Neth. J. agric. Sci. 23 (1975): 3-9

The influence of the method of preservation of forages on the digestion in dairy cows. 1. Composition of the forages and digestibility of dry matter, organic matter and nitrogen

S. Tamminga and C. J. van der Koelen

Institute for Livestock Feeding and Nutrition Research 'Hoorn', Hoorn, the Netherlands

Accepted: 20 August 1974

Summary

Grass silages with formic acid, with a mixture of formic acid and formaldehyde, and without additive were made from the same sward. Another part of the grass was dried artificially and pelleted. The roughages preserved in these four different ways were included in rations for dairy cows, and the chemical composition and digestibilities of the preserved roughages and the rations they were included in, were studied.

Because of conservation, nitrogen solubility decreased in the silage with a mixture of formic acid and formaldehyde, and in the grass pellets, but increased in the silage with formic acid and increased even more in the silage without additive. The apparently digested nitrogen in the different rations showed a tendency to decrease with a decreasing nitrogen solubility, but the differences were not significant.

Good agreement was found between the calculated digestibility of the organic matter in vitro, based on the in vitro digestibilities of the rational components, and on the apparent digestibility determined in vivo for the rations containing silages. The calculated in vitro digestibility of the ration containing grass pellets tended to be rather high.

Introduction

After the growing season, roughage has to be conserved as feed for ruminants. Preservation of green forages as silage often causes considerable protein and energy losses, particularly if it is a high moisture silage. To prevent these losses, additives can be used, such as AIV acid (Virtanen, 1947), formic acid (Saue & Breirem, 1969; Castle & Watson, 1970a, 1970b; Wilson & Wilkins, 1972) and formaldehyde (Waldo et al., 1972; Barry & Fennessy, 1972, 1973; Brown & Valentine, 1972; Valentine & Brown, 1973). It is possible to conserve green forages by drying them, either artificially or in the field. Especially in the field, losses are considerable.

During research on nitrogen metabolism in the ruminant at our Institute, dairy cows were given rations containing artificially dried and pelleted grass (ration GP), grass silage preserved with formic acid (ration GSF), grass silage preserved with a mixture of formic acid and formaldehyde (ration GSFF) and grass silage without a preserving agent (ration GS). The N metabolism was studied by digestion trials, and this paper deals with the results. More detailed digestion studies were undertaken with re-entrant cannulated animals, the results of which will be published in a subsequent paper (Tamminga, 1975).

Materials and methods

Preparation of silages and of artificially dried and pelleted grass

In May, 3 silages were made from freshly cut grass. Quantities of about 7000 kg were ensiled in concrete tower silos. In preparing the first silage each layer of about 500 kg of grass was sprayed with a water-diluted solution of formic acid (14.6 g formic acid/100 g crude protein) in the silo. The second silage was made in the same way with a diluted mixture of formic acid and formaldehyde (10.8 g formic acid/100 g crude protein and 10.6 g formaldehyde/100 g crude protein). The grass of the third silage received no additive. The silages were covered with a polythene sheet and put under pressure by concrete blocks, placed on a wooden plate which covered the polythene. From the same sward about 7000 kg were dried artificially and pelleted.

The experimental animals

The experiments were done with four lactating Friesian cows. Two animals were fitted with a rumen fistula and a re-entrant cannula at the beginning of the small intestine. At the start of the series of experiments all animals were between 2 and 3 months after parturition. Throughout the complete series of experiments, consisting of four experimental periods of five weeks each, the mean weight of the animals increased from 525 to 549 kg and the daily milk production decreased from 17.9 to 17.4 kg fat-corrected milk.

The rations fed

The rations consisted of 3.5 kg dry matter (DM) from long meadow hay, about 5 kg DM from silage or from grass pellets and 7–8 kg DM from concentrates. Feeding took place twice daily, at 7h30 and at 16h00. After the silages were opened in October, a secondary fermentation took place in the upper layers of the silage conserved with formaldehyde and formic acid. To a lesser extent this was also true for the silage treated with formic acid. The fermenting upper layers were discarded.

Experimental procedure

Each experimental period consisted of an adaptation period of 3 weeks for the normal animals and of 4 weeks for the cannulated animals. The adaptation period was followed by a collection period of 10 days for the normal and of 4 days for the cannulated animals. Before the start of this period daily portions of hay, concentrates and, if necessary, grass pellets were weighed and sampled for the entire period. Silage was taken from the silo each day and the portions given during the collection period were weighed and sampled daily. The samples were stored at –15 °C and from the frozen bulked daily samples a composite sample was taken for the entire collection period. During this period feed residues, faeces and milk were collected, and stored at 4 °C. At the end of the collection period feed residues were weighed and sampled. Faeces and milk were weighed and proportional subsamples were taken each day and bulked for each animal.

