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**Original article**

# Manipulation of microbial protein supply and resultant performance of bullocks by increasing straw content in the diet

N Todorov [1*], G Ganev [2], D Djurbinev [2], D Djouvinov [1], R Grigorova [2]

[1] *Thracian University;*
[2] *Research Institute of Cattle and Sheep Production, Stara Zagora 6000, Bulgaria*

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**Summary** — This study involved two similar experiments. Thirty-four Bulgarian Brown bullocks were used in a 2 x 2 factorial design to investigate the effect of the quantity of dry matter intake (DMI) and dietary source of protein on microbial protein supply, nitrogen utilization and resultant performance. The four isonitrogenous experimental diets consisted of concentrate plus wheat straw: 50% straw and urea; 22% straw and urea; 50% straw and sunflower oil meal; and 21% straw and sunflower oil meal. Increasing the level of DMI through higher proportions of straw in the diet with urea tended to improve both the microbial protein supply to the small intestine and the average daily gain (ADG). In addition, the length of the fattening period and the amount of concentrate consumed per kg of live weight gain were reduced. Higher straw levels in the diets with the sunflower oil meal lowered the ADG and increased the length of the fattening period. In conclusion, it was found that adding large quantities of wheat straw to fattening diets containing adequate amounts of natural protein was not justified.

**protein source / dry matter intake / microbial synthesis / performance / fattening bullocks**

**Résumé — Effets de l'augmentation de la quantité de paille dans la ration sur la synthèse de protéines microbiennes et les gains de poids vif des taurillons**. Deux expériences ont été effectuées selon le même schéma. Trente-quatre taurillons bruns bulgares ont été utilisés pour étudier l'influence de la quantité de matière sèche ingérée et de la source de protéines sur la synthèse de protéines microbiennes, l'utilisation de l'azote et les performances animales. Les quatre rations expérimentales

* Correspondence and reprints.
Fax: (359) 42 56 102; e-mail: ntodorov@UZVM.U2VM.bg

iso-azotées étaient composées de concentré et de paille de blé : 50 % de paille et d'urée, 22 % de paille et d'urée ; 50 % de paille et de tourteau de tournesol, et 21 % de paille et de tourteau de tournesol. Les rations avec 50 % de paille ont été offertes à volonté et celles avec 21 % de paille ont été distribuées en quantité limitée (70 % des quantités ingérées avec les rations à 50 % de paille). L'augmentation du niveau de consommation de matière sèche entraînée par l'augmentation de la quantité de paille dans la ration avec de l'urée a amélioré l'entrée de protéines microbiennes dans l'intestin grêle et a augmenté le gain de poids quotidien (ADG). De même la durée, la période d'engraissement et la quantité de concentré dépensée pour 1 kg de gain de poids vif ont été réduites. La plus grande proportion de paille dans la ration avec le tourteau de tournesol a exercé une influence négative sur le ADG et sur la durée d'engraissement. L'introduction de grandes quantités de paille de blé dans les rations des taurillons recevant suffisamment de protéines naturelles n'est pas justifiée.

**source de protéines / matière sèche ingérée / synthèse de protéines microbiennes/ performances animales / taurillon à l'engrais**

## INTRODUCTION

The protein value of feeds for ruminants is determined by measuring the amount of undegraded feed protein and microbial protein entering the small intestine (ARC, 1984; Madsen, 1985; NRC, 1985; Vérité and Peyraud, 1989).

The amount of microbial protein produced in the rumen depends mainly on the energy available for the microbes (Demeyer and Tamminga, 1987). The efficiency of microbial protein synthesis could be improved by increasing the dilution rate of the rumen content, thereby decreasing the bacterial protein turnover (Tamminga et al, 1979; Tamminga, 1980; Zinn and Owens, 1982). The dilution rate could be increased by increasing the dry matter intake (DMI) (Mudgal et al, 1982) or by grinding and pelleting the roughage (Forbes, 1986).

It could therefore be expected that an increased dilution rate would enhance the ruminant performance by providing a better protein supply due to the increased efficiency of microbial protein synthesis and the depressed degradability of feed protein in the rumen.

The aim of this study was to examine the effect of increasing the level of dry matter intake (DMI) in diets supplemented with urea (U) and sunflower oil meal (SM), on microbial protein supply, nitrogen utilization and the performance of fattening bullocks.

