# Protein and starch digestion in steers fed feedlot diets differing in extent of protein degradation

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Twelve steers fistulated in the rumen and duodenum were allocated to one of three diets and fed 80 g DM/kg $W^{0.75}$/d. The diets consisted of about 80% maize meal, 11% cottonseed hulls and either 1.44% urea (Treatment A), 0.96% urea (Treatment B) or 0.47% urea plus 5.6% fish-meal (Treatment C) as protein supplements. Passage and apparent digestion of protein and starch in the digestive tract were studied using Co-EDTA and Na-dichromate as fluid and particulate markers, respectively. A higher ($P \leq 0.05$) proportion of the dietary protein and starch was apparently digested post-duodenally in steers on Treatment C than in steers on Treatments A and B. Also, duodenal lysine flow was greatest with Treatment C. It is suggested that the supply of amino acids to the small intestine may be inadequate on diets with a UDP content of less than 35 to 40% of crude protein (Treatment C).

Twaalf osse toegerus met rumen- en duodenale fistels is toegeken aan een van drie diëte en is teen 80 g DM/kg $W^{0.75}$/d gevoer. Die diëte het uit ongeveer 80% mieliemeel, 11% katoensaaddoppe en onderskeidelik 1.44% ureum (Behandeling A), 0.96% ureum (Behandeling B) en 0.47% ureum plus 5.6% vismeel (Behandeling C) as proteïen-supplemente bestaan. Deurvloei en skynbare verteerbaarheid van proteïen en stysel in die spysverteringskanaal is bestudeer met behulp van onderskeidelik Co-EDTA en Na-dikromaat as vloeistof- en partikulêre merkers. Meer proteïen en stysel ($P \leq 0.05$) is skynbaar ná die duodenum in osse op Behandeling C verteer as in osse op Behandelings A en B. Voorts was die vloei van lisien na die duodenum in osse op Behandeling C ook hoër. Die afleiding is gemaak dat aminosuurvoorsiening na die dunderm onvoldoende kan wees op diëte waar die NDP-inhoud minder as 35 tot 40% van ruproteïen is (Behandeling C).

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The ratio of degraded to undegraded or escape protein may be critical in feedlot diets. This concern originates from observations that the efficiency of microbial synthesis is lower on high concentrate diets than on diets containing more roughage (Van Soest *et al.*, 1982). Figures as low as 13 g microbial N per kg organic matter apparently digested in the rumen have been reported, whereas the average for cattle diets is about 29 g (ARC, 1984). Yet, ARC (1980) calculations for cattle in the live mass range of 200—400 kg fed high-energy diets, indicate very little need for undegraded protein. NRC (1985), on the other hand, indicates a relatively high need for undegraded protein. Meissner *et al.* (1992b) suggest that some 35 to 40% of crude protein should be undegraded protein to ensure optimal growth and efficiency of steers on feedlot diets.

If no supplementary undegraded protein is required, urea or an extensively degraded plant protein source would be adequate. This would save on cost. The question addressed here was whether protein passage to and digestion in the small intestine would be limited by supplementing with urea only. This was compared to supplementing with undegraded protein at a level of 35—40% of crude protein according to the results of Meissner *et al.* (1992b).

## Procedures

### Animals and design

Twelve steers (333 ± 63.0 kg) were fistulated in the rumen and duodenum and allocated at random to one of three treatments. The three treatments differed in daily supply of crude protein (CP) and undegraded protein (UDP):

| | CP (g/d) | UDP (g/d) | % Ruminal degradation |
|---|---|---|---|
| Treatment A | 730 | 190 | 74 |
| Treatment B | 640 | 190 | 70 |
| Treatment C | 730 | 280 | 62 |

Crude protein levels were equal to ARC (1980) estimates of requirement for medium frame steers gaining 1.5 kg/d on diets with a metabolizability of 0.6 and 0.7.

Dry matter (DM) intake was standardized at 80 g/kg $W^{0.75}$/d (6.2 kg for a 330 kg steer). The 730 g CP level, expressed as a percentage of DM intake, equals 11.7%; this is the level recommended by NRC (1984) and confirmed by Meissner *et al.* (1992b) for similarly sized steers and dietary energy concentrations.

Crude protein and degradation values were obtained by compiling different supplements, containing respectively 1.44% urea (Treatment A), 0.96% urea (Treatment B) and 0.47% urea plus 5.6% fish-meal (Treatment C). The composition of diets is shown in Table 1.

### Measurements

Steers were fed four times daily to approach steady state. Measurements commenced after steers had been adapted to their diets for three weeks.

