Annales Agriculturae Fenniae

Maatalouden
tutkimuskeskuksen
aikakauskirja

Vol. 11,4

Journal of the
Agricultural
Research
Centre

Helsinki 1972

Annales Agriculturae Fenniae

JULKAISIJA — PUBLISHER

Maatalouden tutkimuskeskus
Agricultural Research Centre

Ilmestyy 4—6 numeroa vuodessa
Issued as 4—6 numbers a year

ALASARJAT — SECTIONS

Agrogeologia et -chimica — Maa ja lannoitus
Agricultura — Peltoviljely
Horticultura — Puutarhaviljely
Phytopathologia — Kasvitaudit
Animalia nocentia — Tuhoeläimet
Animalia domestica — Kotieläimet

KOTIMAINEN JAKELU

Valtion painatuskeskus, Annankatu 44, 00100 Helsinki 10

FOREIGN DISTRIBUTION

Agricultural Research Centre, Library, SF-01300 Tikkurila, Finland

ANNALES AGRICULTURAE FENNIAE, VOL. 11: 199—276 (1972)
Seria ANIMALIA DOMESTICA N. 36 — Sarja KOTIELÄIMET n:o 36

EFFECT OF DIFFERENT SUCROSE, STARCH AND CELLULOSE SUPPLEMENTS ON THE UTILIZATION OF GRASS SILAGES BY RUMINANTS

LIISA SYRJÄLÄ

Agricultural Research Centre, Tikkurila, Finland

HELSINKI 1972

ISBN 951-729-000-4

Suomalaisen Kirjallisuuden Kirjapaino Oy Helsinki 1972

PREFACE

The question of the effect of readily available carbohydrate supplements on the utilization of roughage by ruminants already interested me, when I was employd in the Department of Animal Husbandry, University of Helsinki. The use of sugar supplements was also suggested to me by Miss Maija-Liisa Salo, Dr. Agr. and For., and my respected teacher, Professor Lauri Paloheimo, Dr. Agr. and For., encouraged me to start experiments with sugar supplements fed to dairy cows on a hay diet (SYRJÄLÄ 1970 b). I am very grateful to both these persons. The increase in silage feeding was a further incentive to study the effect of different carbohydrate supplements on silage utilization.

The present study was carried out at the Department of Animal Husbandry of the Agricultural Research Centre in the years 1970—72. I wish to express my sincere gratitude to Professor Martti Lampila, Dr. Agr. and For., for giving me the opportunity to perform this work at his Department and for valuable advice offered during the work.

I have had many interesting discussions with Professor Esko Poutiainen, Dr. Agr. and For., on various aspects of the study. I wish to thank him warmly for many valuable comments and suggestions, and his never failing interest.

I am indebted to Mr. Bengt Westerling, Dr. Vet. Med., for the fistulation of the experimental animals and to Mr. Erkki Välimaa and Mrs. Anna Torvinen for the excellent care, which they took of the animals.

I am most grateful to all the persons who helped me with the sample analyses, especially Miss Ritva Kuosmanen, Mrs. Aino Matilainen, Miss Maila Kraatari and Miss Leena Ijas, who performed the determination of volatile fatty acids. The determination of mineral and trace elements was carried out in the Department of Animal Husbandry, University of Helsinki, by Mr. Jaakko Tolonen. My best thanks are due to him and Mrs. Vappu Kossila, Dr. Agr. and For., Acting head of the Department at that time.

I am also grateful to my colleagues for their help with several practical and scientific questions, especially to Miss Lea Huida, Mag. Phil., for discussions and assistance with chemical methods and Mr. Mikko Tuori, Mag. Agr. and For., for his indefatigable help with different kinds of technical problems and for the statistical treatment of the results. The computer programming was done by Mr. Erkki Nenonen, Mag. Phil., for which I express my thanks.

I am most indebted to Mr. Esko Vuori who helped me to draw the figures, and thank Mrs. Anna Damström, M. A., for checking the English of the manuscript.