## MATERIALS AND METHODS

### Animals, feeding and management

Two similar experiments were conducted. Each experiment used 34 Bulgarian Brown bullocks which were divided into four groups. All groups were of the same average age and live weight (LW). Two groups of eight bullocks had sunflower oil added to their diets while the remaining two groups, consisting of nine bullocks each, had urea added to their diets. The number of bullocks in the different groups was not equal due to the availability of experimental stalls. The average initial LW was 215 ± 7.8 and 230 ± 8.5 kg for experiments 1 and 2, respectively. The bullocks were slaughtered at an average LW of 542 kg in experiment 1 and at 486 kg in experiment 2. The animals were kept tied and were fed individually. Drinking water was always available.

The experiments were conducted using the 2 x 2 factorial method with diets of two levels of DMI and two different protein supplements (U and SM). All bullocks received a complete pelleted diet in two equal portions twice daily (0700 and 1500 hours). The four isonitrogenous experimental diets (on the basis of crude protein equivalent and total nitrogen intake per day) consisted of concentrate plus wheat straw: 50% straw and urea (HSU); 22% straw and urea (LSU); 50%

straw and sunflower oil meal (HSM); and 21% straw and sunflower oil meal (LSM) (table I). The animals on the HSU and HSM diets were fed ad libitum. The DMI of the bullocks receiving the LSU and LSM rations was restricted to approximately 74% (experiment 1) and 70% (experiment 2) of the DMI of the other two groups. It was attempted, in this ways to equilibrate the net energy intake (NEI) in all groups regardless of the differences in DMI. However, the equalization was not completely successful due to the differences between the net energy values of the diets calculated on the basis of the published data for the net energy content of the feeds (Todorov, 1991) and the real net energy values calculated on the basis of their chemical composition and digestibility, such as those found in these experiments. There were differences in the estimated intake of protein that was digestible in the small intestine (PDI) among the groups.

## Measurements and analyses

The bullocks were weighed on 2 consecutive days at the beginning and every 4 weeks until the end of the experiments (after 24 h of fasting and 12 h without drinking water). At the end

**Table I.** Composition and nutritive value of pellets.

| *Item* | *Diet* | | | |
|---|---|---|---|---|
| | *HSU* | *LSU* | *HSM* | *LSM* |
| Ingredients (g/kg) | | | | |
| Maize | 214 | 330 | 184 | 246 |
| Wheat | 213 | 330 | 182 | 253 |
| Alfalfa, dehydrated | 30 | 50 | 30 | 50 |
| Wheat straw | 500 | 222 | 500 | 210 |
| Sunflower oil meal | – | – | 70 | 200 |
| Urea | 16 | 23 | 9 | 3 |
| Dicalcium phosphate | 7 | 10 | 3 | – |
| Limestone | – | 4 | 2 | 7 |
| Sodium chloride | 10 | 15 | 10 | 15 |
| Magnesium sulphate | 4 | 6 | 4 | 6 |
| Trace mineral mixture * | 3 | 5 | 3 | 5 |
| Vitamin premix ** | 3 | 5 | 3 | 5 |
| Chemical composition | | | | |
| Dry matter (g/kg) | 900 | 882 | 892 | 885 |
| In 1 kg dry matter (g) | | | | |
| Crude protein | 134 | 176 | 135 | 174 |
| Ether extract | 23 | 25 | 24 | 27 |
| Crude fibre | 215 | 159 | 219 | 160 |
| Nitrogen free extract | 552 | 574 | 543 | 572 |
| Ash | 75 | 66 | 79 | 67 |
| Calcium | 6 | 7 | 7 | 7 |
| Phosphorus | 5 | 5 | 6 | 5 |

HSU: diet with high straw content and urea; LSU: diet with low straw content and urea; HSM: diet with high straw content and sunflower oil meal; LSM: diet with low straw content and sunflower oil meal. * $CaCO_3$, 44.06%; $MgSO_4.7H_2O$, 30.00%; $FeSO_4.7H_2O$, 8.4%; $CuSO_4.5H_2O$, 1.7%; $ZnSO_4.7H_2O$, 7.5%; $MnSO_4.5H_2O$ 8.00%; $CoSO_4.7H_2O$, 0.30%, KI, 0.04%. ** Vitamin A, 2 400 UI/g; vitamin $D_3$, 400 UI/g premix.

of the experiments, the animals were slaughtered and the separable inner fat (only for experiment 1) and the carcasses were weighed. The muscle tissue, fat tissue and bones of the 11th rib cut (Zakhariev and Pinkas, 1979) were separated. The chemical composition of the *m longissimus dorsi* between the 9th and 11th ribs, without the surface membrane, was determined according to the Weende method (AOAC, 1980). The morphological composition of the carcass was estimated using the equations proposed by Hopper (1944).

