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The influence of the method of preservation of forages on the digestion in dairy cows. 2. Digestion of organic matter, energy and amino acids in forestomachs and intestines

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Summary

Two re-entrant cannulated dairy cows were given rations containing artificially dried and pelleted grass (GP), grass silage treated with formic acid (GSF), grass silage treated with a mixture of formic acid and formaldehyde (GSFF) and grass silage without additive (GS). Dry matter intake ranged from 14.8 to 16.0 kg per day and about 30 % of the nitrogen in the rations originated from grass pellets or silages. Between 45 and 57 % of the apparently digested organic matter and between 26 and 41 % of the apparently digested energy disappeared before the intestines. The higher values were found after feeding the rations GSF and GS.

Total amino acid N reaching the duodenum was between 104 and 134 % of the intake, with highest values after feeding ration GP and ration GSFF. The amount of individual amino acids reaching the small intestine ranged from 75 to 270 % of the amounts ingested. High values (> 150 %) were found for glycine, lysine, methionine and tyrosine; low values (< 100 %) were found for arginine, glutamic acid and proline. The amount of amino acids containing sulphur reaching the intestine was between 123 and 159 % of the intake, with lowest values for the ration GS.

Total N disappearing from the intestines was 66.1 ± 0.50 % of the amount entering the small intestine and 76.8 ± 2.22 % of the amount ingested. For amino acid N these values were 73.2 ± 0.91 % and 91.6 ± 2.01 %, respectively. Between 71 and 107 % of the ingested amount of sulphur-containing amino acids disappeared from the intestines, with the lowest values after feeding ration GS. The different digestion of the rations GP and GSFF, compared with the rations GSF and GS, was ascribed to an increased flow due to the reduced particle size and protein protection by heat treatment for ration GP, and due to protein protection by formaldehyde treatment for ration GSFF.

The possibilities of further research with high-yielding dairy cows and the use of computer modelling techniques in this area are discussed.

Introduction

It is assumed that in the forestomachs of ruminants food protein is broken down to a certain extent, due to the action of the ruminal microbial population. Often this leads to a loss of protein nitrogen from the diet, without contributing to the amino acid supply of the host-animal. In recent years, however, methods have been developed to protect food protein against microbial breakdown in the rumen. Some of these methods are based on influencing physiological mechanisms, like increasing the flow through the stomachs by reducing the particle size of the ration (Balch, 1961), or by-passing the rumen due to stimulation of the oesophageal groove reflex (Ørskov & Frazer, 1969; Ørskov, 1972). Other methods are based on reducing the protein solubility by heat treatment (Chalmers et al., 1954; Tagari et al., 1962), or by treatment with chemical agents such as formaldehyde (Ferguson et al., 1967) or tannins (Zelter & Leroy, 1966; Zelter et al., 1970).

Artificial drying and pelleting of green forage is suggested to reduce the microbial protein breakdown in the rumen (Beever et al., 1969; Coelho da Silva et al., Thomson, Beever and Armstrong, 1972a, 1972b; Thomson, 1972; Harrison et al., 1973; Armstrong, 1973; Hartmann, 1973). In addition, it was shown that casein can be protected against microbial breakdown in the rumen by treatment with formaldehyde in sheep (Ferguson et al., 1967; Offer et al., 1971; Faichney & Weston, 1971; McRae et al., 1972) and in dairy cows (Hagemeister & Pfeffer, 1973). In sheep it appeared also possible to protect forage protein against microbial protein breakdown in the rumen by treatment with formaldehyde (Hemsley et al., 1970).

These results suggested that treatment of the roughage part of the ration of dairy cows might provide some protection against microbial protein breakdown in the forestomachs. Since comparable research with dairy cows is very limited, it was decided to study the influence of heat treatment and reducing the particle size and of treatment with some chemical agents as a way of preserving grass, on the digestion in the dairy cow. Therefore, experiments were carried out in which rations containing artificially dried and pelleted grass (ration GP), grass silage treated with formic acid (ration GSF), grass silage treated with a mixture of formic acid and formaldehyde (ration GSFF), and grass silage without additive (ration GS) were given to re-entrant cannulated dairy cows. The digestion of compounds containing energy and nitrogen in forestomachs and intestines was studied; this paper deals with the results.