I am very grateful for the financial help given by the Valtion maatalous-metsätieteellinen toimikunta (The National Research Council for Agriculture and Forestry) and the August Johannes ja Aino Tiuran Maatalouden Tutkimussäätiö (Tiura Foundation).

I am greatly indepted to the Agricultural Research Centre for the publication of this work.

Tikkurila, 10 October 1972

Liisa Syrjälä

CONTENTS

Page

Introduction 206
Review of the literature 208
Ensiling methods 208
Pre-treatment of crop 208
Stimulation of lactic acid fermentation 208
Direct acidification 208
Use of chemicals having selective bacteriostatic effect 209
Silage quality and its evaluation 210
Factors affecting the nutritive value and intake of silage 210
Grass species 210
Stage of growth of grass 211
Nitrogen fertilization 211
Pre-treatment of crop 212
Added preservatives 212
Feed supplements 213
Effect of carbohydrate supplements on the utilization of roughage 213
Digestibility 213
Nitrogen retention 214
Rumen fermentation products 214
Ammonia production 214
VFA production 215
Experimental procedures 216
Experimental feeds 216
The grass and its conservation 216
Carbohydrate supplements used in feeding 217
Experimental design and rations 217
Experimental animals and their feeding 219
Sampling and analyses 220
Determination of chemical composition and quality of silage 220
Digestibility experiments 220
Nitrogen balance experiments 221
Rumen fluid investigations 221
Blood analyses 222
Results and discussion 222
Chemical composition and quality of the experimental silages 222
Effect of sucrose, starch and cellulose supplements on the utilization of silage 224
Digestibility 224
Nitrogen retention 230
Other feeding values 232
Rumen fermentation 235
pH values 235
Ammonia concentration 235
VFA concentration 242
Effect of preservatives on the utilization of silage 246
Digestibility, nitrogen retention and other feeding values 246

Rumen fermentation 249
Silage intake and water consumption 250
Composition of blood of sheep on different silage and carbohydrate feeds 251
General considerations 254
References 257
Appendix 266
Selostus 275

SYRJÄLÄ, LIISA 1972. **Effect of different sucrose, starch and cellulose supplements on the utilization of grass silages by ruminants.** Ann. Agric. Fenn. 11: 199—276.

A comparative study was made of the effect of sucrose, potato starch and sulphite cellulose supplements on the utilization by ruminants of grass silages prepared with different preservatives: AIV II (80 % formic acid and 2 % orthophosphoric acid) in one experiment and A IV I (25 % formic acid and 20 % hydrochloric acid), formic acid and Viher solution (26 % formic acid and 70 % formalin) in the other. Each carbohydrate supplement was given at two levels constituting 15 % and 30 % of the dry matter of the daily rations, which was 947 g in the first and 928 g in the second experiment. The supplements thus represented on the average 2—3 g and 5 g per animal live weight. Pure silage diets were also given and the silages used in the latter experiment were compared.

The experiments were performed with rumen-fistulated adult Finnish landrace rams. A Latin-square design was used in both experiments. The experiments comprised digestibility and balance trials based on the quantitative collection method with a preliminary period of 14 days and a collection period of 7 days, measurements of silage consumption made in the preliminary period, and rumen fluid and blood investigations. The pH, NH_3-N and VFA were determined on rumen samples and the haematological criteria, glucose, urea- and NH_3-N and mineral and trace elements on jugular blood samples.

The sucrose and starch supplements had a rather similar effect on the apparent digestibility of the silages. The digestibility coefficients generally decreased with increasing amounts of those supplements, whereas with cellulose supplements they tended to increase in some cases. The total concentration of the rumen VFA clearly decreased with sucrose and increased with cellulose supplements, but starch had a varied effect. Sucrose supplements decreased the relative proportions of acetic and isovaleric acids, but increased those of propionic, butyric and valeric acids, when compared with diets of only silage. The effect of starch and cellulose on their proportions were not so clear. Sucrose supplements seemed to promote the utilization of the N content of silage better than starch and cellulose supplements at the same levels, the sucrose diets showing a somewhat higher N balance and biological value and lower rumen NH_3-N contents than the other diets.