**Table 1** Composition of diets, percentage as fed

| | Treatment | | |
|---|---|---|---|
| | A | B | C |
| Cottonseed hulls | 11 | 11 | 11 |
| Dicalcium phosphate | 0.2 | 0.2 | – |
| Fish-meal | – | – | 5.6 |
| Limestone ($CaCo_3$) | 1.3 | 1.3 | 1.2 |
| Maize meal | 81.06 | 81.54 | 76.73 |
| Molasses meal[1] | 1 | 1 | 1 |
| Premix[2] | 4 | 4 | 4 |
| Urea | 1.44 | 0.96 | 0.47 |
| **Analyses,[3] % of DM** | | | |
| Crude protein (CP) | 11.7 | 10.2 | 11.8 |
| Undegraded protein (UDP) | 3.02 | 2.84 | 4.51 |
| ME, MJ/kg | 11.7 | 11.7 | 11.6 |
| Crude fibre | 7.74 | 7.75 | 7.67 |
| Calcium | 0.52 | 0.52 | 0.69 |
| Phosphorus | 0.24 | 0.24 | 0.33 |
| Ca : P ratio | 2.2:1 | 2.2:1 | 2.1:1 |

[1] Calorie 3 000.

[2] Premix contained vitamins, trace minerals, salt, $NaHCO_3$, KCl, an ionophore and an antibiotic.

[3] Analyses and UDP values (rate constant of 0.04/h) were calculated from Meissner *et al.* (1992a).

Ruminal volume, digesta content and fluid volume were determined by emptying the rumen (Pienaar *et al.*, 1980). Digesta flow was measured by the double marker technique (Faichney, 1980) with Na-dichromate as particulate marker and Co-EDTA as fluid marker (Coleman *et al.*, 1984). These markers were mixed into the feed after a primer dose had been introduced through the rumen cannula. Duodenal digesta samples were collected over four days (12 samples) at randomly allotted times to simulate one 24-h cycle; samples were pooled for analyses. Faeces were collected *in toto*. Passage and apparent absorption (disappearance) of organic matter (OM), nitrogen (N), non-ammonia nitrogen (NAN) and starch were determined between the mouth and the duodenum and between the duodenum and the faeces where applicable. Additionally, the flow of selected amino acids at the duodenum, ruminal volatile fatty acids (VFA), ammonia ($NH_3$) and pH, and pH at the duodenum and of faeces were measured. Ruminal samples, collected at the same allotted times as the duodenal samples, were pooled. Samples for VFA determination were preserved with NaOH and samples for $NH_3$ determination were preserved with $H_2SO_4$. Ruminal and duodenal pH values were measured in the supernatant fluid after filtration. Faecal pH was measured directly from rectal samples (rectal samples contained about 80% moisture).

### Chemical analysis

Dry matter contents of feed, ruminal, duodenal and faecal samples were determined by drying to constant mass at 60 °C. Ash was determined by incineration at 550 °C. Nitrogen content was determined by kjeldahl; ruminal and duodenal $NH_3$ were determined by auto-analyser (Technicon Auto Analyser II, Indust. Method 334–74A), and amino acids of duodenal samples by amino acid analyser. Feed, duodenal and faecal samples were analysed for starch by α-amylase (MacRae & Armstrong, 1968), and ruminal samples were analysed for VFA concentrations by gas chromatography. Organic matter was calculated as the difference between DM and ash and NAN of duodenal samples was calculated as the difference between total N and $NH_3$.

### Statistical analysis

Differences between treatment means were tested by one-way analysis of variance and Tukey's test, employing the methods of the General Linear Model's programme of SAS (1985).

## Results and Discussion

Reliability of flow measurements was determined in two ways. Digesta passage at the duodenum was calculated both by the double marker technique and by using Co-EDTA as single marker (Faichney, 1980). Average digesta passage was 49.8 kg/d by reconstitution (double marker) procedure and 49.1 kg/d when calculated from single marker flow (mean standard error 9.56 kg; PR≥F 0.97). Recovery of Cr in the faeces was estimated by calculating faecal DM output from Cr concentration and comparing these estimates with DM output collected with faecal bags. Average faecal DM collected in faecal bags was 5.32 kg/d vs. 5.31 kg/d estimated from Cr concentration (mean standard error 1.19 kg; PR≥F 0.99). The results suggest that the reliability was satisfactory.

Results of measurement of some rumen parameters and passage of constituents through the duodenum are shown in Table 2.