Materials and methods

Experimental animals and rations

Four experiments were conducted with two lactating Friesian cows (cows 93 and 94) fitted with a rumen fistula and a re-entrant cannula at the proximal part of the duodenum, just beyond the pancreatic and biliary duct. Surgery was performed within one week after parturition, and the first experiment started after eight weeks. Milk production decreased from 22.0 (cow 93) and 19.3 (cow 94) kg/day to 19.7

and 16.3 kg/day, respectively, and live-weight increased from 520 kg (cow 93) and 560 kg (cow 94) to 535 and 579 kg, respectively, over a period of 20 weeks.

The animals were given rations containing long meadow hay, grass pellets or grass silage, and concentrates. Grass pellets and silages accounted for between 27 and 34 % of the crude protein (CP) in the ration. For more details about the rations see Tamminga & van der Koelen (1975).

Experimental procedure

Each experimental period lasted 5 weeks and consisted of a transition and adaptation period of 30 days and a collection period of 5 days. Twice daily the cows were given equal amounts of feed, at 07h30 and 16h00. Sequence of feeding was long meadow hay (1), concentrates (2) and silage or grass pellets (3).

From at least 10 days before the start to the end of each collection period, 25 g of paper impregnated with chromic oxide was administered twice daily by the rumen fistula.

In the collection period the duodenal flow was measured continuously for 96 hours. During the same time faeces were collected, weighed and sampled daily. Faecal samples were preserved with formalin and stored at 4 °C, and bulked samples were made for each animal.

Collecting and sampling the duodenal digesta

Duodenal content flowed from the proximal part of the re-entrant cannula into a receiving barrel with a capacity of about 10 litres. From this barrel amounts of about 4.5 kg were weighed and a proportional sample of 1.65 % was taken by means of a sampling bucket. The remainder was poured into another barrel from where it was pumped upwards by a peristaltic pump to a funnel which was connected with the distal part of the cannula. For a detailed description of the measuring and sampling procedure and the equipment used, see Tamminga et al. (1973). In this way a proportional sample of the duodenal digesta flowing through the cannula was collected each day. The samples were preserved with toluene and stored at 4 °C. After terminating the 96-hour collection, composite samples were made from the daily samples for each animal.

Laboratory analysis

Silages, hay, grass pellets and concentrates were dried at 60 °C for 24 hours and milled. The air-dry samples were analysed for dry matter (DM), ash, energy, and nitrogen content. Corrections were made for losses of organic acids and ammonia from the silages during drying. Wet samples of faeces were analysed for dry matter (DM) and nitrogen content, and the air-dry faecal samples for DM, ash, energy and chromic oxide content. Composite and daily samples of duodenal content were analysed for DM content by drying at 103 °C to a constant weight. Parts of these samples were freeze-dried. Freeze-dried daily samples were analysed for DM and chromic oxide content, and freeze-dried composite samples were analysed for DM, ash, energy, nitrogen and chromic oxide content. Chromic oxide analyses were done according to the method of Williams et al. (1962).

Amino acid analyses were performed in fresh samples of faeces and silages, in air dry samples of grass pellets, hay and concentrates and in freeze-dried samples of duodenal content. The amino acid compositions were determined by column chromatography on a Carlo Erba amino acid analyser (two-column system).

Results

The digestion of dry matter, organic matter and energy in stomachs and intestines
The duodenal flow and the quantity of faeces produced were corrected for a 100 % recovery of chromic oxide. The mean daily recoveries of chromic oxide in the duodenal flow increased from 83 % during the first day up to 99 % during the fourth day of the collection periods. Recoveries for the entire collection period ranged from 83 to 102 % with a mean recovery in all experimental periods of 93.3 ± 3.57 %. The corrected values were used in all calculations.

The measured daily duodenal flow ranged between 177 and 331 kg per day, with a dry matter content ranging from 3.43 to 4.33 %. Correction of the flow for 100 % recovery of Cr_2O_3 reduced the variation substantially and the corrected daily duodenal flow was calculated to range between 255 and 374 kg per day.