The intake, digestibility coefficients and N balance of the A IV I, formic acid and Viher solution silages did not differ significantly from each other, except that the digestibility of crude protein was lower in Viher solution silage than in the other silages. The average rumen NH_3-N content was lowest with Viher solution silage and highest with formic acid silage. The total rumen VFA content was highest with formic acid silage, lower with Viher solution and lowest with A IV I silage, while there were only slight differences between different silages in the relative amounts of the individual acids. The effect of different carbohydrate supplements varied only slightly with the different silages.

The pH values of the rumen fluid, and the values of the blood analyses generally remained within the normal ranges on all the diets.

INTRODUCTION

Grass and grass products are the main basis of ruminant nutrition. As the indoor feeding period in Finland lasts from 7 to 8 months, harvested forage constitutes a large part of the feeds. In recent years the proportion of grass silage in winter feeding has greatly increased. This is due not only to the demand for protein-rich, home-produced and more economical food for animals, but also to the great progress in harvesting techniques and preservation methods. Much research has thus been done and much still remains to be done on the optimal utilization of grass preserved as food for ruminants.

Since the high nutritive value of young grass was established by WOODMAN et al. (1926, 1927, 1928) in the 1920's, its preservation as a winter feed for ruminants has attracted great interest. Ensilage has appeared to be the most promising form of preservation.

The object of storing green crops as silage is to preserve the material with a minimum loss of nutrients and with good palatability. The methods for attaining this have been widely investigated during the last decade. As the preparation of silage is based on the activity of microbes, attempts have been made to produce conditions that favour the beneficial microbes, while preventing the growth of the injurious ones. The first, most essential step is to achieve and maintain anaerobic conditions, thereby inhibiting the wasteful activities of aerobic micro-organisms and oxidative enzymes of the plant material. The second step is to stimulate the formation of lactic acid so as to prevent butyric acid fermentation and breakdown of protein.

The respiration process and the action of micro-organisms produce marked changes in the chemical make-up of the ensiled material, which primarily affect the carbohydrates and nitrogenous compounds of the raw material.

Glucose, fructose, sucrose and fructosans are the main water-soluble carbohydrates in grass. Their amount is extremely variable, and depends upon the grass species, stage of growth, weather and fertilizer application (WAITE and BOYD 1953, BREIREM and ULVESLI 1954, WAITE 1957, 1958, MACKENZIE and WYLAM 1957, NOWAKOWSKY 1962, SALO 1965 a, 1965 b, REID 1966, HUOKUNA 1968). These soluble carbohydrates are the main energy source for the micro-organisms, of which lactic acid bacteria are the most important, since under ideal conditions they rapidly make growth conditions inhibitory for the undesirable butyric acid-forming and protein-degrading bacteria. The fermentation pattern is, however, not simple, even when only the lactic acid bacteria are considered. In silage two fermentative types of these organisms are always encountered: homofermentative and heterofermentative. Under anaerobic conditions, the first-mentioned type forms only lactic acid from glucose and fructose, while the second also forms alcohols and CO_2 (WOOD 1961).

The organic acids of plant material (»plant acids») also affect the fermentation of silage. Considerable attention has recently been given to their content in plants and silage (WILSON and TILLEY 1964, L'ESSARD and MCDONALD 1966, PLAYNE and MCDONALD 1966). They amount to 4—5 % in the dry matter of young grass and to 8—10 % in legumes, the commonest being citric acid and malic acid. Besides phosphates and proteins, these organic acids and their salts constitute important buffer systems in the plant (PLAYNE and MCDONALD 1966). Lactic acid bacteria will readily dissimilate malate and citrate by a number of pathways (WHITTEN-

BURY et al. 1967) producing acetic acid, lactic acid, formic acid, acetoin, alcohols and CO_2.

