The effect of feeding sugar-beet silage and non-protein-N on rumen and blood metabolites in bulls

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1. The purpose of the experiments was to determine certain properties of the metabolism of nitrogen compounds and carbohydrates in the rumen and tissues of growing bulls which were given either a diet containing sugar-beet silage, a urea-mineral preparation and hay or a control diet with maize silage, ground barley and hay. Daily rations were given in two equal portions twice daily at 07·00 hours and 13.00 hours. The experiment lasted 182 d.

2. The experimental diet containing 0·54 g urea and 5·0 g saccharose/kg body-weight did not cause any symptoms of toxicity in the animals although there were large changes in the concentration of metabolites in the forestomach. The lowest pH (6·2–6·4) in the rumen of animals in the experimental group was observed 1·5 h after feeding. At the same time the highest level of lactic acid was observed, but the highest level of volatile fatty acids (VFA) was observed 3 h after feeding. Although there was a large increase in ammonia in the rumen contents (approximately 20 mmol/l at 1·5 h after feeding) an increase in the blood level of ammonia was not observed.

3. A lower level of acetic acid and higher level of butyric acid and valeric acid were observed in the rumen of animals given sugar-beet silage than in animals given maize silage and ground barley. Non-glucogenic ratio of VFA in the rumen of bulls after feeding the experimental diet was approximately 3·5 while on the control diet the value was considerably higher.

4. The causes of the low concentration of glucose in the blood and changes in other metabolites in the blood of experimental animals are discussed.

5. Average daily gains were higher (*P* ⩽ 0·05) in both groups of bulls given a diet containing sugar-beet silage and NPN (1087 and 1043 g/d) than with the control diet (887 g/d). Changes in the concentration of metabolites in the rumen contents and blood of sugar-beet-silage-fed bulls confirmed the possibility of effective addition of urea in an amount corresponding to 50% of the N content and also indicated good utilization of the energy in this diet.

The successful fattening of bulls given urea and sugar beet (Dvořáček & Kosař, 1967; Dvořáček *et al.* 1969; Kosař *et al.* 1970), urea and sugar cane (Creek *et al.* 1976) and urea and molasses (Preston *et al.* 1967; Preston & Willis, 1970; Ranjhan *et al.* 1976) indicates the validity of feeding diets containing a large amount of sucrose and urea. The ability to preserve sugar beet enabled us to conduct the experiments for a longer period without changing the diet.

The main purpose of the present experiment was to investigate rumen metabolism and its influence on tissue metabolism in bulls given sugar-beet silage and a urea-mineral concentrate as the main sources of energy and nitrogen respectively.

EXPERIMENTAL

Animals

Black and White Lowland bulls weighing an average of 231 kg, divided into three groups of five were fed three different diets for 182 d. Group 1 was given sugar-beet silage, urea-mineral concentrate and hay, group 2 was given sugar-beet silage, ground barley, urea-mineral concentrate and hay, group 3 was given maize silage, ground barley urea-mineral concentrate and hay. All diets were equalized with regard to crude protein (nitrogen ×6·25) content

and energy value. Daily rations were given in equal portions at 07.00 and 13.00 hours. Vitamins A, D₃ and E were given periodically. The details of dietary composition are described in Table 1.

Sampling and analytical procedures

In the course of the experiment the rumen content and blood from all bulls were examined four times: after 4, 8, 16 and 24 weeks. Samples of the rumen contents were taken by a stomach tube just before and 1·5, 3·0 and 5·0 h after the morning feeding and 1·5 and 3·0 h after the 13·00 hours feed (afternoon feeding). Simultaneously blood from the jugular vein was collected.