Table 1 shows the mean digestion of DM, organic matter (OM) and energy in stomachs and intestines, after feeding the different rations. Although the results showed a considerable variation between animals, both cows showed the same tendency in digestion of the different rations. When artificially dried and pelleted grass or a silage treated with a mixture of formic acid and formaldehyde are in-

Table 1. Mean intake and digestion of dry matter (DM), organic matter (OM) and energy after feeding two dairy cows rations containing artificially dried and pelleted grass (ration GP), grass silage treated with formic acid (ration GSF), grass silage treated with a mixture of formic acid and formaldehyde (ration GSFF) or grass silage without additive (ration GS).

	Ration GP	Ration GSF	Ration GSFF	Ration GS
Intake				
DM (kg/day)	15.2	15.1	15.7	14.8
OM (kg/day)	13.8	13.7	14.3	13.5
Energy (Mcal/day)	64.3	63.8	68.1	63.1
Apparently digested				
DM (% of intake)	67.5	68.6	69.2	70.7
OM (% of intake)	69.8	71.2	72.1	73.1
Energy (% of intake)	63.7	65.0	66.4	66.8
Disappeared from the stomachs				
DM (% of app. digested)	32.4	38.6	34.2	40.8
OM (% of app. digested)	46.5	52.7	49.6	54.4
Energy (% of app. digested)	28.2	35.1	31.7	37.8

Table 2. Mean intake, duodenal flow and apparent absorption of total N (TN), amino acid N (AAN), essential amino acid N (EAAN), nonessential amino acid N (NEAAN) and sulphur-containing amino acid N (SAAN) after feeding rations containing artificially dried and pelleted grass (ration GP), grass silage treated with formic acid (ration GSF), grass silage treated with a mixture of formic acid and formaldehyde (ration GSFF) and grass silage without additive (ration GS), to two dairy cows.

		Ration GP	Ration GSF	Ration GSFF	Ration GS
Intake (g/day)	TN	397	372	402	370
	AAN	266	267	266	240
	EAAN	130	132	134	119
	NEAAN	137	130	132	121
	SAAN	7.2	7.2	7.2	6.9
Duodenal content (% of intake)	TN	116	112	125	114
	AAN	128	114	130	120
	EAAN	131	110	125	113
	NEAAN	125	117	135	126
	SAAN	150	138	151	128
Apparently absorbed from the intestines (% of duodenal flow)	TN	66	65	67	66
	AAN	77	73	69	72
	EAAN	77	72	68	70
	NEAAN	76	74	70	74
	SAAN	66	64	62	60
Apparently absorbed from the intestines (% of intake)	TN	76	74	84	76
	AAN	98	82	90	86
	EAAN	100	79	86	78
	NEAAN	96	86	94	94
	SAAN	96	88	95	76
Apparently digested (% of intake)	TN	60	61	58	62

cluded in the ration, the digestion of organic matter and energy seems to move from the stomachs towards the intestines.

The fate of amino acids in stomachs and intestines

In Table 2 a survey is given of mean total nitrogen (TN), amino acid N (AAN), essential amino acid N (EAAN), non-essential amino acid N (NEAAN) and sulphur-containing amino acid N (SAAN) in intake and duodenal flow. In the same table the mean quantities that disappeared from the intestines are given as a percentage of the quantity entering the duodenum and as a percentage of the intake. From these results it is concluded that amino acid N is absorbed from the intestine to a larger extent than non amino acid N.

Table 3 shows the intake of the individual amino acids and only minor differences were found between the different rations. The amounts of individual amino

Table 3. The mean intake of total amino acid N (AAN) (g/day) and the mean amino acid composition of the intake (individual amino acid N as a percentage of total amino acid N), after feeding rations containing artificially dried and pelleted grass (ration GP), grass silage treated with formic acid (ration GSF), grass silage treated with a mixture of formic acid and formaldehyde (ration GSFF) and grass silage without additive (ration GS) to 2 dairy cows.