The cannulated animals were not allowed to wear harnesses for a separate collection of faeces and urine. From these animals faeces were collected manually only during the 96-hour period in which the duodenal flow was measured. The quantity of faeces in these animals was corrected for a 100 % recovery of chromic oxide, which was administered twice daily via the rumen fistula as paper impregnated with chromic oxide.

Laboratory analysis

Silage samples were dried at 60 °C for 24 hours and milled. In the air-dry material dry matter, ash and nitrogen were determined. Dry matter was corrected for losses of volatile organic acids and ammonia, according to the method of Nijkamp (1970). The nitrogen content was corrected for losses of ammonia. Hay, concentrates and faeces were likewise dried at 60 °C and milled and the air-dry material was analysed for dry matter, ash and nitrogen. Nitrogen solubility in silages and grass pellets was determined according to the method of Tagari et al. (1962).

Volatile fatty acids in the silage samples (acetic acid and butyric acid) were determined by steam distillation. The distilled acids were neutralized with sodium hydroxide. After distillation, the residue was extracted with ether and the extracted acids (mainly lactic acid) were dissolved in ethanol and after dilution with water neutralized with sodium hydroxide.

The digestibility of the organic matter in the silages, the grass pellets, the hay and the concentrates were determined in vitro by the method of Tilley & Terry (1963) as adapted in our laboratory (van der Koelen & Dijkstra, 1971).

Samples of wet silage and of grass pellets were incubated with rumen fluid for 48 hours, according to the first stage of the in vitro method for determining the digestibility of organic matter. Fermentation was stopped by the addition of 0.5 ml sulphuric acid (98 %) and after centrifuging, ammonia was determined in the supernatant by the method of Kaplan (1965). The ammonia content was considered to give an indication of the extent of ruminal protein breakdown.

Results

Chemical composition and in vitro digestibilities of silages and grass pellets

The chemical composition of the silages and the grass pellets, together with the in vitro digestibilities, are given in Table 1. The highest digestibility was found for the grass pellets, the lowest for the untreated silage. The most striking differences in the chemical composition of the silages were found in pH, ammonia-N, organic acids and nitrogen solubility. Compared with fresh grass, the nitrogen solubility

Table 1. Chemical composition and digestibilities of artificially dried and pelleted grass and of grass silages.

Factors[1]	Artificially dried grass pellets	Silage with formic acid	Silage with formic acid and form-aldehyde	Silage without additive	Fresh grass
DM (%)	86.6	21.5	23.7	17.7	18.5
OM/DM (%)	88.0	89.7	90.3	89.1	88.5
N/DM (%)	2.65	2.49	2.79	2.57	2.59
NH_3-N/DM (%)		0.25	0.07	0.52	
pH		4.1	4.0	5.1	
VFA/DM (%)					
L		4.1	1.0	0.2	
A		1.0	1.5	1.9	
B		—	0.2	1.3	
Soluble N (%)	34	51	40	64	42
NH_3 formation in rumen fluid (% NH_3-N/DM)	0.07	0.59	0.31	0.94	
DOM/DM (vitro) (%)	65.0	59.4	59.4	58.2	

[1] DM = dry matter; OM = organic matter; VFA = volatile fatty acids; L = lactic acid; A = acetic acid; B = butyric acid; DOM = apparently digested organic matter.

decreased due to the artificial drying, remained unchanged in the silage treated with a mixture of formic acid and formaldehyde, but increased in the silage treated with formic acid alone and increased even more in the silage without additive. Thus fermentation losses due to protein breakdown were prevented by artificial drying and by treatment with a mixture of formic acid and formaldehyde. These results are in good agreement with the differences in the amounts of ammonia which were produced in the medium after incubation with rumen fluid.

Intake and digestion of dry matter, organic matter and nitrogen

In Table 2 a survey is given of the mean intake after feeding the different rations and of the apparent digestibilities in the entire ration of dry matter, organic matter and nitrogen, together with the in vitro digestibility of the organic matter. This in vitro digestibility was calculated from the in vitro digestibilities and the intakes of organic matter from the different components of the ration.

Between the different rations no significant differences ($P > 0.05$) were found in the apparent digestibilities of dry matter organic matter, and nitrogen. Except for the ration containing artificially dried and pelleted grass, good agreement was found between the apparent digestibility of the organic matter in the ration and the calculated in vitro digestibility of the organic matter in the same ration. The difference between both digestibilities after feeding the ration containing grass pellets was not significant ($P > 0.05$).