In experiment 2, faeces and urine were collected during a 7 and 4 day period, respectively. The first collection period was at an average LW of 280 kg and the second at an average LW of 406 kg. Five percent of the daily faeces were taken as subsamples and were oven-dried at 65 °C for at least 72 h. Urine was collected in sulphuric acid so that the final pH was between 2 and 3. The daily urine subsamples (10% aliquots) were stored at –20 °C until analysis. Feeds, feed refusals and faeces were analysed according to the Weende method (AOAC, 1980). The mean retention time of feed particles in the rumen was determined by coloured wheat straw, counting feed particles in the faeces and calculating the time needed for the passage of 80% minus 5% of the total particles according to Balch (1950). The solid dilution rate as a fraction of the rumen content was calculated as a reciprocal of the mean retention time. The digestibility of the nutrients in the whole digestive tract was determined after a total faeces collection. The net energy values of the diets were calculated on the basis of the chemical composition and digestibility of nutrients, according to Kellner for the starch equivalent, and Todorov (1995) for feed units for growth (FUG).

**Table II.** Live weight (LW) and average daily gain (ADG) of bullocks.

| *Item* | *Diet* * | | | |
|---|---|---|---|---|
| | *HSU* | *LSU* | *HSM* | *LSM* |
| Experiment 1 | | | | |
| Initial LW (kg) | 216.5[a] | 215.0[a] | 214.3[a] | 211.6[a] |
| Final LW (kg) | 551.7[a] | 544.1[a] | 531.0[a] | 543.7[a] |
| Gain in LW (kg) | 335.2[a] | 329.1[a] | 16.7[a] | 332.1[a] |
| ADG (g) | 1010.0[ab] | 948.0[ab] | 905.0[a] | 1016.0[b] |
| Fattening period (days) | 331.9[a] | 347.0[b] | 350.0[b] | 327.0[a] |
| Experiment 2 | | | | |
| Initial LW (kg) | 226.5[a] | 233.6[a] | 227.3[a] | 239.9[a] |
| Final LW (kg) | 497.7[a] | 459.3[a] | 457.8[a] | 493.3[a] |
| Gain in LW (kg) | 271.2[a] | 261.7[a] | 230.5[b] | 260.4[a] |
| ADG (g) | 1012.0[a] | 910.0[ab] | 847.0[b] | 972.0[ab] |
| Fattening period (days) | 268.1[a] | 287.5[b] | 272.1[a] | 267.9[a] |
| Experiment 1 + Experiment 2 | | | | |
| Initial LW (kg) | 221.5[a] | 224.3[a] | 220.8[a] | 222.2[a] |
| Final LW (kg) | 524.7[a] | 519.7[a] | 494.4[a] | 518.5[a] |
| Gain in LW (kg) | 303.2[a] | 295.4[a] | 273.6[a] | 296.3[a] |
| ADG (g) | 1011.0[a] | 931.0[ab] | 880.0[b] | 996.0[ab] |
| Fattening period (days) | 300.0[a] | 317.2[b] | 311.0[a] | 297.4[a] |

* Abbreviations as in table I. [ab] Means in the same row without common letters within each experiment differ significantly at $P < 0.05$.

Urine samples were analysed for allantoin, uric acid, xanthine and hypoxanthine following the procedure reported by Fujihara et al (1987). Microbial protein supply to the small intestine was calculated on the basis of total purine derivative excretion in urine as proposed by Chen (1989).

Protein degradability in the rumen was determined in sacco as described by Ørskov and McDonald (1979). Effective protein degradability was calculated according to McDonald (1981). Calculations were based on the measured dilution rates in experiment 2. Digestibility coefficients of protein in the small intestine were taken from INRA tables (Vérité and Peyraud, 1989). On the basis of this data, PDI (equal to PDIE) was calculated following the French protein evaluation system (Vérité and Peyraud, 1989). The protein balance in the rumen (PBR) was calculated as proposed by Todorov (1995). All data were subjected to statistical analysis by the Student's t-test.