	Ration GP	Ration GSF	Ration GSFF	Ration GS
AAN intake (g/day)	266	267	266	240
Lysine	6.7	7.4	7.1	7.0
Histidine	4.2	4.7	4.4	4.3
Arginine	14.2	14.6	14.8	14.0
Threonine	3.8	3.8	3.9	3.5
Valine	5.4	5.1	5.3	5.4
Methionine	1.2	1.3	1.2	1.3
Isoleucine	3.4	3.5	3.5	3.6
Leucine	6.8	6.8	6.9	7.1
Phenylalanine	3.0	3.3	3.3	3.4
Essential AAN (% of total AAN)	*48.6*	*50.4*	*50.4*	*49.6*
Aspartic acid	8.6	7.6	8.2	7.3
Serine	5.0	5.0	5.0	4.8
Glutamic acid	13.2	12.2	12.2	12.3
Proline	6.4	6.2	6.1	6.2
Glycine	7.6	7.6	7.4	7.8
Alanine	7.4	8.0	7.7	8.8
Tyrosine	1.6	1.8	1.6	1.7
Cystine + cysteïne	1.6	1.4	1.4	1.5
Non-essential AAN (% of total AAN)	*51.4*	*49.6*	*49.6*	*50.4*

acid N entering the duodenum were compared with the intakes, and the results are given in Table 4. For all rations a substantial increase was found for lysine, threonine, methionine, glycine and tyrosine. Smaller increases were found for valine, isoleucine, leucine, phenylalanine, aspartic acid, serine, alanine and cystine + cysteïne. Arginine and histidine remained about the same and decreases were found for glutamic acid and proline. Only sometimes could these differences be ascribed to the ration. Higher increases in quantities of lysine, histidine and arginine were found after feeding the ration containing grass pellets. The amount of methionine seems to be less increased after feeding the ration containing grass silage without additive.

The mean apparent absorptions of the individual amino acids from the intestines are shown in Tables 5 and 6. Table 5 shows the mean apparent absorptions as a percentage of the amount present at the beginning of the small intestine, which were calculated as follows:

apparent absorption = 100 (duodenal AAN – faecal AAN)/duodenal AAN.

Only minor differences were found between the different rations. Sometimes no tyrosine could be detected in the faecal samples, so that apparent absorption was

Table 4. The mean amount of amino acid N, flowing through the duodenum of two dairy cows, given as a percentage of the amount ingested, after feeding rations containing artificially dried and pelleted grass (ration GP), grass silage treated with formic acid (rations GSF), grass silage treated with a mixture of formic acid and formaldehyde (ration GSFF), and grass silage without additive (ration GS).

	Ration GP	Ration GSF	Ration GSFF	Ration GS
Lysine	188	152	176	158
Histidine	121	92	112	102
Arginine	104	84	96	90
Threonine	138	125	148	146
Valine	125	116	123	115
Methionine	191	168	183	140
Isoleucine	128	114	138	114
Leucine	132	109	116	101
Phenylalanine	124	104	116	101
Aspartic acid	118	119	131	136
Serine	122	107	123	116
Glutamic acid	86	82	96	88
Proline	81	74	85	78
Glycine	226	216	257	242
Alanine	128	105	121	100
Tyrosine	290	157	192	177
Cystine + cysteïne	218	108	124	114

100 %. The apparent absorption of the amino acids from the intestines, after feeding silage treated with a mixture of formic acid and formaldehyde, showed a tendency of being slightly reduced. Differences in the apparent absorption were higher for some individual amino acids. Basic amino acids seem to be absorbed slightly better than the remaining essential amino acids. Of the non-essential amino acids glycine and tyrosine showed the highest apparent absorption. Relatively low apparent absorptions were found for the sulphur-containing amino acids and alanine.

In Table 6, a comparison is made between the mean amount of individual amino acids apparently absorbed from the intestines and the amounts ingested, which were calculated as follows:

$$\text{absorption} = 100\ (\text{duodenal AAN} - \text{faecal AAN})/\text{ingested AAN}.$$

The results show striking differences between the individual amino acids. The differences between the different rations are less pronounced, partly due to the large variation between cows given the same rations. Compared with the other rations, the amounts of sulphur-containing amino acids, after feeding the ration containing silage without additive, were absorbed in smaller quantities.

Table 5. The apparent absorption of amino acids from the intestines of two dairy cows (expressed as a percentage of the amount entering the duodenum), fed with rations containing artificially dried and pelleted grass (ration GP), grass silage treated with formic acid (ration GSF), grass silage treated with a mixture of formic acid and formaldehyde (ration GSFF), and grass silage without additive.