The changes connected with the nitrogenous components of the crop vary considerably and are important from the point of view of losses in silage. The harvesting of a forage crop is followed by rapid and extensive proteolysis which is terminated only by the attainment of either a high dry matter level (KAPPELLE and POSTMA 1952, ULVESLI et al. 1954) or a low pH (VIRTANEN 1933). Virtanen has shown that protein breakdown is almost inhibited below pH 4.0 and that the ammonia nitrogen increases with the pH value. Together with the pH value and the organic acids, the ammonia content of silage is considered a criterion of its quality. Even in well-preserved silage, about 50—60 % of the protein is broken down, a considerable part of the degradation products being amino acids. A part of the amino acids is further degraded by clostridia. Destruction of amino acids is by three main pathways (BARKER 1961): 1) oxidative-reduction resulting in the production of fatty acids, CO_2 and NH_3; 2) deamination to fatty acids, CO_2 and NH_3; 3) decarboxylation with the fermentation of amines.

If the changes in the chemical composition of grass during ensiling are examined from the standpoint of standard food analyses, some changes can be seen in the interrelations of different components. The N-free extract in the dry matter of the silage shows a decrease and all the other constituents, with the exception of true protein, show a slight increase compared with those of fresh grass (WATSON and NASH 1960). The organic acids formed during fermentation from N-free extract are dissolved in ether and are thus included in the crude fat fraction.

In the fermentation processes occurring during ensiling the sugars and other soluble carbohydrates thus disappear more or less completely, depending on the preservation methods used. This does not need to mean that they are completely lost to the animal. A large proportion of these soluble carbohydrates is converted to lactic acid, which has a feeding value almost as great as that of glucose (BARNETT 1954). Also the volatile fatty acids possess considerable value, being absorbed both directly from the rumen and through the intestinal wall. However, these fermentation products are not an energy source for so large an amount of the rumen microbes as the soluble carbohydrates.

Since TAPPEINER (1884) established the importance of the rumen microflora as a digesting agent, it has been known that the utilization of feed by ruminants depends to a great degree on these rumen micro-organisms. Through their action a significant portion of the relatively indigestible plant polysaccharides is degraded and fermented, thereby yielding products useful to the animal. If a high roughage diet is to be efficiently utilized, it is therefore important to consider not only the requirements of the animal itself but also the requirements of these microbes. Various factors and conditions have been shown to influence the extent of their degrading and synthetizing work in the rumen. One of the nutritional factors is the proportion of different carbohydrates in the ration.

Information is lacking on the effect of adding sugars or other readily available carbohydrates as an energy source for rumen micro-organisms when feeding silage. Experiments concerning the use of different carbohydrate supplements with other forage, such as hay, have given widely varying results (MITCHELL and HAMILTON 1940, HAMILTON 1942, BARNETT and REID 1961, KOMKRIS et al. 1965, SUTTON 1968, KELLOG 1969, SYRJÄLÄ 1971 b).

The purpose of the present study was to investigate the factors affecting the utilization of grass silage, especially its nitrogenous but also other components. Attention was mainly directed to the different silage preservatives and carbohydrate supplements used with silage diets. The experimental silages were made with the preservatives commonly used in Finland: AIV I and II solutions, Viher solution and formic acid. Different amounts of sucrose, starch and cellulose were used as energy sources when feeding these silages. The experiments, which were made with rumen-fistulated adult rams, consisted

mainly of digestibility and nitrogen balance trials and rumen fluid and blood investigations. The results of growth experiments with corresponding diets fed to young lambs will be published in a separate paper.

REVIEW OF THE LITERATURE

Ensiling methods

Different procedures have been used to ensure that the fermentation taking place in ensiled protein-rich grass will be of the kind producing good-quality silage. For instance, the grass is wilted or, when this is impracticable as in rainy conditions, preservatives are added. These usually include sugar, sugar-containing fodder substances, acids, acid salts, and chemicals of selective bacteriostatic effect.

