d}$</td>
<td>.08</td>
<td>.08</td>
</tr>
<tr>
<td>Thiamin</td>
<td>.3</td>
<td>.3</td>
</tr>
<tr>
<td>Vitamin premix$^{e}$</td>
<td>.2</td>
<td>.2</td>
</tr>
<tr>
<td>Ground corn</td>
<td>4.34</td>
<td>30.72</td>
</tr>
</tbody>
</table>

$^{a}$Containing soybean meal (SBM) or SBM and urea (SBM-U).

$^{b}$Composition (g/100 g): NaCl (97 to 99), Zn (> .35), Fe (> .2), Mn (> .18), Cu (> .35), I (> .01), Se (> .009), Co (> .006).

$^{c}$Contains 176 g of monensin/kg.

$^{d}$Contains 88 g of tylosin/kg.

$^{e}$Composition (per gram): vitamin A (3,300 IU), vitamin D$_3$ (330 IU), vitamin E (44 IU), vitamin K (2.2 mg), vitamin B$_{12}$ (.0176 mg), riboflavin (4.4 mg), D-pantothenic acid (12.1 mg), niacin (16.5), choline chloride (165.0 mg).
coating was shown to be stable at a ruminal pH of 5.4, which can occur in cattle fed 90% concentrate diets, but it loses its integrity when it enters the abomasum (Polan et al., 1991). Steers were given ad libitum access to the diets andorts were weighed as necessary and analyzed for DM (AOAC, 1984). Steers were weighed at 28-d intervals. Six steers were removed from the trial for reasons not related to treatment (leg injury).

Analytical Procedures. Ground (1-mm screen) samples of feeds were analyzed for absolute DM by drying at 105°C for 24 h. Organic matter was determined by ashing the dried samples in a muffle furnace at 500°C for 16 h. Samples were analyzed for concentrations of Kjeldahl-N (AOAC, 1984), NDF (Jeraci et al., 1988), and ADF (Goering and Van Soest, 1970).

Carcass Characteristics. Steers were slaughtered at a commercial packing plant and hot carcass weights were obtained. After carcasses were chilled for 24 h, the following measurements were obtained by trained University of Illinois personnel: 1) longissimus muscle area taken by direct grid reading of the longissimus muscle at the 12th rib; 2) subcutaneous fat over the longissimus muscle at the 12th rib; 3) kidney, pelvic, and heart fat estimated as a percentage of carcass weight; and 4) marbling score (USDA, 1975). Dressing percentage was calculated for each steer and carcass measurements were used to calculate yield grade (USDA, 1975).

Statistical Analyses. Data (feedlot performance and carcass characteristics) were analyzed as a completely randomized design experiment (Steel and Torrie, 1980) according to the GLM procedure of SAS (1985). Because treatments were arranged as a 2 × 4 factorial, the sum squares for the treatments in the GLM model were separated into source of dietary CP, level of RPLM, and the source of dietary CP × level of RPLM interaction. Pen was the experimental unit for the performance data and steer was the experimental unit for the carcass data.

Because interactions were not detected (P > .10), means for source of dietary CP were compared by the LSD procedure (Fisher, 1949), whereas orthogonal contrasts (Steel and Torrie, 1980) were used to test for linear, quadratic, and cubic effects of RPLM supplementation.

Results

No interactions (P > .10) between source of dietary CP and level of RPLM were observed for feedlot performance or carcass characteristics. Therefore, results of the main factors are presented.

Feedlot Performance. The influence of source of dietary CP and levels of RPLM on growth performance of steers is shown in Table 3. Steers responded differently to source of dietary CP during different growth periods. During the first 84 d of the trial, steers fed diets containing SBM had 7% faster (P < .10) ADG and they were 5% more (P < .10) efficient in utilizing feed than those fed diets containing SBM-U. During the second 84 d of the trial, however, feedlot performance was similar (P > .10) for steers fed diets containing either source of dietary CP. During the last 98 d of the trial, the advantage to feeding SBM-U was obvious. Steers fed diets containing SBM-U had 10% faster (P < .10) ADG and 8% better (P < .10) gain:feed ratio than those fed diets containing SBM. The cumulative (266 d) performance showed that source of dietary CP did not alter (P > .10) ADG, DMI, or gain:feed. This observation indicates that 50% of CP in SBM can be replaced by a cheaper source of CP (i.e., urea) without compromising feedlot performance of Holstein steers when fed high-concentrate diets (13% CP; DM basis) during growing and finishing.