	Ration GP	Ration GSF	Ration GSFF	Ration GS	Mean
Lysine	80	75	72	72	74.7 ± 1.41
Histidine	82	80	76	74	77.7 ± 1.59
Arginine	81	74	75	72	75.6 ± 1.24
Threonine	71	66	64	67	67.0 ± 1.22
Valine	73	68	61	67	67.3 ± 1.81
Methionine	68	66	63	62	64.7 ± 1.55
Isoleucine	72	67	64	68	67.3 ± 1.33
Leucine	76	71	67	68	70.2 + 1.61
Phenylalanine	70	69	63	68	67.5 ± 1.17
Aspartic acid	74	68	64	70	69.1 ± 1.19
Serine	76	72	68	70	71.2 ± 1.33
Glutamic acid	74	69	65	70	69.5 ± 1.17
Proline	71	70	68	71	69.8 ± 0.77
Glycine	84	82	80	84	82.7 ± 0.67
Alanine	70	66	58	64	64.2 ± 1.67
Tyrosine	93	94	79	98	90.9 ± 3.21
Cystine + cysteïne	64	62	62	56	61.2 ± 1.47

Discussion

Digestion of organic matter and energy in stomachs and intestines

In the experiments reported here the portion of the apparently digested organic matter and energy disappearing before the intestine is low compared with most of the results in cows (van 't Klooster & Rogers, 1969; Pfeffer et al., 1972; Watson et al., 1972; Tamminga, 1973). So far results were obtained in cows with a daily intake of between 6 and 10 kg DM, which is considered to be a low or a medium level of intake for the dairy cow. In the experiments reported here DM intakes ranged between 14 and 16 kg/day. Increases in the feeding level may increase the flow of digesta through the stomachs (Balch, 1961), and thereby reduce the portion of the digestion of OM in this part of the digestive tract. Moreover about half of the DM in all rations consisted of ground and pelleted concentrates. Changes in the physical form of forage diets, by reducing the particle size, resulted in sheep in a shift of the digestion of OM and energy from the stomachs towards the intestines (Thomson, 1972). Reduction of the portion of roughage in the ration of dairy cows, provided with rations consisting of roughage and concentrates, had the same effect (Kaufmann & Hagemeister, 1973).

Compared with the other rations, the portion of the organic matter and the energy disappearing before the intestines is reduced after feeding a ration con-

Table 6. The mean apparent absorption of amino acids from the intestines of two dairy cows (expressed as a percentage of the intake), fed with rations containing artificially dried and pelleted grass (ration GP), grass silage treated with formic acid (ration GSF), grass silage treated with a mixture of formic acid and formaldehyde (ration GSFF), and grass silage without additive.

	Ration GP	Ration GSF	Ration GSFF	Ration GS
Lysine	150	116	126	114
Histidine	99	74	184	76
Arginine	84	62	72	64
Threonine	98	82	94	98
Valine	91	80	75	76
Methionine	130	110	116	88
Isoleucine	92	77	89	76
Leucine	100	73	77	68
Phenylalanine	88	72	73	68
Aspartic acid	86	82	85	95
Serine	93	77	83	80
Glutamic acid	64	57	62	62
Proline	58	52	58	56
Glycine	190	184	206	204
Alanine	88	68	70	64
Tyrosine	175	147	152	173
Cystine + cysteïne	76	68	77	64

taining artificially dried and pelleted grass (Table 1). In this ration the portion of long roughage was further reduced by replacing silage with artificially dried and pelleted grass. These results are in agreement with the results of other research workers as is discussed above. Feeding a ration containing grass silage treated with a mixture of formic acid and formaldehyde also seems to reduce the OM digestion in the stomachs compared with the other rations containing silage. This decrease is thought to be the result of the protein-protecting properties of formaldehyde. The same was found in dairy cows after feeding formaldehyde-treated casein (Hagemeister & Pfeffer, 1973).