Pre-treatment of crop

It has proved difficult to obtain satisfactory silage from young fresh grass or legumes without the use of preservatives (VIRTANEN 1952, BREIREM and ULVESLI 1954). Many experiments (SHEPHERD et al. 1946, MURDOCH 1954) have, however, shown that wilting the grass to a dry matter content of 30—35 % results in good-quality silage and small effluent losses. The quality of wilted silage is good, even at pH values of about 5 (DIJKSTRA 1952, KAPPELLE and POSTMA 1952). According to the experiments of MCDONALD et al. (1968), the more silage is predried the more sugars it contains. The favourable effect of the high dry matter content may also be due to retardation of acetic acid and, in particular, butyric acid fermentation. This has been supported by investigations showing that the development of butyric acid-forming clostridia bacteria is promoted by excessive moisture (STIRLING 1954). The breakdown of protein and the amount of ammonia have been shown to be lower in wilted than in unwilted silage (KAPPELLE and POSTMA 1952, ULVESLI et al. 1954, MURDOCH et al. 1955). From the standpoint of feeding, an advantage of silage with a high dry matter content is that the animals consuming it tend to ingest more dry matter (SHEPHERD et al. 1946, PRESTHEGGE 1959).

Laceration promotes fermentation by making the nutrients in the plant sap more available to the bacteria (JARL 1951, STIRLING 1954, ULVESLI et al. 1954). It has been shown that crushing favours fermentation more than chopping (WATSON 1952, BREIREM and ULVESLI 1954, BARNETT 1954). Laceration also reduces the amount of preservatives required in silage making (JARL 1951, BREIREM and ULVESLI 1954).

Stimulation of lactic acid fermentation

Lactic acid fermentation may be stimulated with a view to lowering the pH value of silage below the critical point (pH 4). In foods containing plenty of soluble carbohydrates this decrease in pH has been achieved without the addition of extra carbohydrates. When the material contains less soluble carbohydrates and more protein, the addition of carbohydrates has given better results. Supplements of molasses (JARL 1947, AXELSSON 1952) and raw sugar (KUCHLER and WACHTER 1931) have given good acid fermentation, as has done also the starch of cereals and potatoes (DIJKSTRA 1952, ARCHIBALD and KUZMESKI 1954, NORDFELDT 1955). Cultures of lactic acid bacteria have been added in attempts to control and increase lactic acid fermentation in silage (KUCHLER and WACHTER 1931, PAPENDICK and BRUHN 1970).

Direct acidification

Acids had been added to grass (WATSON and NASH 1960) even before the development of the AIV method, but their practical application

was made possible by the discovery of the favourable range pH (pH 3—4). The experiments of VIRTANEN (1929) showed, that this values within this range can be achieved with different acids and salts. However, he gave priority to the strong mineral acids because of their low price. The mineral acids gradually react with the basic components of the fodder and thus the final acidity of the silage depends on the organic acids. The first AIV solution contained 2 N HCl (VIRTANEN 1933); later this was superseded by a 14 N solution of H_2SO_4 and HCl, which was applied to silage after dilution with water (1 part acid to 6 parts water) to give a 2 N solution. This solution was given at the rate of 5—8 l per 100 kg food.

The improvement of harvesting techniques made it possible to decrease the amounts of acid, because the acid can react more easily with chopped or crushed grass. Thus weaker acids could be used for preservation. In the solution known as AIV I, the H_2SO_4 has been replaced be formic acid (KREULA 1969). It contains 25 % formic acid (86 %) and 20 % hydrochlorid acid (37 %) and is used at the rate of 4.3—4.5 l per 1 000 kg grass.

Besides acids, many salts are used as preservatives in silage making. Of the acidic salts, sodium bisulphate and ammonium bisulphate have been employed in many investigations (ULVESLI and SAUE 1965, LUKŠO 1966, MCCARRICK 1969). Ammonium bisulphate is used in Finland under the name AIV salt. Sodium bisulphate is known as Reymersholm salt. Reymersholm phosphate ($NaH_5(PO_4)_2 . NaHSO_4$), ammoniummonohydrophosphate and some salts of formic acid, such as Kofa salt, have also been used in ensiling (SCHARRER et al. 1952, POIJÄRVI 1955, WATSON and NASH 1960, ULVESLI and SAUE 1965).