After the pH value was measured, the rumen contents were filtered through four layers of gauze and ammonia was estimated by the modified method of Conway (Kulasek *et al.* 1975), volatile fatty acids (VFA) by steam distillation and L(+)-lactic acid by the Boehringer test. VFA were also separated by gas–liquid chromatography using the method described by Ziołecki & Kwiatkowska (1973). In the blood, ammonia (Okuda *et al.* 1965), glucose (Tomaszewski, 1970) and the haematocrit values were determined while in the plasma urea (Kulasek, 1972), free fatty acids (FFA) (Mosinger, 1963) and transaminases (Tomaszewski, 1970) were determined. Analysis of variance was used for statistical evaluation of the results.

RESULTS

The bulls of groups 1 and 2 ate their diets rapidly. Feed intake in group 3 was lower than in groups 1 and 2 (Table 1). The average daily gains were 1087, 1043 and 887 g in groups 1, 2 and 3 respectively, and as seen were significantly higher ($P < 0·05$) in groups 1 and 2 than in group 3.

The average values of pH and the concentrations of the estimated metabolites in the rumen fluid and the blood are presented in Tables 2 and 3.

The lowest pH was observed in the rumen of bulls in group 1 ($P < 0·05$). Feeding caused a significant decrease in the pH value of the rumen liquid in all groups but the changes were more pronounced in group 1 than in groups 2 and 3.

The concentration of ammonia in the rumen fluid (Table 2) increased sharply and reached a peak value 1·5 h after feeding. The greatest increase (more than 20 mmol/l) in the ammonia level was observed in group 1.

The mean levels of VFA in the rumen fluid did not differ between groups (Table 2). However, the rate in increase of VFA after feeding was different in individual groups. In bulls of group 1 the VFA content after feeding was twice as high as the initial value, while in group 3 the increase was approximately 40 %. The ratio of individual VFA differed significantly: in groups 1 and 2 the concentration of acetic acid was less ($P < 0·01$) than in group 3, while the levels of *n*-butyrate and *n*-valerate were higher ($P < 0·01$; see Table 2).

The sugar-beat silage used in groups 1 and 2 considerably increased L(+)-lactic acid in the rumen of bulls 1·5 h after feeding. This concentration decreased rapidly and 5 h after feeding was the same as in bulls of group 3.

After feeding the ammonia levels in the blood of all bulls did increase slightly, but the changes were not significant. On the contrary, the urea level in the plasma increased up to 3 h after feeding. The average daily concentration of urea in the blood plasma of bulls of group 1 was slightly lower than in other groups; this difference was more pronounced before and 1·5 h after feeding than at any other time.

From the results in Table 3 it can be seen that the average daily concentration of glucose was greater in the blood of bulls in group 3 than in groups 1 and 2 given sugar-beet silage. Feeding caused a significant decrease in blood glucose level in all groups ($P < 0·05$), but

Table 1. *Composition of diets and feed intake*

	Group		
Items	I	2	3
Composition of dry matter (DM) of diets (g/kg DM):			
Sugar-beet silage	535	388	—
Maize silage	—	—	528
Meadow hay	392	395	227
Ground barley	—	152	209
Urea-mineral preparation*	73	65	36
DM content (g/kg of feed)	360	430	310
Crude protein (g/kg DM)	140	144	145
DM intake (kg/d)	7·4	7·3	7·0
Sucrose intake			
(g/d per kg body-weight)	5·0	3·6	—
Calculated digestible protein intake (excluded urea) (g/d)	355	417	530
Urea intake (g/d)	173	152	81
Calculated metabolizable energy (ME) (MJ/d)	83·5	81·6	72·4
ME concentration (MJ/kg DM)	11·3	11·2	10·3

* Composition of urea-mineral preparation (g/kg) urea 320, minerals 260 and ground barley 420.