If it is assumed that the OM disappearing from the forestomachs consists entirely of carbohydrates, the percentages of energy expected to disappear from the forestomachs can be calculated. It appeared, however, that only 60.4 ± 1.80 % of these calculated values were in fact disappearing between the intake and the re-entrant cannula. This difference can at least partly be explained by the input of endogenous energy containing substances in digestive enzymes and bile, which have a higher energy content than carbohydrates. However, the possible contribution of the microbial fermentation in the forestomachs should not be overlooked. Due to the microbial fermentation in the forestomachs of the ruminant, carbohydrates and amino acids are broken down into volatile fatty acids, methane, carbon dioxide, water and heat. Volatile fatty acids are absorbed, mainly from the stomachs and due to the disappearance of carbohydrates, the remaining organic matter contains higher percentages of protein and lipids. The energy content of protein and of lipids exceeds the energy content of carbohydrates, and this partly explains the difference between the energy content of the OM in the ration and the OM in duodenal digesta. The anaerobic fermentation in the rumen means the generation of a limited amount of energy as adenosine triphosphate (ATP), which subsequently can be used in microbial synthesis. Due to the absence of oxidative phosphorylation in anaerobic micro-organisms the anaerobic generation of ATP is coupled with the formation of 'metabolic hydrogen', such as reduced co-factors and phosphoroclastic hydrogen. Several possibilities have been suggested for the way the micro-organisms in the rumen get rid of their surplus of 'metabolic hydrogen', like reducing carbon dioxide to methane, biohydrogenation of unsaturated long-chain fatty acids (Dawson & Kemp, 1970), changing the fermentation pattern towards propionic acid (Demeyer et al., 1972; Czerkawski, 1973a), synthesis of palmitate from acetate (Czerkawski, 1973a) and probably the formation of water from oxygen and hydrogen (Czerkawski, 1972). It has been suggested that phosphoroclastic hydrogen is used te reduce carbon dioxide to methane (Demeyer et al., 1970; Wolfe, 1971).

Reduced co-factors, however, are suggested to be used at least partly in the microbial synthesizing processes (Demeyer et al., 1972). Synthesis of microbial material from carbohydrates means a net uptake of hydrogen (Demeyer et al., 1972), since proteins as well as lipids are CHO-containing organic compounds which are more reduced than carbohydrates. It is suggested therefore that, as a result of the microbial action in the rumen, a net synthesis of protein and lipids takes place, also causing an increased energy content of the OM in duodenal digesta, compared with the energy content of the OM in the ration.

Amino acid supply in the intestines

In sheep given artificially dried and chopped forages, the amount of non-ammonia nitrogen (NAN) reaching the duodenum was calculated to exceed the nitrogen intake, if the ingested nitrogen was less than 4 % of the apparently digested organic matter (DOM) (Hogan & Weston, 1970). This was also found to be true in dairy cows, given different rations with a varying nitrogen content (van 't Klooster & Boekholt, 1972). The amounts of nitrogen ingested with the rations of the experiments reported here, ranged from 3.7 to 4.2 % of the DOM; so sometimes the amount of NAN reaching the small intestine was expected to be less than the amount of nitrogen ingested. However, the amount of NAN reaching the duodenum always ranged between 100 and 123 % of it the nitrogen intake. Most divergence was found after feeding the rations containing grass pellets and grass silage treated with a mixture of formic acid and formaldehyde. In sheep it was also found that after feeding processed rations the amount of NAN entering the duodenum was larger than was expected from the nitrogen content and the amount of DOM in the ration (Coelho da Silva et al., 1972a, 1972b). It is suggested, therefore, that the relationship mentioned before may be influenced by grinding, pelleting or treating the ration with the chemical agents.

Apparent absorption of amino acids from the intestines

The findings in sheep showing a larger apparent absorption of essential amino acids from the small intestine compared with non-essential amino acids (Coelho da Silva et al., 1972a, 1972b), which was also found in cows (van 't Klooster & Boekholt, 1972), do not seem to be valid for the entire intestine in dairy cows, as can be seen from the results in Table 2.

Earlier results, indicating that the percentage of amino acids entering the small intestine of cows that is apparently absorbed ranges between narrow limits (van 't Klooster & Boekholt, 1972; Hagemeister & Pfeffer, 1973), were confirmed in our experiments. The results agreed fairly well with the findings of Hagemeister & Pfeffer (1973). In sheep about the same percentage was found to disappear from the small intestine only (Coelho da Silva et al., 1972a; 1972b; Harrison et al., 1973), and an additional disappearance of 5-15 % from the large intestine was shown (Coelho da Silva et al., 1972a; 1972b). Results on the disappearance of amino acid N from the large intestine of dairy cows are not available yet, but nitrogen losses of between 5 and 10 % of the nitrogen intake have been reported (van 't Klooster & Rogers, 1969). If it is assumed that the losses of amino acid N from the large intestine of dairy cows do not differ much from the losses found in sheep, the apparent absorption of amino acids from the small intestine of dairy cows is about 10 % less than the apparent absorption of amino acids from the small intestine of sheep. This difference has probably to be ascribed to the difference in relative length of the small intestine. In small ruminants like sheep and goats, the length of the small intestine is about 22 times the body length, in larger ruminants about 16 times (Hill, 1970).