Treatment did not significantly affect ruminal volume, digesta content or ruminal fluid. Also, there was no significant treatment effect on pH of the rumen, duodenum, or faeces. Rumen $NH_3$ level was lower ($P \leq 0.05$) on Treatment C (low urea, fish-meal) compared to Treatment A (high urea); duodenal $NH_3$ also tended to be lower (Table 2).

Ruminal $NH_3$ levels clearly were not limiting. In comparison to other high concentrate feedlot diets, these values are at the top end of the scale (4.2—18.5 mg/100 ml) (Morris *et al.*, 1990; Ceceva *et al.*, 1991; Streeter *et al.*, 1990). Feeding level, however, would have had an effect; Kreikemeier *et al.* (1990) reported ruminal $NH_3N$ levels of 9.4—13.8 mM when steers were fed at twice maintenance vs. 6.1—8.9 mM when fed three times maintenance. The present feeding level of 80 g DM/kg $W^{0.75}$/d was about 65—70% of observed *ad libitum* and twice maintenance.

Duodenal fluid passage did not differ significantly between treatments, but passage of OM, starch and NAN was greater ($P \leq 0.05$) on Treatment C, compared to either Treatment A or Treatment B (Table 2). Passage of individual amino acids to the duodenum was not significantly affected by treatment, except for lysine where the passage was greater ($P \leq 0.05$) on Treatment C than Treatment A. This can be attributed to lysine from the added fish-meal. Unfortunately the results on methionine were unreliable. Overall, however, the difference in amino acid flow was small, which is not surprising.

The amino acid composition of bacterial protein is relatively constant (Bergen *et al.*, 1968; Harrison *et al.*, 1973). As 60—85% of NAN entering the small intestine is of microbial

**Table 2** Rumen parameters, pH, $NH_3$ and duodenal passage measurements as affected by protein level and degradation of protein

| | Treatment | | | |
|---|---|---|---|---|
| | A[1] | B[2] | C[3] | MSE |
| Steer mass (kg) | 336 | 337 | 326 | 33.7 |
| Ruminal volume (l) | 38.7 | 32.0 | 38.8 | 4.00 |
| Ruminal digesta (kg) | 37.7 | 32.3 | 37.6 | 5.36 |
| Ruminal fluid (l) | 33.2 | 27.7 | 32.5 | 5.22 |
| pH: rumen | 5.99 | 6.00 | 5.87 | 0.30 |
| duodenum | 2.58 | 2.42 | 2.62 | 0.23 |
| faeces | 6.03 | 6.17 | 6.08 | 0.12 |
| **$NH_3$ (mg/100 ml)** | | | | |
| Rumen | $29.5^{b}$ | $27.3^{ab}$ | $17.8^{a}$ | 5.70 |
| Duodenum | 10.4 | 8.90 | 8.68 | 2.07 |
| **Duodenal passage** | | | | |
| Fluid (l/h) | 2.12 | 2.11 | 2.30 | 0.35 |
| OM (g/h) | $113^{ab}$ | $99.7^{a}$ | $124^{b}$ | 9.16 |
| Starch (g/d) | $521^{a}$ | $588^{ab}$ | $758^{b}$ | 121 |
| NAN (g/d) | $89.6^{ab}$ | $68.5^{a}$ | $98.5^{b}$ | 16.8 |
| **Amino acids (mmol/d)** | | | | |
| Alanine | 11.9 | 10.1 | 11.0 | 2.03 |
| Histidine | 2.23 | 1.81 | 2.12 | 0.34 |
| Isoleucine | 4.01 | 3.56 | 4.17 | 0.82 |
| Lysine | $3.43^{a}$ | $3.55^{ab}$ | $4.67^{b}$ | 0.74 |
| Treonine | 6.02 | 5.13 | 5.14 | 1.12 |
| Valine | 5.41 | 4.82 | 5.65 | 1.07 |

[1] 1.44% urea.

[2] 0.96% urea.

[3] 0.47% urea, 5.7% fish-meal.

[a,b] Values in the same line with different superscripts differ significantly ($P \leq 0.05$).