## RESULTS AND DISCUSSION

### Effect of dry matter intake (DMI) in urea supplemented diets

The average daily gain (ADG) in the HSU group was 1 010 g versus 948 g in the LSU group for experiment 1, and 1 012 g versus 910 g for experiment 2 ($P > 0.05$) (table II). Crude protein intake was approximately equivalent for both groups but the amount of digestible protein in the small intestine (PDI) for the HSU group was 20% more than for the LSU group (table III). The increase in ADG for the HSU group could be explained by the slightly higher net energy intake (fig 1) and protein supply to the small intestine due to the increased amount of microbial protein reaching the duodenum and, probably, to the increased flow of undegraded feed protein (table IV).

Because of the higher level of net energy and PDI in the HSU groups compared to the LSU groups for both experiments, it was not possible to distinguish the effects of energy and protein levels. In a previous experiment, conducted on wethers, 60% of the increase in non-ammonia nitrogen flux to the duodenum was explained by a decrease in the feed protein degradability at a higher DMI level (Djouvinov and Todorov, 1994). The higher consumption of dry matter led to a faster dilution rate of the rumen content (table V). This effect was probably intensified by grinding and pelleting the feed (Forbes, 1986). As a result, the retention time of liquid and the solid phase of rumen content was decreased and more rumen microbes could escape the lysis and pass to the duodenum (Tamminga, 1981).

It is not clear whether the effect of DMI could be related to the expected shift of digestion from the forestomachs to the intestine (Zinn and Owens, 1982). The difference in ADG between the HSU and LSU groups was not due to the impact of filling the gastrointestinal tract. This factor was partly eliminated by a 24 h fasting period before the bullocks were weighed (see dressing percentage in table VII). More inner fat tissue was separated in the HSU group. Hence, the influence of water retention on the ADG should be excluded.

The dressing percentage of the bullocks slaughtered after 24 h of fasting was not significantly altered by the diet. Sokac et al (1991) also did not find significant differences in the

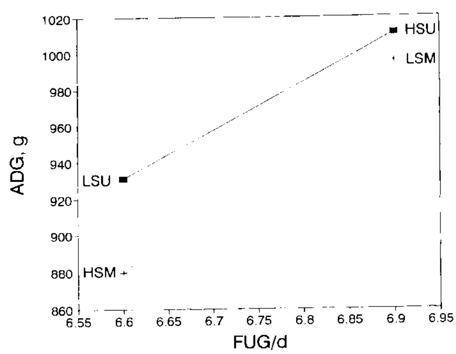


**Fig 1.** Relationship between daily intake of feed units for growth (FUG) and average daily gain (ADG) of live weight of bullocks (mean of experiment 1 and experiment 2).

**Table III.** Daily intake of nutrients.

| *Item* | *Diet* * | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Experiment 1* | | | | *Experiment 2* | | | | *Experiment 1 + Experiment 2* | | | |
| | *HSU* | *LSU* | *HSM* | *LSM* | *HSU* | *LSU* | *HSM* | *LSM* | *HSU* | *LSU* | *HSM* | *LSM* |
| Daily intake | | | | | | | | | | | | |
| Dry matter (kg) | $8.1^{a}$ | $5.9^{b}$ | $7.9^{a}$ | $6.0^{b}$ | $7.9^{a}$ | $5.8^{b}$ | $7.6^{a}$ | $6.1^{b}$ | $8.0^{a}$ | $5.9^{b}$ | $7.8^{a}$ | $6.1^{b}$ |
| Starch equivalent | $3.8^{a}$ | $3.7^{a}$ | $3.7^{a}$ | $3.8^{a}$ | $3.7^{a}$ | $3.6^{a}$ | $3.6^{a}$ | $3.9^{a}$ | $3.8^{a}$ | $3.7^{a}$ | $3.7^{a}$ | $3.8^{a}$ |
| FUG ** | $7.0^{a}$ | $6.7^{a}$ | $6.7^{a}$ | $6.9^{a}$ | $6.8^{a}$ | $6.6^{a}$ | $6.5^{a}$ | $7.0^{a}$ | $6.9^{a}$ | $6.6^{a}$ | $6.6^{a}$ | $6.9^{a}$ |
| CP (g) | $1\,085^{a}$ | $1\,038^{a}$ | $1\,066^{a}$ | $1\,044^{a}$ | $1\,059^{a}$ | $1\,021^{a}$ | $1\,026^{a}$ | $1\,061^{a}$ | $1\,072^{a}$ | $1\,030^{a}$ | $1\,046^{a}$ | $1\,053^{a}$ |
| Digestible protein (g) | $696^{a}$ | $805^{ab}$ | $764^{ab}$ | $834^{b}$ | $679^{a}$ | $792^{ab}$ | $735^{ab}$ | $848^{b}$ | $687^{a}$ | $799^{ab}$ | $749^{ab}$ | $841^{b}$ |
| PDI ** (g) | $610^{a}$ | $506^{b}$ | $619^{a}$ | $564^{a}$ | $595^{a}$ | $498^{b}$ | $595^{a}$ | $573^{a}$ | $602^{a}$ | $506^{b}$ | $611^{a}$ | $573^{a}$ |
| Calcium (g) | $52.0^{a}$ | $43.0^{a}$ | $57.0^{a}$ | $43.0^{a}$ | $50.0^{a}$ | $41.6^{a}$ | $54.6^{a}$ | $44.4^{a}$ | $51.5^{a}$ | $42.8^{a}$ | $55.8^{a}$ | $43.7^{a}$ |
| Phosphorus (g) | $38.0^{a}$ | $30.0^{a}$ | $40.0^{a}$ | $31.0^{a}$ | $40.2^{a}$ | $28.8^{a}$ | $39.4^{a}$ | $33.0^{a}$ | $39.6^{a}$ | $29.4^{a}$ | $40.2^{a}$ | $32.6^{a}$ |