Supplementation of diets with increasing levels of RPLM did not affect (P > .10) ADG during the three growth periods of the trial. However, DMI and gain:feed showed cubic (P < .10) responses to increasing dietary level of RPLM. Supplementation of RPLM at the 10 g/d level improved gain:feed by 12% during the last 98 d of the trial, and this was a direct response to the cubic effects of RPLM on DMI.

The cumulative (266 d) performance showed a quadratic (P < .10) gain response to RPLM supplementation. Steers fed either 5 or 10 g/d of RPLM had similar final weights and similar ADG that were 3 to 4% higher than those of steers fed diets without RPLM supplementation. Cubic responses (P < .10) to RPLM were also detected for DMI and gain:feed; steers fed diets that contained 10 g of RPLM had the highest gain:feed ratio. The results are interpreted to suggest that with the diets fed in this trial, lysine and(or) methionine were not limiting feedlot performance of Holstein steers when fed for extended periods (266 d).

Carcass Characteristics. The influence of source of dietary CP and levels of RPLM on carcass characteristics of steers is shown in Table 4. No liver abscesses were detected, indicating that Holstein steers were well adapted to the high-concentrate diets during the 266-d feeding period.

Source of dietary CP did not affect (P > .10) most of the carcass characteristics. The only exception was noted for fat thickness. Steers fed diets containing SBM-U had 12% less (P < .10) fat thickness than those fed diets containing SBM. This observation suggests that steers fed diets containing SBM were fatter at equal weights. However, these differences in fat thickness did not affect the dressing percentage. No advantage was observed (P > .10) in carcass characteristics when high-corn diets were supplemented with RPLM at levels up to 15 g/d. It is noteworthy that 85% of these steers graded Choice after receiving two Revalor-S implants. Administering
Table 3. Feedlot performance of Holstein steers as affected by source of crude protein in the diets and levels of ruminally protected lysine and methionine supplementation

<table>
<thead>
<tr>
<th>Item</th>
<th>Source of Cp</th>
<th>Levels of RPLM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SBM</td>
<td>SBM-U</td>
</tr>
<tr>
<td>No. of pens</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>No. of steers</td>
<td>81</td>
<td>81</td>
</tr>
<tr>
<td>Initial wt, kg</td>
<td>183.1</td>
<td>182.3</td>
</tr>
<tr>
<td>Day 1 to d 84 ADG, kg</td>
<td>1.84</td>
<td>1.72</td>
</tr>
<tr>
<td>Day 1 to d 84 DMI, kg</td>
<td>7.22</td>
<td>7.09</td>
</tr>
<tr>
<td>Gain/feet</td>
<td>.255</td>
<td>.242</td>
</tr>
<tr>
<td>Day 85 to d 168 ADG, kg</td>
<td>1.69</td>
<td>1.64</td>
</tr>
<tr>
<td>Day 85 to d 168 DMI, kg</td>
<td>8.69</td>
<td>8.58</td>
</tr>
<tr>
<td>Gain/feet</td>
<td>.194</td>
<td>.192</td>
</tr>
<tr>
<td>Day 169 to d 266 ADG, kg</td>
<td>.72</td>
<td>.79</td>
</tr>
<tr>
<td>Day 169 to d 266 DMI, kg</td>
<td>8.71</td>
<td>8.73</td>
</tr>
<tr>
<td>Gain/feet</td>
<td>.083</td>
<td>.090</td>
</tr>
<tr>
<td>Whole trial (266 d) ADG, kg</td>
<td>1.38</td>
<td>1.35</td>
</tr>
<tr>
<td>Whole trial (266 d) DMI, kg</td>
<td>8.23</td>
<td>8.17</td>
</tr>
<tr>
<td>Gain/feet</td>
<td>.168</td>
<td>.165</td>
</tr>
</tbody>
</table>

*aSteers were fed high-concentrate (90% of DM) diets containing 13.2% CP during the growing-finishing trial.

*bDietary sources of CP were soybean meal (SBM) or SBM and urea (SBM-U).