There is a tendency in grass preservation today to change strong acids for organic acids. Formic acid has received most attention. It was first proposed as an additive by DIRKS in 1923 (cf. BREIREM and ULVESLI 1960), and has been marketed in Germany under the trade name of Amasil. In recent decades interest in experiments with formic acid has increased (JARL 1951, SCHARRER et al. 1952, ULVESLI and SAUE 1965, CASTLE and WATSON 1970, TAYLOR and PHILLIPS 1970). In Finland the use of formic acid was recently introduced, both by itself or mixed with a small amount of phosphoric acid. The name of the last-mentioned solution is AIV II. It contains 80 % formic acid (86 %) and 2 % orthophosphoric acid (85 %). As in the case of pure formic acid, a suitable rate is 4 l per 1 000 kg grass (KREULA 1969). The preservative effect of formic acid is partly due to the reduction in pH it causes, and also to the selective antibacterial effect it appears to exercise (VIRTANEN 1969).

Use of chemicals having selective bacteriostatic effect

Attempts have been made to inhibit the growth of injurious bacteria in the grass mass by using chemicals having a selective bacteriostatic effect. In this case the pH of the silage need not be under 4. This method is based on the fact that the lactic acid bacteria tolerate the chemicals better than the butyric acid bacteria. The duration of their effect should be short, so that they do not disturb the growth of the rumen micro-organisms. Among the chemicals used, are nitrite, bisulphite, formaldehyde and common salt (WATSON and NASH 1960). NaCl is the one of the oldest chemicals in use. The effect and dosage of formaldehyde were investigated at the beginning of the 1930's (KUCHLER and WACHTER 1931), and in Finland the »Viher» solution, consisting of formaldehyde and organic acid, came on to the market. It first contained 26 % formic acid and 70 % formalin (37 % formaldehyde; VIRTANEN, O. E. 1970) but later the formic acid was replaced by acetic acid. In the present experiments, the acid used in the Viher solution was formic acid.

Silage quality and its evaluation

The term »silage quality» is generally used to denote not the nutritive value of the silage, but the extent to which the silage fermentation has proceeded in a desirable manner. A subjective evaluation of silage on the basis of appearance and odour is of some value, but is not very reliable.

Fundamental studies conducted by VIRTANEN (1933, 1952) have shown that a desirable type of fermentation is promoted by a high degree of acidity and he asserts that the pH of silage should not exceed 4.0. Many other investigators (STEENSBERG 1948, DIJKSTRA 1952, KAPPELLE and POSTMA 1952, BREIREM and ULVESLI 1954) have confirmed these conclusions. It has, however, been shown that when silage is made from wilted grass containing more than 35 % dry matter, its quality can be good even with pH values as high as 5.0 (DIJKSTRA 1952, KAPPELLE and POSTMA 1952). Since the pH is not always a reliable index of quality, it is necessary to use other criteria as well, and it is usual to determine the contents of lactic acid and volatile fatty acids (VFA), primarily acetic acid and butyric acid, too (WATSON and NASH 1960). The so-called Flieg's value (FLIEG 1938) is widely used and is based on the proportions of lactic, acetic and butyric acids present, all expressed in milliequivalents. The introduction of chromatographic techniques has facilitated the determination of VFA.

Besides the pH, lactic acid, acetic acid and butyric acid, the amount of ammonia nitrogen (BREIREM and ULVESLI 1954, NORDFELDT 1955, WIERINGA 1966) has also been used as a criterion of the quality of silage. BREIREM and ULVESLI (1954) give the following values as indicative of quality in grass silage:

pH value	4.2
Lactic acid	1.5—2.5 %
Acetic acid	0.5—0.8 %
Butyric acid	< 0.1 %
NH_3-N % of total N	5—8

NILSSON and NILSSON (1956) used the contents of butyric acid and ammonia nitrogen as indicators of silage quality giving five quality groups for silage according to the following scheme:

Quality	NH_3-N % of total N	Butyric acid
Very good	< 12.5	< 0.10
Good	12.6—15.0	0.11—0.20
Medium	15.1—17.5	0.21—0.30
Bad	17.6—20.0	0.31—0.40
Very bad	> 20.1	> 0.40

Factors affecting the nutritive value and intake of silage

The digestibility and feeding value of silage depend mainly on the corresponding values of the raw material, which are further greatly influenced by the plant species and the stage of growth and also by fertilizer application. In addition, the procedures used in silage making, as pre-treatments of the crop and the addition of preservatives, can affect its value as a feed for animals, by leading to nutrient losses and possible changes in the digestibility and intake of the crop. The other feeds offered to the animals at the same time as silage can also affect its utilization.