Table 2. *The mean level of the rumen indices (mmol/l) in steers given diets containing sugar-beet silage and non-protein-nitrogen or maize silage**

(Means from 120 analyses (five animals in each group × six samplings/d × four periods) except for L(+)-lactic acid where values are means from fifteen analyses (five animals in each group × three samplings/d: before morning feeding and 1·5 and 3 h after morning feeding × one period) (first))

	Group			Standard
Index	I	2	3	error
pH	6·82	6·93	6·95	0·02
Ammonia	12·21	9·07	9·79	0·44
Total volatile fatty acids	89	86	89	1·68
Acetic acid	50·03	50·94	59·40	1·10
Propionic acid	17·66	15·91	17·16	0·36
n-Butyric acid	14·51	14·47	9·29	0·52
n-Valeric acid	4·48	4·12	1·72	0·42
L(+)-lactic acid	7·56	6·33	1·78	0·19

* For details of diets, see p. 229 and Table 1.

these changes were more pronounced in bulls given sugar-beet silage than in the control group (group 3).

The concentrations of FFA and transaminases in the blood plasma of bulls did not differ significantly between groups. The haematocrit values were higher ($P < 0.05$) in groups given sugar-beet silage (groups 1 and 2) than in those given maize silage (group 3).

DISCUSSION

The bulls given sugar-beet silage and urea-mineral concentrate had greater body-weight gains than those given maize silage and barley. Animals in group 3 consumed less dry matter (DM), probably because this diet had a lower DM content, metabolizable energy (ME) concentration was lower in DM (Table 1) and the ration was probably less palatable. One could expect body gains of bulls in group 3 to be higher than they were in relation to feed intake. Utilization of consumed energy and nutrients was higher in groups 1 and 2 than

Table 3. *The mean level of blood indices in steers given diets containing sugar-beet silage and non-protein-nitrogen or maize silage**

(Means from 120 analyses (five animals in each group × six sampling/d × four periods) except for: ammonia, where values are means from eighty analyses (five animals in each group × four sampling/d × four periods), free fatty acids, where values are means from twenty-four analyses (four animals in each group × three sampling/d – first, second and four × two periods – third and fourth), transaminases where values are means from eight analyses (two animals in each group × two sampling/d – first and third × three periods – second, third and fourth), haematocrit where values are means from forty analyses (five animals in each group × two sampling/d – first and third × four periods))

	Group			Standard error
Index	1	2	3	
Ammonia (mmol/l blood)	0·099	0·133	0·119	0·006
Urea (mmol/l plasma)	4·70	4·90	5·00	0·17
Glucose (mmol/l blood)	3·28	3·06	3·61	0·08
Free fatty acids (mmol/l plasma)	293	330	341	22·5
AspAT of plasma (u. Reitman)	42	38	46	2·20
AlAT of plasma (u. Reitman)	6	5	4	0·73
Haematocrit	0·33	0·32	0·30	0·005

AspAT, asparagin aminotransferase; AlAT, alanin aminotransferase.
* For details of diets, see p. 229 and Table 1.

in group 3. Utilization of ME and digestible protein (DP)/kg body-weight gains were 77, 78 and MJ of ME and 693, 735 and 807 g of DP respectively in groups 1, 2 and 3. In the experiment of Vérité (1975), dairy cows given sugar beet also better utilized ME than those given maize silage. Based on the ARC scheme (Roy *et al.* 1977) calculated that deficiencies in rumen degradable protein (RDP) could be supplemented by 160, 131 and 61 g of urea/d respectively in groups 1, 2 and 3, and these quantities were similar to those consumed by animals (Table 1). This calculation indicates that in all groups of animals conditions should be favourable for body gains over 1 kg/d. Changes in the rumen and blood indices of bulls in groups 1 and 2 must be considered in relation to their greater body-weight gains as compared to bulls of group 3.