*cLevels of ruminally protected lysine and methionine (RPLM) were 0, 5, 10, or 15 g·steer⁻¹·d⁻¹ of Smartamine ML® (Rhône-Poulenc Animal Nutrition, Atlanta, GA).

*dEffect of dietary source of CP (P < .10).

*eCubic (P < .10) response to RPLM supplementation.

*fQuadratic (P < .10) response to RPLM supplementation.

the second implant 154 d before the end of the trial prevented the decrease in quality grade that has been observed with shorter periods between implanting and slaughter.

Discussion

Methionine and lysine frequently have been identified as the first- and second-limiting AA (respectively) for growing sheep (Nimrick et al., 1970; Reis et al., 1973) and cattle (Chalupka and Chandler, 1975; Fenderson and Bergen, 1975; Richardson and Hatfield, 1978; Komarek et al., 1983). Ruminants' requirements for these limiting AA have been estimated from studies in which these AA were either infused postruminally or fed in a protected form to allow escape from the ruminal microbial deamination but availability for digestion and absorption in the small intestine. Supplementation of diets with RPAA was shown to improve the quantity and quality of AA leaving the ruminal fermentation (Titgemeyer et al., 1988). However, growth responses to supplementation of diets with RPLM have been inconsistent.

Positive growth responses and increased N retention of growing ruminants were reported when lysine and(or) methionine were infused postruminally (Schelling et al., 1973; Chalupka and Chandler, 1975; Burris et al., 1976; Hill et al., 1980) or fed in ruminally protected forms (Komarek and Jandzinski, 1978; Oke et al., 1986; Veira et al., 1991). In these studies, the diets were either low in CP (≤ 12% DM basis) or based on ingredients that are low in their contribution to the ruminally undegraded fraction of feed protein (NRC, 1985a). Under such dietary conditions, the profile of essential AA of duodenal digesta approximates that of microbial protein and AA limitations will be similar to those observed for microbial protein (Merchen and Titgemeyer, 1992). In addition, the amounts of essential AA may not be enough to meet the requirements of growing ruminants (NRC, 1985a). Increasing the supply of limiting or colimiting AA at the duodenum by postruminal infusion or dietary supplementation of ruminally protected forms, therefore, may have corrected such limitations and improved performance.

Merchen and Titgemeyer (1992) illustrated that the quality of the undegraded fraction of feed protein may influence which AA are most limiting. Fenderson and Bergen (1975) demonstrated that methionine was first-limiting for steers fed diets containing 80% barley, a protein source that is extensively degraded in the rumen (80%; NRC, 1985a). In contrast, responses to postruminal infusions of lysine by steers fed diets based on corn (Burris et al., 1976; Titgemeyer et al., 1988) suggest that lysine is probably
first-limiting when these diets are fed. A large fraction (65%; NRC, 1985a) of corn protein escapes the ruminal microbial degradation, and corn is a relatively good source of sulfur AA (e.g., methionine) and a poor source of lysine (NRC, 1982). Therefore, postruminal AA supply reflects this and alters the order in which individual AA are limiting. The quality of the basal dietary ingredient also imposed similar effects on AA limitations when RPLM were fed (Oke et al., 1986; Veira et al., 1991). In a trial (154 d) by Veira et al. (1991), beef steers (278 kg) were given ad libitum access to grass silage and were offered barley (.5 kg/d) with or without RPLM to provide dietary supplementation of .11% of lysine and .04% of methionine (DM basis). Steers fed RPLM had 16.3% faster (P < .05) ADG, were 15.7% more efficient (P < .05) in feed utilization, and maintained higher (P < .05) levels of these AA than the control. Because feed intake was not affected (P > .05), improved ADG and gain:feed presumably resulted from correction of a deficiency in lysine and methionine when grass silage was fed. Thomas and Chamberlain (1982) hypothesized that a deficiency in lysine and methionine limits the productivity of ruminants when fed diets based on grass silage. This deficiency in these two essential AA is most probably a result of the high degradability of CP (70 to 75% NRC, 1985a) in grass silage and the low ruminal microbial protein synthesis when corn silage is the main feed consumed (ARC, 1984). Oke et al. (1986) reported that growing lambs and beef steers responded positively to RPLM supplementation of diets containing high proportions of corn. In the lamb (32 kg) trial, supplementation of diets (12% CP and containing 69% corn; DM basis) with .05% lysine and .03% methionine increased (P < .05) N retention by 33%. In the steer (247 kg) trial (84 d), supplementation of diets (11.3% CP and containing 53% corn silage and 30% corn; DM basis) with .11% lysine and .19% methionine improved (P < .05) ADG and gain:feed by 13 and 10%, respectively. In these two trials dietary CP was marginal compared with those recommended for lambs (NRC, 1985b) or steers (NRC, 1984). The high dietary corn in the lamb trial and the high ruminal degradability of CP in corn silage (73% NRC, 1985a) in the steer trial may have resulted in limitation of lysine and methionine at the duodenum. Dietary supplementation of RPLM at those levels corrected for such limitations and, therefore, improved performance.