* Abbreviations as in table I; ** FUG: feed units for growth; PDI: protein digestible in the small intestine according to the new Bulgarian feed evaluation system (Todorov, 1995); CP: crude protein. $^{abc}$ Means in the same row without common letters within each experiment differ significantly at $P < 0.05$.

**Table IV.** Urine purine derivatives excretion and microbial nitrogen supply to the duodenum of bullocks (experiment 2) **.

| *Item* | *Diets* * | | | |
|---|---|---|---|---|
| | *HSU* | *LSU* | *HSM* | *LSM* |
| At average 280 kg LW | | | | |
| Purine derivatives (mmol/day) | | | | |
| Allantoin | 74.6 | 70.2 | 74.0 | 79.1 |
| Uric acid | 18.2 | 17.3 | 17.0 | 18.7 |
| Xanthine hypoxanthine | 2 | 3.3 | 1.8 | 2.5 |
| Total | 95.7 | 90.8 | 92.8 | 100.3 |
| Microbial nitrogen entering duodenum (g/day) | 59.3 | 55.1 | 56.8 | 61.3 |
| At average 406 kg LW | | | | |
| Purine derivatives (mmol/day) | | | | |
| Allantoin | 105.2 | 95.3 | 110.2 | 103.9 |
| Uric acid | 20.9 | 25.6 | 18.5 | 20.0 |
| Xanthine hypoxanthine | 3.6 | 3.1 | 4.8 | 2.1 |
| Total | 130.3 | 124.7 | 133.5 | 126.0 |
| Microbial nitrogen entering duodenum (g/day) | 81.3 | 76.2 | 83.5 | 80.0 |

* Abbreviations as in table I, LW: live weight. ** Differences between the means were not significant at $P < 0.05$.

**Table V.** Digestibility of nutrients (%), protein degradability (%) and energy and protein value of pellets (experiment 2).

| *Item* | *Diet* * | | | |
|---|---|---|---|---|
| | *HSU* | *LSU* | *HSM* | *LSM* |
| Digestibility | | | | |
| Dry matter | 60.8 | 72.6 | 60.8 | 72.6 |
| Organic matter | 63.6 | 74.9 | 62.9 | 74.7 |
| Crude protein | 64.1 | 77.6 | 71.6 | 79.9 |
| Ether extract | 67.4 | 74.2 | 67.5 | 71.6 |
| Crude fibre | 44.8 | 48.6 | 41.7 | 45.9 |
| Nitrogen free extract | 70.8 | 80.6 | 69.5 | 81.3 |
| Protein degradability | 76.0 | 81.4 | 71.9 | 74.1 |
| Ruminal solids dilution rate | 0.055 | 0.037 | 0.050 | 0.039 |
| In 1 kg dry matter | | | | |
| Starch equivalent | 0.47 | 0.64 | 0.47 | 0.63 |
| FUG ** | 0.87 | 1.13 | 0.85 | 1.14 |
| Digestible protein (g) | 85.9 | 136.6 | 96.7 | 139.0 |
| PDI (g) ** | 75.3 | 85.8 | 78.3 | 94.0 |
| PBR (g) | 10.0 | 31.7 | 7.4 | 19.7 |

* Abbreviations as in table I; ** abbreviations as in table III; PBR: protein balance in the rumen.