Table 2. Intake and digestibilities of rations containing artificially dried and pelleted grass (rations GP), grass silage with formic acid (ration GSF), grass silage with a mixture of formic acid and formaldehyde (ration GSFF), and grass silage without additive (ration GS), and given to dairy cows.

Factors		Ration GP	Ration GSF	Ration GSFF	Ration GS
Intake (kg/day)	DM[1]	15.2	15.6	15.6	14.6
	OM[1]	13.7	14.1	14.3	13.3
	N	0.38	0.38	0.40	0.36
Apparent digestibility (% of intake)	DM[1]	69.0±0.89	69.7±1.16	70.9±1.04	71.1±0.83
	OM[1]	71.4±0.95	72.6±1.39	73.8±1.09	74.3±0.94
	N	61.1±1.20	62.7±2.16	60.8±1.60	63.5±1.45
Digestibility in vitro (% of intake)	OM[1]	74.8±0.68	72.7±0.49	73.2±0.54	74.2±1.13

[1] DM = dry matter; OM = organic matter.

Discussion

Chemical composition of the silages

From the results of Table 1 it is concluded that the untreated silage is of poor quality and that the addition of chemical agents like formic acid and formaldehyde seems to be a good practice in making high-moisture grass silages.

Addition of formic acid usually lowers the pH in the grass silage to a level which is favourable for bacteria that produce lactic acid and harmful for undesirable silage bacteria (Saue & Breirem, 1969). Formaldehyde, however, is often used as a bactericidal agent. Addition of formaldehyde to freshly cut grass inhibits the fermentation, and therefore the amount of organic acids produced is much lower. Due to the bactericidal effect of formaldehyde, the protein in the grass silage is protected against microbial breakdown during conservation. In general, a chemical bond is formed between formaldehyde and protein and this usually decreases the solubility of the protein. Because this bond is stable at a neutral pH, as found in the rumen, but weak at a low pH, as is found in the abomasum, formaldehyde has been used as a protecting agent against microbial protein breakdown in the rumen (Ferguson et al., 1967). Compared with fresh grass, only a small decrease was found in protein solubility in our experiments, possible because the forage was ensiled without cutting or macerating. The formation of a chemical bond between formaldehyde and the soluble protein in the cytoplasma may have been prevented by the intact cell walls in the long material.

It is also possible to reduce the solubility of protein by heat treatment (Chalmers et al., 1954). Therefore the low protein solubility in the artificially dried and pelleted grass is considered to be the result of a high temperature during drying and during the passage through the die in the press.

Digestion of the rations

To maintain rumination and digestion in the forestomachs, even when grass pellets and concentrates were given, a minimum quantity of 4 kg long meadow hay was included in all rations. The intake of silage was about ad libitum, but to maintain the level of milk production, it was necessary to include a considerable amount of concentrates in the rations. Hence only about 30–35 % of the dry matter intake originated from artificially dried grass pellets or from silage. The remaining 65–70 % of the dry matter intake was the same in all rations, and this of course limits the differences to be expected between the rations. The slightly reduced apparent digestibility of the organic matter in the ration containing grass pellets compared with the in vitro digestibility, has probably to be ascribed to a decreased ruminal fermentation due to an increased flow of digesta from the rumen to the lower parts of the digestive tract. A reduction in the particle size of the ration, as with grass pellets, increases the rate of passage of digesta through the forestomachs of ruminants (Balch, 1961; Thomson, 1972).

No significant differences in apparent nitrogen digestibilities were found between the different rations in our experiments, but, compared with the ration containing grass silage without additive, the apparent nitrogen digestibility seems to be slightly depressed in the rations containing grass pellets or formaldehyde-treated silage.

In literature it was mentioned in some experiments, in which formaldehyde-treated protein was compared with untreated protein, that the apparent nitrogen digestibility was decreased after feeding the treated protein (Coetzee, 1970; Faichney, 1971; Nishimuta et al., 1973). This may be explained by decreased ammonia losses from the rumen due to the protection against microbial breakdown. On the other hand it is possible that the protein was not only protected against microbial breakdown in the rumen, but also against enzymic digestion in the intestines. This problem is further discussed in a subsequent paper (Tamminga, 1975).

The practical application of formaldehyde as a silage additive for high-moisture silages seems to be limited, as a result of the secondary fermentation and mould growth that took place in some experiments after the silo was opened (Barry & Fennessy, 1972; Brown & Valentine, 1972). Addition of formic acid may overcome this problem (Waldo et al., 1972; Brown & Valentine, 1973), but in our experiments this was not sufficient to protect the silage against secondary fermentation. However, the development of this fermentation could be influenced by the slow rate of removing the silage, due to the limited number of experimental animals involved. Under practical circumstances the rate of feeding may be fast enough to prevent the development of this secondary fermentation.