The slightly reduced apparent absorption of amino acids from the intestines after feeding formaldehyde-treated silage (ration GSFF), is in agreement with the findings in cows given formaldehyde-treated casein (Hagemeister & Pfeffer, 1973) and also with the reduced apparently digested nitrogen found in sheep several times after feeding formaldehyde-treated protein (Coetzee, 1971; Faichney, 1971; Nishimuta et al., 1973).

Special attention has been paid to the supply of sulphur-containing amino acids from fresh and conserved forages. The suggestion that the supply of sulphur-containing amino acids in ruminants may be deficient after feeding grass products which are not conserved in the right way (Armstrong, 1973), seems to be confirmed by the results reported here, as is shown in Table 2.

Possibilities of digestion studies in high yielding dairy cows

During the last decades many experimental results about the influence of rumen fermention on the digestive processes in the ruminant have become available. The research about this subject in the high-yielding dairy cow, however, is very limited. From a nutritional point of view, however, research about sites of digestion and the influence of rumen fermentation on digestive processes in the high-yielding dairy cow are urgently needed. One of the possibilities of increasing the productivity in animal husbandry is stimulating the production per animal. Milk yields of 6000 kg and more are therefore expected to be normal in the future. These levels of production can only be achieved if a balanced ration is supplied, with a high level of intake, and if concentrates based on grains, grain by-products and vegetable proteins are fed. Grains as well as protein are expected to become scarce in the future, due to the increasing demand for human consumption. So, more attention will have to be paid to the efficiency with which the food is used, and that needs a better understanding of the digestive processes in stomachs and intestines in high-yielding cows.

Unfortunately, it is far from easy to perform complicated nutritional experiments in such animals for various reasons. In this type of research the experimental animals usually have to be prepared surgically which often reduces their high production. Maintaining a high production is only possible if mixed rations of roughage and (rather high amounts) of concentrates are provided. This limits the possible differences between the different experimental rations and also the possible influence on ruminal fermentation. The variation between animals appears to be considerable, so that the results could be easily misunderstood. Because of the substantial amount of labour involved in this type of research, the number of experiments and the number of animals in each experiment has to be limited. For these reasons experimental results about the digestive processes in high-yielding dairy cows are expected to remain rather rare, and progress in this field will be made slowly.

To gain a better understanding of the digestive processes in these animals, simulation techniques may be very helpful in estimating the influence of alterations of the various physiological mechanisms and biochemical pathways within the digestive tract on the digestive processes. One should realize, however, that in doing so, the accuracy and reliability of the results of simulation techniques depend on the accuracy of the data used in the computer programme. Therefore, the results will always have to be controlled by physiological and nutritional experiments.

Attempts were made to simulate the ruminal fermentation processes (Baldwin et al., 1970) and to simulate the rate of passage of digesta in sheep (Grovum & Phillips, 1973). A more predicting model of ruminal fermentation was suggested by Czerkawski (1973). In the same area it is possible to make forecasts about protein digestion and amino acid supply in the dairy cow. Recently, attempts to do so have been made (Kaufmann & Hagemeister, 1973; Van Es & Boekholt, 1974). It was concluded from their results that more research is needed about the influence of various biochemical transactions and physiological mechanisms in the ruminant on its digestive processes, such as the influence of the physical form of the ration and the level of feeding on the rate of passage of digesta and the rate and proportion of ruminal fermentation, the efficiency of microbial protein synthesis in the rumen and the extent of ruminal breakdown of food protein in the fore-stomachs.

With a better understanding of these problems it should be possible to improve the simulation in order to trace the most important parameters determining the digestive processes in the high-yielding dairy cow and to concentrate research on those particular topics.

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