**Table VI.** Feed conversion.

| *Item* | *Diet* * | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Experiment 1* | | | | *Experiment 2* | | | | *Experiment 1 + Expriment 2* | | | |
| | *HSU* | *LSU* | *HSM* | *LSM* | *HSU* | *LSU* | *HSM* | *LSM* | *HSU* | *LSU* | *HSM* | *LSM* |
| Feed conversion ratio | | | | | | | | | | | | |
| Dry matter (kg/kg LW gain) | 8.0$^{a}$ | 6.2$^{b}$ | 8.7$^{a}$ | 5.9$^{b}$ | 7.8$^{a}$ | 6.4$^{b}$ | 9.0$^{a}$ | 6.3$^{b}$ | 7.9$^{a}$ | 6.3b | 8.8$^{a}$ | 6.1$^{b}$ |
| Concentrates (kg/kg LW gain) | 3.8$^{a}$ | 4.7$^{b}$ | 4.4$^{ab}$ | 4.7$^{b}$ | 3.8$^{a}$ | 4.9$^{b}$ | 4.7$^{b}$ | 4.9$^{b}$ | 3.8$^{a}$ | 4.7b | 4.5$^{b}$ | 4.8$^{b}$ |
| Starch equivalent (per kg LW gain) | 3.8$^{a}$ | 3.9$^{a}$ | 4.1$^{a}$ | 3.7$^{a}$ | 3.7$^{a}$ | 4.0$^{a}$ | 4.2$^{a}$ | 4.0$^{a}$ | 3.7$^{a}$ | 3.9$^{a}$ | 4.2$^{a}$ | 3.8$^{a}$ |
| FUG (per kg LW gain) ** | 6.9$^{a}$ | 7.1$^{a}$ | 7.4$^{a}$ | 6.7$^{a}$ | 6.8$^{a}$ | 7.2$^{a}$ | 7.6$^{a}$ | 7.2$^{a}$ | 6.8$^{a}$ | 7.1$^{a}$ | 7.5$^{a}$ | 6.9$^{a}$ |
| CP (g/kg LW gain) ** | 1 075$^{ab}$ | 1 096$^{ab}$ | 1 178$^{b}$ | 1 028$^{a}$ | 1 047$^{a}$ | 1 122$^{ab}$ | 1 211$^{b}$ | 1 092$^{ab}$ | 1 081$^{a}$ | 1 106$^{ab}$ | 1 189$^{b}$ | 1 057$^{ab}$ |
| PDI (g/kg LW gain) | 604$^{ab}$ | 534$^{a}$ | 684$^{b}$ | 555$^{a}$ | 588$^{a}$ | 546$^{a}$ | 702$^{b}$ | 589$^{a}$ | 595$^{ab}$ | 538$^{a}$ | 690$^{b}$ | 570$^{a}$ |

* Abbreviations as in table I; ** abbreviations as in table III . $^{abc}$ as in table III.

dressing proportion in heifers fed rations with different roughage:concentrate ratios. In contrast, Slabbert et al (1992) found an inverse relationship between the amount of concentrate in the diet and the dressing percentage of steers.

From an economical point of view, the HSU diet was more successful. Both the amount of concentrate consumed per kg gain (table VI) and the fattening period were reduced, the latter by 2 weeks (table II). The shorter fattening period decreased the maintenance energy requirements of the bullocks and other farming expenditures. There was also a tendency of better feed efficiency (fewer feed units per kg of LW gain) for animals fed the HSU diet (table VI).

### Effect of DMI in diets with sunflower oil meal supplementation

The DMI level had an opposite effect on the performance of bullocks when sunflower oil meal was used as a protein supplement instead of urea. The average daily gain of the LSM group (low level of DMI) was 12-15% higher than the HSM group (high level of DMI) (table II). A similar trend of a decreasing ADG of bullocks fed a diet with a natural protein source and high straw content was observed by Platikanov et al (1985). The difference in the ADG between the LSM and HSM groups may be due to different NEI levels (fig 1). Differences in PDI intake for the two groups were relatively small and probably did not play a significant role due to the slight surplus of PDI in both the LSM and HSM diets.

The animals from the LSM group reached slaughtering weight earlier than those in the HSM group. Increasing the DMI and straw content in the diet supplemented with sunflower oil meal resulted in lower energy and protein utilization. More starch equivalents or FUG and crude protein or PDI were consumed per kg of LW gain in the HSM group than in the LSM group (table VI).