Grass species

HARRIS and RAYMOND (1963) investigated the relation between grass species and the digestibility of silage. The digestibility of silage made from ryegrass was slightly higher than that of cocksfoot and meadow fescue. Similar differences relating to the raw material have also been shown by MINSON et al. (1960, 1964). In *in vitro* trials, STEEN (1968) found the digestibility of organic matter to be 77.1 % with timothy grass, 76.9 % with meadow fescue and 75.1 % with cocksfoot. POIJÄRVI (1929) also obtained a

higher digestibility value for meadow fescue than for cocksfoot.

Stage of growth of grass

It is widely known that changes in the chemical composition of sward grasses take place as they age. These changes concern mainly the content of crude protein, which decreases, and that of crude fibre, which increases (GEERING 1941, HUOKUNA 1960, SALO 1965 a, FARRIES 1966, WILSON and MCCARRICK 1967, RAININKO 1968). The growth stage of grass has been found to have a great effect on its digestibility (REID et al. 1959, MINSON et al. 1960, 1964, O'SHEA and BROWNE 1964, WINCH et al. 1970, PEDERSEN et al. 1971). With an increase in the age of the herbage, the content of VFA in the rumen fluid also decreases (DAVEY 1965). The intake of grass has been shown to decrease with the increase in crude fibre content (HALLEY and DOUGALL 1962). Similarly, the digestibility and feeding value of silage can be expected to change with the stage of growth of the grass (WATSON and NASH 1960).

HARRIS and RAYMOND (1963) found that when the grass for silage was harvested before the emergence of the ear, the digestibility changed only slightly. After that it decreased rather fast. The same results were obtained by POUTIAINEN and RINNE (1971). They compared silages made from meadow fescue-timothy grass at four different growth stages, with one week between each. The digestibility value (%) of the organic matter decreased by 0.47 and that of crude protein by 0.43 per day until the third cutting time, when 20 % of the meadow fescue had ears and the first ears of timothy were visible. After that the digestibility value decreased by about 1 per day. The amount of nitrogen retained by sheep was also smaller when the stage of growth of the grass was more advanced. In the experiments of KORMOS and CHESTNUTT (1966), the digestibility value (%) of timothy-meadow fescue-clover silage decreased by 0.5—0.6 per day during 19 days. CRAVEN (1963) showed that early cutting resulted in high digestibility of the silage as well as high consumption when it was fed *ad lib.* to sheep, as follows:

Date of cutting	State of maturity	Crude fibre, %	Digestibility coefficient	Daily consumption of DM per sheep, kg
June 1	Young leafy	18.9	77.3	1.06
June 9	Late leafy	24.3	75.5	0.86
June 15	Ear emergence	25.5	73.3	0.78

In general, the consumption of silage has been shown to diminish as the stage of growth advances (MURDOCK 1965, 1967, POUTIAINEN and RINNE 1971).

Nitrogen fertilization

Increased N fertilization has been shown to decrease the dry matter and sugar content and to increase the crude protein and nitrate content of grass, whereas its effect on the crude fibre content varies (NOWAKOWSKY 1962, OLOFSSON 1962, HOLMES and LANG 1963, JÄNTTI and KÖYLIJÄRVI 1964, BARLOW 1965, REID 1966, WIERINGA 1966, HUOKUNA 1968, RAININKO 1968, STEEN 1968, ETTALA et al. 1971). The changes in digestibility and palatability have been observed to be rather slight (HOLMES and LANG 1963, CAMERON 1966, REID et al. 1966, LESLIE et al. 1968).