**Table 3** Intake, VFA concentrations and digestion as affected by protein level and degradation of protein

| | Treatment | | | |
|---|---|---|---|---|
| | A[1] | B[2] | C[3] | MSE |
| **Intake of:** | | | | |
| OM (kg/d) | 5.68 | 5.70 | 5.51 | 0.42 |
| Starch (kg/d) | 3.49 | 3.50 | 3.22 | 0.26 |
| CP (g/d) | $738^{b}$ | $644^{a}$ | $725^{b}$ | 55.2 |
| UDP (g/d) | $194^{a}$ | $181^{a}$ | $271^{b}$ | 16.1 |
| UDP[4] (g/d) | 200 | 46 | 263 | – |
| VFA (mmol/100 ml) | 14.8 | 14.1 | 13.0 | 1.05 |
| $C_2$ (%) | 58.9 | 58.8 | 62.8 | 8.68 |
| $C_3$ (%) | 25.5 | 24.5 | 24.5 | 6.47 |
| $C_4$ (%) | 13.0 | 14.6 | 11.0 | 5.30 |
| **Apparent digestion of OM** | | | | |
| Before duod.: | | | | |
| kg/d | $2.97^{ab}$ | $3.30^{b}$ | $2.55^{a}$ | 0.37 |
| % of intake | $52.2^{ab}$ | $57.8^{b}$ | $46.0^{a}$ | 3.07 |
| % of OM digested | $68.2^{ab}$ | $76.0^{b}$ | $59.6^{a}$ | 3.61 |
| After duod.: | | | | |
| kg/d | $1.36^{ab}$ | $1.04^{a}$ | $1.70^{b}$ | 0.26 |
| % of intake | $24.4^{ab}$ | $18.3^{a}$ | $31.1^{b}$ | 5.33 |
| Total (%) | 76.5 | 76.1 | 77.2 | 4.34 |
| **Starch digestion** | | | | |
| Before duod.: | | | | |
| kg/d | $2.96^{b}$ | $2.91^{b}$ | $2.46^{a}$ | 0.27 |
| % of intake | $85.1^{b}$ | $83.2^{b}$ | $76.2^{a}$ | 3.90 |
| % of starch digested | $90.3^{b}$ | $88.3^{b}$ | $80.8^{a}$ | 4.02 |
| After duod.: | | | | |
| kg/d | $0.32^{a}$ | $0.38^{b}$ | $0.57^{b}$ | 0.15 |
| % of intake | $9.20^{a}$ | $11.0^{ab}$ | $18.0^{b}$ | 4.86 |
| % starch entering duod. | $61.4^{a}$ | $64.6^{a}$ | $75.2^{b}$ | 4.91 |
| Total (%) | 94.2 | 94.2 | 94.3 | 1.53 |
| **Apparent protein digestion** | | | | |
| After duod.: | | | | |
| g/d | $354^{ab}$ | $213^{a}$ | $416^{b}$ | 105 |
| % of intake | $48.1^{ab}$ | $33.1^{a}$ | $57.4^{b}$ | 15.8 |
| Total (%) | 68.8 | 65.6 | 71.4 | 7.52 |

[1] 1.44% urea.

[2] 0.96% urea.

[3] 0.47% urea, 5.7% fish-meal.

[4] Calculated from the 'All cattle' relationship: 29.0 g microbial N/kg OM apparently digested in the rumen (ARC, 1984).

[a,b] Values in the same line with different superscripts differ significantly ($P \leq 0.05$).

origin, the composition of the escape fraction would have to be markedly different from that of microbial protein to significantly affect the composition of the total protein. Nevertheless, any protein (such as fish-meal) that supplies limiting amino acids may have a disproportionate effect on N retention (MacRae & Lobley, 1986), because microbial protein may be deficient in certain amino acids such as methionine, lysine, histidine and arginine (Storm & Ørskov, 1984). The typical escape proteins of plant proteins used in feedlot diets, therefore, are unlikely to alter amino acid passage to the duodenum.

Intake and digestion of protein and energy fractions are shown in Table 3.

Intake of CP, as planned, was lower ($P \leq 0.05$) for Treatment B than for Treatments A and C (Table 3). Intake of UDP according to our estimates of degradation (Meissner *et al.*, 1992a) also was as planned, being more ($P < 0.05$) with Treatment C than Treatments A and B. Microbial protein synthesis was calculated from ruminal OM digestion (ARC, 1984) to determine whether these estimated degradations were accurate. Degradation in the rumen based on these calculations from ARC (1984) were 73, 93 and 64% for Treatments A, B and C respectively, compared with predicted values of 74, 72 and 63%. Estimates of UDP for Treatments A and C were within 3% of calculated values, but the estimate for Treatment B (low CP, low UDP) did not correspond.

Volatile fatty acid concentrations did not differ significantly between treatments, either in terms of the total or the proportional contribution of the major acids. Neither organic matter nor starch digestion *in toto* was significantly influenced by treatment, but the partial digestion before and after the duodenum differed significantly. The main difference was between Treatment C and the other treatments, with less OM ($P \leq$