The chemical composition of the *m longissimus dorsi* of animals from the HSM group was the same as those from the LSM group. No significant differences between the two groups were found in the morphological tissue composition of the 11th rib cut and carcass. In the experiment on heifers, the carcass composition was also unaffected by the DMI level (Maentysaari, 1993). A higher carcass yield was obtained in bullocks fed the LSM diet than those given the HSM diet (table VII).

It is evident from these two experiments that adding large quantities of wheat straw to diets already containing a sufficient amount of natural protein was not justified. Moreover, there was a trend towards a lower yield of lean carcass tissue (table VII) when the straw content in the diets was increased.

It should be noted that the differences between the groups in these experiments (in most of the cases) were not statistically significant. However, the differences between the groups were consistent in both experiments, thereby validating the results.

## CONCLUSION

The increased level of DMI due to the inclusion of straw in the diet and by feeding ad libitum versus restricted feeding with a low straw diet had various effects on the performance of fattening bullocks depending on the nature of the protein supplement.

A higher DMI and a higher straw content in the diet supplemented with urea tended to improve the ADG and increase the energy content in the carcass as was demonstrated by the greater amounts of fat. Higher DMI reduced the fattening period and decreased the amount of concentrates consumed per kg of LW gain per animal. A higher ruminal dilution rate increased both the efficiency of microbial protein synthesis in the rumen and the bullocks' protein supply when a diet with a high straw content was fed to the animals.

In the diets with sunflower oil meal, a high level of straw adversely affected the ADG. The