No growth responses (P > .05) of finishing beef steers weighing 319 (Strasias et al., 1986) or 368 kg (Oke et al., 1986) were detected when ruminally protected lysine and(or) methionine were added to diets containing approximately 86% corn (DM basis). The absence of response in these finishing trials may be explained by results of Titgemeyer and Merchen (1990), who studied AA requirements of finishing beef steers (325 kg gaining 1.3 kg/d) using N retention as the response criterion. They indicated that absorbable sulfur-containing AA requirements (40 g of retained N) were 14.7 g/d and suggested that this amount would be supplied by diets containing corn as the primary energy source.

Because most trials evaluating supplemental RPLM were of short duration, this trial was conducted to offer such evaluation in an extended feeding period (266 d). In our trial, performance of Holstein steers during growing and finishing was evaluated when graded levels of RPLM were added to high-concentrate diets containing CP (13%; DM basis) from preformed AA (SBM) or from preformed AA and urea (SBM-U). Results (Tables 3 and 4) indicate that our diets (Table 1) were able to support AA requirements of steers for growth. Because the quantity and quality of AA reaching the small intestine of ruminants are the result of microbial protein synthesis in the rumen and

Table 4. Carcass characteristics of Holstein steers as affected by source of crude protein in the diets and level of ruminally protected lysine and methionine supplementation

<table>
<thead>
<tr>
<th>Item</th>
<th>Source of CP b</th>
<th>Levels of RPLM c</th>
<th>SEM</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot carcass wt, kg</td>
<td>SBM</td>
<td>SBM-U</td>
<td>SEM</td>
<td>309.7</td>
<td>314.2</td>
<td>315.2</td>
<td>309.8</td>
</tr>
<tr>
<td>Dressing percentage</td>
<td>57.4</td>
<td>57.4</td>
<td>.3</td>
<td>57.6</td>
<td>57.0</td>
<td>57.6</td>
<td>57.3</td>
</tr>
<tr>
<td>Longissimus muscle area, cm²</td>
<td>71.9</td>
<td>71.7</td>
<td>.8</td>
<td>71.8</td>
<td>71.8</td>
<td>72.2</td>
<td>71.3</td>
</tr>
<tr>
<td>Fat thickness, cm²</td>
<td>.69</td>
<td>.61</td>
<td>.03</td>
<td>.67</td>
<td>.64</td>
<td>.64</td>
<td>.65</td>
</tr>
<tr>
<td>Kidney, pelvic, and heart fat, %</td>
<td>3.61</td>
<td>3.64</td>
<td>.10</td>
<td>3.75</td>
<td>3.54</td>
<td>3.66</td>
<td>3.56</td>
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<tr>
<td>Marbling score, degree e</td>
<td>1072</td>
<td>1056</td>
<td>10</td>
<td>1058</td>
<td>1088</td>
<td>1059</td>
<td>1049</td>
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<tr>
<td>Yield grade d</td>
<td>2.98</td>
<td>2.86</td>
<td>.05</td>
<td>2.94</td>
<td>2.91</td>
<td>2.92</td>
<td>2.90</td>
</tr>
<tr>
<td>USDA Choice carcass, %</td>
<td>82.8</td>
<td>87.2</td>
<td>4.2</td>
<td>85.5</td>
<td>92.2</td>
<td>83.6</td>
<td>78.6</td>
</tr>
</tbody>
</table>

aSteers were fed high-concentrate (90% of DM) diets containing 13.2% CP during the growing-finishing trial.

bDietary sources of CP were soybean meal (SBM) or SBM and urea (SBM-U).