It is worth mentioning that the daily intake of sucrose was approximately 5·0 g/kg body-weight (BW) and urea 0·52 g/kg BW in bulls of group 1. Corresponding values for group 2 were: sucrose 3·6 g/kg BW and urea 0·44 g/kg BW. The quantity of sucrose or its fermentation products in sugar-beet silage could produce acidosis in the ruminant (Krohg, 1959) but no syndromes of such an illness were observed. According to Helmer & Bartley (1971) 0·3–0·5 g urea/kg BW could cause ammonia toxicity. In our experiment the amount of urea in the daily rations exceeded the toxic doses but no signs of toxicity were observed. Clinical examination and laboratory estimation of transaminases, blood ammonia level and haematocrit value (Table 3) indicated that all animals were healthy. It can therefore be assumed that a diet containing a large amount of both sucrose and urea or other kind of readily RDP prevents the adverse effects of either compound.

It should be emphasized that in some instances the pH value of the rumen contents of bulls given sugar-beet silage decreased to 5·0. This value could be considered as a sign of acidosis (Dirksen, 1969). Since no toxicity in animals could be observed and the low pH value quickly returned to normal (approximately 6·5), it was suggested that the sharp changes of pH shortly after administration of sugar-beet silage were related to the rumen concentration of lactic acid which was readily buffered and metabolized.

The amount of VFA in the rumen of bulls given sugar beet silage and the urea-mineral concentrate was lower before feeding and increased rapidly 1·5–3·0 h after feeding as

compared to the group given maize silage (group 3). Lactic acid appeared temporarily in large amounts in the rumen after administration of sugar-beet silage. The concentrations of *n*-butyrate abd *n*-valerate in the rumen fluid of bulls in groups 1 and 2 were much higher than in group 3. In contrast, sugar-beet silage caused a significant decrease in the proportion of acetic acid. Such variations in individual VFA are characteristic for the fermentation of mono- and disaccharides and were observed by Orth & Kaufmann (1961), Kellogg & Owen (1969), Kowalczyk (1971), Vérité (1975), Abdel-Rahman & Pfeffer (1977). The production of VFA in the rumen is accompanied by the release of available energy (ATP) used for microbial protein synthesis. On the other hand, VFA supplied anabolic processes in the body. According to Ørskov (1975), the efficiency of utilization of the metabolic energy of VFA absorbed from the forestomach of ruminants depends on the proportion of VFA expressed by the value called the non-glucogenic ratio (NGR). The efficiency of utilization of metabolic energy by cattle is the greatest at a value for NGR of 2·25–3·00 (Ørskov, 1975). In our experiment the NGR value for all groups exceeded 3·0 but at the time of the most intensive fermentative processes in the rumen the NGR was closest to the optimum in group 1 which showed rapid growth.

Satter & Slyter (1972) suggested that 3·5 mmol ammonia/l in the rumen is the optimal value for protein synthesis, but according to other authors this level should be higher (Lampila, 1966; Ørskov *et al.* 1971). In our experiment a high concentration of ammonia in the rumen of bulls given urea-mineral concentrate provided a source of N for protein synthesis synchronized with VFA production. Synchronization of energy and nitrogen metabolism in the rumen improved the efficiency of microbial synthesis (Johnson, 1976; McMeniman *et al.* 1976).

Although rumen VFA increased considerably in groups given sugar-beet silage, the concentration of glucose in the blood of bulls in groups 1 and 2 was lower than in group 3. This seems to suggest that in instances of large amounts of readily-digested carbohydrates and urea (e.g. sugar-beet silage and urea in the diet), the effect of these compounds on glucose metabolism in the tissues may involve hormonal mediation (Bassett, 1975; Barej & Harmeyer, unpublished results). It should also be brought to mind that the carbohydrates of maize are not fully fermented in the rumen and a substantial proportion could be digested in the intestine and absorbed in the form of glucose (Ørskov *et al.* 1969).