Acknowledgment

Thanks are expressed to Dr A. J. H. van Es for his advice and interest in the work, to Dr J. M. van Leeuwen for surgical preparation of the animals, to Mrs E. Brouns for reading the manuscript and to all others who gave technical and analytical assistance.

References

Balch, C. C., 1961. In: Lewis, D. (Ed.), Digestive physiology and nutrition of the ruminant, p. 23-34, Butterworth, London.

Barry, T. N. & P. F. Fennessy, 1972. The effect of formaldehyde treatment on the chemical composition and nutritive value of silage. I. Chemical composition. *N.Z. Jl agric. Res.* 15: 712-722.

Barry, T. N. & P. F. Fennessy, 1973. Effect of formaldehyde treatment on the chemical composition and nutritive value of silage. II. Digestibility of the silages and the chemical composition of rumen fluid in sheep supplemented or not supplemented with D, L-methionine. *N.Z. Jl agric. Res.* 16: 59-63.

Brown, D. C. & S. C. Valentine, 1972. Formaldehyde as a silage additive. I. The chemical composition and nutritive value of frozen lucerne, lucerne silage and formaldehyde treated lucerne silage. *Aust. J. agric. Res.* 23: 1093-1100.

Castle, M. E. & J. N. Watson, 1970a. Silage and milk production, a comparison between grass silage with and without formic acid. *J. Br. Grassld Soc.* 25: 65-70.

Castle, M. E. & N. J. Watson, 1970b. Silage and milk production, a comparison between wilted and unwilted grass silage, made with and without formic acid. *J. Br. Grassld Soc.* 25: 278-284.

Chalmers, M. I., D. P. Cuthbertson & Synge, 1954. Ruminal ammonia formation in relation to the protein requirement of sheep. *J. agric. Sci., Camb.* 44: 254-262.

Coetzee, C. G., 1971. Die benutting van formaldehied-behandelde vismeel en grondboneoliekoekmeel deur skape. *Agroanimalia* 2: 139-143.

Faichney, G. J., 1971. The effect of formaldehyde treated casein on the growth of ruminant lambs. *Aust. J. agric. Res.* 22: 453-460.

Ferguson, K. A., J. A. Hemsley & P. J. Reis, 1967. Nutrition and woolgrowth. The effect of protecting dietary protein from microbial degradation in the rumen. *Aust. J. Sci.* 30: 215-217.

Koelen, C. J. van der & N. D. Dijkstra, 1971. Bepaling van de verteerbaarheid in vitro als hulpmiddel bij de schatting van de voederwaarde van ruwvoeders. *Landbouwk. Tijdschr.* 83: 494-499.

Nishimuta, J. F., D. G. Ely & J. A. Boling, 1973. Nitrogen metabolism in lambs fed soyabeanmeal treated with heat, formalin and tannic acid. *J. Nutr.* 103: 49-53.

Nijkamp, H. J., 1969. The use of silage in balance trials. *Proc. 4th EAAP Symp. Energy Metabolism Farm Anim.* (Warsaw) 451-454.

Saue, O. & K. Breirem, 1969. Formic acid as a silage additive. *Prov. 3rd gen. Meet. Eur. Grassld Fed.* (Braunschweig) 161-172.

Tagari, H., J. Ascarelli & A. Bondi, 1962. The influence of heating on the nutritive value of soyabean meal for ruminants. *Br. J. Nutr.* 16: 237-243.

Tamminga, S., 1975. 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. *Neth. J. agric. Sci.* 23 (in press).

Thomson, D. J., 1972. Physical form of the diet in relation to rumen fermentation. *Proc. Nutr. Soc.* 31: 127-134.

Tilley, J. M. & R. A. Terry, 1963. A two stage technique for the in vitro digestion of forage crops. *J. Br. Grassld Soc.* 18: 104-111.

Valentine, S. C. & D. C. Brown, 1973. Formaldehyde as a silage additive. II. The chemical composition and nutritive value of lucerne hay, lucerne silage and formaldehyde and formic acid treated lucerne silage. *Aust. J. agric. Res.* 24: 939-946.

Virtanen, A. I., 1947. Silage by the AIV-method. *Eco. Proc. Roy. Dublin Soc.* 3: 311-342.

Waldo, D. R., J. E. Keys & C. H. Gordon, 1972. Formaldehyde and formic acid as a silage additive. *J. Dairy Sci.* 56: 229-232.

Wilson, R. F. & R. J. Wilkins, 1973. Formic acid as a silage additive for wet crops of cocksfoot and lucerne. *J. agric. Sci., Camb.* 80: 225-231.