Levels of ruminally protected lysine and methionine (RPLM) were 0, 5, 10, or 15 g·steer⁻¹·d⁻¹ of Smartamine ML® (Rhône-Poulenc Animal Nutrition, Atlanta, GA).

eEffect of dietary source of CP (P < .10).

fYield grade was calculated according to the USDA (1975).

d1000 = Choice, 1100 = Choice, 1200 = Choice.
the extent at which feed proteins escape ruminal microbial degradation, results (Tables 3 and 4) suggest that microbial protein synthesis in the rumen was maximized and the remainder of AA requirements was met by the ruminally undegraded fraction of feed protein. It seems that NH₃ N from hydrolysis of urea and(or) degradation of SBM protein were utilized efficiently in the presence of the readily available energy from corn to promote and maximize microbial protein synthesis in the rumen. Because no improvement (P > .10) was detected in feedlot performance (for the whole trial; Tables 3) or carcass characteristics (Tables 4) when supplemental CP was from SBM alone, results suggest a feed cost advantage for replacing 50% of SBM-N by urea.

The high-corn diets (Table 1) fed to Holstein steers seem not to be limiting in lysine or methionine and, therefore, supplementation with RPLM may be unnecessary. Results of two lamb trials (Hussein and Jordan, 1991) showed that high-corn diets contributed a proportion of undegraded protein (from corn) that may have complemented bacterial protein synthesized in the rumen with no need to replace SBM with a low ruminally degradable protein source (i.e., fish meal). Results of Loerch and Berger (1981) also showed little or no response in feedlot performance of steers or lambs when SBM was compared with blood meal and meat and bone meal in high-corn diets. Feeding diets containing high levels of corn to growing-finishing ruminants always is associated with a decrease in ruminal pH. Loerch et al. (1983) found that the decrease in ruminal pH due to increasing dietary level of corn markedly reduced CP degradation of SBM to levels similar to those observed for low ruminal degradable protein sources such as meat and bone meal. The low ruminal pH expected with feeding our diets (Table 1) may have resulted in a greater contribution of SBM protein to the undegraded fraction of feed protein that complemented microbial protein at the duodenum.

Van Amburgh et al. (1993) fed high-concentrate diets (13.5% CP; similar in composition to those in Table 1) to Holstein steers (157 kg BW) for 98 d. These diets were supplemented with graded levels (0, 3, 6, and 9 g/d) of RPLM (the same product used in our trial). They indicated that ADG was improved (by 19%; P < .05) from 1.45 for the control diet (with no RPLM) to 1.73 kg/d for the diet with 3 g/d RPLM. Increasing level of RPLM to 6 or 9 g/d improved ADG (P < .05) only by 13%. In our trial, supplementation of diets with levels of RPLM that were higher than those in the trial by Van Amburgh et al. (1993) did not improve (P > .10) ADG (averaged 1.78 kg/d) during the first 84 d of the trial (Table 3). The variability in response to RPLM in these two trials despite similar experimental conditions (feeding Holstein steers high-corn diets of close CP content) may partially be attributed to the 26 kg lighter initial BW of their steers than ours (183 kg; Table 3), which may have affected rate and composition of gain. Results in Table 3 show that ADG for steers fed diets containing no RPLM was 1.74 kg/d. This ADG is similar to the maximum ADG achieved by RPLM supplementation in the trial by Van Amburgh et al. (1993) and suggests that AA requirements for maximum ADG by our steers were met from the basal dietary ingredients. These ingredients seem to promote maximum ruminal microbial protein synthesis and deliver undegraded intake protein that complemented AA at the duodenum.

**Implications**

Results of feeding high-concentrate (71% whole-shelled corn) diets (13% CP of which 40% was provided by soybean meal or soybean meal and urea) to growing-finishing Holstein steers for an extended period (266 d) suggest that 50% of soybean protein in the diet can be replaced with a cheaper source of CP such as urea, without compromising feedlot performance or carcass characteristics. Supplementation of these diets with graded levels of ruminally protected lysine and methionine did not enhance feedlot performance or carcass characteristics of the steers, indicating that the diets were not limiting in lysine or methionine.

**Literature Cited**