REFERENCES

Abdel-Rahman, K. & Pfeffer, E. (1977). *Z. Tierphysiol, Tierernährg. Futtemittelkde* **39**, 204.
Bassett, J. M. (1975). In *Digestion and Metabolism in the Ruminant*, p. 383 [I. W. McDonald and A. C. I. Warner, editors]. Armidale: The University of New England Publishing Unit.
Creek, M. J., Squire, H. A. & Mulder, J. (1976). *Wld Rev. Anim. Prod.* **12**, 35.
Dirksen, G. (1969). In *Physiology of Digestion and Metabolism in the Ruminant*, p. 612 [A. T. Phillipson, editor]. Newcastle upon Tyne: Oriel Press.
Dvořáček, M. & Kosař, J. (1967). *Živočišna Výroba* **12**, 767.
Dvořáček, M., Kosař, J. & Rohliček, J. (1969). *Živočišna Výroba* **14**, 715.
Helmer, L. G. & Bartley, E. E. (1971). *J. Dairy Sci.* **54**, 25.
Johnson, R. R. (1976). *J. Anim. Sci.* **43**, 184.
Kellogg, D. W. & Owen, F. G. (1969). *J. Dairy Sci.* **52**, 657.
Kosař, J., Dvořáček, M. & Rohliček, J. (1970). *Živočišna Výroba* **15**, 25.
Kowalczyk, J. (1971). Nitrogen and carbohydrate metabolism in the rumen and abomasum in bulls fed molasses and urea. PhD Thesis, Jablonna: Institute of Physiology and Nutrition of Animals, Poland.
Krogh, N. (1959). *Acta vet. scand.* **1**, 74.
Kulasek, G. (1972). *Pol. Arch. Wet.* **15**, 4.
Kulasek, G., Leontowicz, H. & Krasicka, B. (1975). *Roczn. Nauk Roln.* **96B**, 67.
Lampila, M. (1966). *Karjatalous* **42**, 114.
McMeniman, N. P., Ben-Ghedalia, D. & Armstrong, D. G. (1976). In *Protein Metabolism and Nutrition*, p. 217 [D. I. A. Cole, K. N. Borman, P. J. Buttery, D. Lewis, R. J. Neale & H. Swan, editors]. London: Butterworths.

Mosinger, F. (1963). *J. Lipid Res.* **6**, 1.

Okuda, H., Fujii, S. & Kawashima, Y. (1965). *J. exp. Med.* **12**, 11.

Ørskov, E. R. (1975). *Wld Rev. Nutr. Diet.* **22**, 152.

Ørskov, E. R., Fraser, C. & Kay, R. N. B. (1969). *Br. J. Nutr.* **23**, 217.

Ørskov, E. R., Fraser, C. & McDonald, I. (1971). *Br. J. Nutr.* **26**, 477.

Orth, A. & Kaufmann, W. (1961). *Die Verdaung im Pansen und ihre Bedeutung fur die Futterung der Wieder-kauer.* Hamburg u. Berlin: Paul Parey.

Preston, T. R., Elias, A., Willis, M. B. & Sutherland, T. M. (1967). *Science, N.Y.* **216**, 721.

Preston, T. R. & Willis, M. B. (1970). *Intensive Beef Production.* Oxford: Pergamon Press.

Ranjhan, S. K., Krishna Mohan, D. V. G. & Pathak, N. N. (1976). *Tracer Studies on Non-Protein Nitrogen for Ruminant. vol. 3. Proc. Res. Coordination Meeting Alexandria*, 1976, p. 97. Vienna: International Atomic Energy Agency

Roy, J. H. B., Balch, C. C., Miller, E. L., Ørskov, E. R. & Smith, R. H. (1977). *Proc. of the Second International Symp. on Protein Metabolism and Nutrition.* Flevohof, The Netherlands, 1977, p. 126. Wageningen: Centre for Agricultural Publishing and Documentation.

Satter, L. P. & Slyter, L. L. (1972). *J. Anim. Sci.* **35**, 273.

Tomaszewski, L. (1970). *Biochemical Micromethods in Clinical Laboratory.* Warszawa: PZWL (Pol).

Vérité, R. (1975). *Ann. Zootech.* **24**, 373.

Ziołecki, A. & Kwiatkowska, E. (1973). *J. Chromatog.* **80**, 250.