**Table VII.** Yield and morphological composition of carcass and chemical composition of m longissimus dorsi.

| *Item* | *Diet* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Experiment 1* | | | | *Experiment 2* | | | | *Experiment 1 + Experiment 2* | | | |
| | *HSU* | *LSU* | *HSM* | *LSM* | *HSU* | *LSU* | *HSM* | *LSM* | *HSU* | *LSU* | *HSM* | *LSM* |
| Live weight before slaughtering (kg) | 551.7$^{a}$ | 544.1$^{a}$ | 531.0$^{a}$ | 543.7$^{a}$ | 497.7$^{a}$ | 495.3$^{a}$ | 457.8$^{a}$ | 493.3$^{a}$ | 524.7$^{a}$ | 519.7$^{a}$ | 494.4$^{a}$ | 518.5$^{a}$ |
| Weight of warm carcass (kg) | 292.3$^{a}$ | 249.8$^{a}$ | 278.9$^{b}$ | 293.9$^{a}$ | 260.9$^{a}$ | 269.7$^{a}$ | 241.6$^{b}$ | 265.9$^{a}$ | 276.6$^{a}$ | 264.4$^{a}$ | 260.2$^{a}$ | 279.9$^{a}$ |
| Dressing percentage | 53.0$^{a}$ | 54.2$^{a}$ | 52.5$^{a}$ | 54.0$^{a}$ | 51.0$^{a}$ | 52.4$^{a}$ | 50.6$^{a}$ | 52.6$^{a}$ | 52.0$^{a}$ | 52.8$^{a}$ | 51.6$^{a}$ | 53.3$^{a}$ |
| Separate inside fat (kg) | 13.2$^{a}$ | 9.2$^{b}$ | 9.9$^{bc}$ | 11.9$^{ac}$ | | | | | | | | |
| Separable inside fat, % of carcass weight | 4.5$^{a}$ | 3.1$^{b}$ | 3.5$^{bc}$ | 4.0$^{ac}$ | | | | | | | | |
| Chemical composition of m longissimus dorsi (g/kg) | | | | | | | | | | | | |
| Water | 742.6$^{a}$ | 738.2$^{a}$ | 737.0$^{a}$ | 743.3$^{a}$ | 745.4$^{a}$ | 760.2$^{a}$ | 748.7$^{a}$ | 752.8$^{a}$ | 744.0$^{a}$ | 742.0$^{a}$ | 742.9$^{a}$ | 748.1$^{a}$ |
| Protein | 213.1$^{a}$ | 220.4$^{a}$ | 210.9$^{a}$ | 220.4$^{a}$ | 224.1$^{a}$ | 216.6$^{a}$ | 220.0$^{a}$ | 213.5$^{a}$ | 218.6$^{a}$ | 218.5$^{a}$ | 219.5$^{a}$ | 216.8$^{a}$ |
| Fat | 35.6$^{a}$ | 30.9$^{a}$ | 33.3$^{a}$ | 26.0$^{a}$ | 19.3$^{a}$ | 13.0$^{a}$ | 20.0$^{a}$ | 21.5$^{a}$ | 27.5$^{a}$ | 22.0$^{a}$ | 26.7$^{a}$ | 23.8$^{a}$ |
| Ash | 10.7$^{a}$ | 10.6$^{a}$ | 10.8$^{a}$ | 10.3$^{a}$ | 11.2$^{a}$ | 10.2$^{a}$ | 11.3$^{a}$ | 12.2$^{a}$ | 11.0$^{a}$ | 10.4$^{a}$ | 11.1$^{a}$ | 11.3$^{a}$ |
| Morphological composition of 11th rib cut (g/kg) | | | | | | | | | | | | |
| Muscle tissue | 594.1$^{a}$ | 628.9$^{a}$ | 623.3$^{a}$ | 617.6$^{a}$ | 621.1$^{a}$ | 638.0$^{a}$ | 679.6b | 654.2$^{ab}$ | 607.6$^{a}$ | 633.5$^{ab}$ | 651.5b | 635.9$^{ab}$ |
| Fat tissue | 199.4$^{a}$ | 162.3$^{b}$ | 179.2$^{ab}$ | 177.3$^{ab}$ | 153.0$^{a}$ | 133.7$^{b}$ | 150.5$^{ab}$ | 167.3$^{a}$ | 176.2$^{a}$ | 148.0b | 164.9$^{ab}$ | 172.3$^{a}$ |
| Bones | 206.5$^{a}$ | 208.8$^{a}$ | 197.5$^{a}$ | 205.1$^{a}$ | 225.9$^{a}$ | 228.3$^{a}$ | 169.9$^{b}$ | 178.5$^{ab}$ | 216.2$^{a}$ | 218.6$^{a}$ | 183.7$^{b}$ | 191.8$^{ab}$ |
| Morphological composition of carcass (g/kg) | | | | | | | | | | | | |
| Muscle tissue | 634.0$^{a}$ | 666.6$^{a}$ | 653.3$^{a}$ | 652.8$^{a}$ | 655.1$^{a}$ | 668.6$^{a}$ | 701.9$^{b}$ | 681.6$^{ab}$ | 644.6$^{a}$ | 667.6$^{ab}$ | 677.6$^{b}$ | 667.2$^{ab}$ |
| Fat tissue | 176.6$^{a}$ | 150.6b | 166.6$^{ab}$ | 169.4$^{ab}$ | 150.3$^{a}$ | 135.1$^{b}$ | 138.4$^{ab}$ | 157.3$^{a}$ | 163.5$^{a}$ | 142.9$^{b}$ | 152.5$^{a}$ | 163.4$^{a}$ |
| Bones | 189.4$^{a}$ | 182.8$^{a}$ | 180.1$^{a}$ | 177.8$^{a}$ | 194.6$^{a}$ | 196.3$^{a}$ | 159.7$^{b}$ | 161.1$^{ab}$ | 192.0$^{a}$ | 189.6$^{a}$ | 169.9$^{b}$ | 169.5$^{ab}$ |
| Yield of carcass (kg) | | | | | | | | | | | | |
| Muscle tissue | 185.3$^{a}$ | 196.5$^{a}$ | 182.2$^{a}$ | 191.8$^{a}$ | 170.9$^{a}$ | 180.4$^{a}$ | 169.6$^{a}$ | 181.2$^{a}$ | 178.1$^{a}$ | 188.4$^{a}$ | 175.9$^{a}$ | 186.5$^{a}$ |
| Fat tissue | 51.6$^{a}$ | 44.4$^{a}$ | 46.5$^{a}$ | 49.08$^{a}$ | 39.3$^{a}$ | 36.4$^{a}$ | 33.4$^{a}$ | 41.2$^{a}$ | 45.5$^{a}$ | 40.4$^{a}$ | 39.9$^{a}$ | 45.5$^{a}$ |
| Bones | 55.4$^{a}$ | 53.9$^{a}$ | 50.2$^{a}$ | 52.2$^{a}$ | 49.8$^{a}$ | 52.9$^{a}$ | 38.6$^{b}$ | 43.5$^{ab}$ | 52.6$^{a}$ | 53.4$^{a}$ | 44.4$^{a}$ | 47.9$^{a}$ |

* Abbreviations as in table I. $^{abc}$ as in table III.

most probable reason for the lower ADG of animals receiving a diet with a high straw content (HSM) was the lower NEI. The slight increase in microbial protein synthesis in the rumen of bullocks fed the HSM diet probably did not affect the ADG due to the surplus of dietary protein.

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