High N fertilization can produce abnormal changes in silage fermentation (WIERINGA 1966, FOX and BROWN 1969), which can affect the palatability of the silage (GORDON et al. 1964, CASTLE and WATSON 1969). CARLSON (1963) found increased protein content and protein digestibility in silage made of grass which had received increased N fertilization. No differences were found in the feeding value or in the content of volatile fatty acids in the rumen after feeding those silages. SCHMEKEL (1967 a) studied the effect in sheep of varying levels of N fertilization on the rumen digestion of timothy silage. The nitrogen dressing was 186, 116.2 and 25 kg N per hectare. He found positive correlations between the level of nitrogen dressing and 1) the protein content of the feed and 2) the NH_3-N content and 3) the isoacid content of the rumen fluid.

Pre-treatment of crop

A low intake of silage has often been associated with a high moisture content (McGULLOUGH 1961, THOMAS et al. 1961). The intake has been successfully increased by reducing the moisture content of the forage before it is ensiled (MOORE et al. 1960, MURDOCH 1960, 1964, THOMAS et al. 1961, HARRIS and RAYMOND 1963, WELLMAN 1966, ALDER et al. 1969). KORMOS and CHESTNUTT (1966) have shown that the digestibility is lower in silage made from wilted than fresh grass. They think that this is due to the higher temperature of wilted grass during ensiling. Similar results have been obtained in other investigations (INOUE and OHYAMA 1966, FARRIES 1969). STRICKLAND et al. (1966), however, did not find any differences in the digestibility of silage made from fresh and wilted grass.

According to the experiments of MURDOCH (1965), chopping and crushing the raw material increase the intake and digestibility of silage. POIJÄRVI (1950) also obtained better digestibility for AIV silage made from chopped than unchopped timothy grass.

Added preservatives

WATSON and NASH (1960) collected and compared the results of numerous experiments concerning the nutrient losses and quality of different silages. The differences between the preservatives used are very difficult to detect, because so many factors influence these values. In practice the nutritive value and intake of silage often depend on how well ensiling has succeeded.

POIJÄRVI (1955) compared silages prepared with AIV, Calcifor and Kofa and without any added preservative. The digestibility percentages of the organic matter were, respectively: 77.6, 72.5, 73.3 and 72.1. POUTIAINEN and HUIDA (1970) compared the digestibility and nitrogen retention of meadow fescue silages prepared with four different preservatives, AIV I, AIV II, Viher solution and formic acid. In the Viher solution silage, the digestibility of the dry matter and crude protein were significantly lower but the N balance slightly higher than in the other silages. CASTLE and WATSON (1970) compared the feeding values of timothy-English ryegrass silages prepared with and without formic acid, and found that the former silage was better in respect of all the nutrients except protein.

The effect of the ensiling methods on the intake has been shown to be variable (WATSON and NASH 1960). OSLAGE and OSLAGE (1958) did not find any differences in the consumption by dairy cows of AIV silage and silage prepared without preservatives. In the experiments of MCCARRICK et al. (1965), the cows ate more of the silage prepared with molasses than of that prepared with ammonium bisulphate. SCHMEKEL (1967 b) found in experiments with sheep, that ensiling preservatives can influence feed consumption as follows:

Preservative	DM consumption g/day/sheep
Reymersholm salt	510 ± 35
Silotex ($Na_2S_2O_5$)	644 ± 22
None	718 ± 25
Kofa salt	750 ± 47
Malt-cereal	774 ± 19

SAUE (1968) compared the value of silages prepared with AIV solution, formic acid, molasses and without added preservative as a feed for lambs and obtained the best results with formic acid silage and the poorest with silage prepared without a preservative.

LAMPILA (1960) investigated the effect of different preservatives on the rumen ammonia content of the cow. The silages had been prepared with AIV salt, AIV solution, Calcifor salt and without any preservative. The mean ammonia concentrations during the 12-hour period between feeding were, respectively: 0.903, 0.726, 0.683 and 0.705 mmol per 100 ml of rumen ingesta. SCHMEKEL (1967 c) and SAUE (1970) also found that different preservatives have different effects on the rumen digestion. Schmekel also measured the VFA content of the rumen fluid of sheep.

Feed supplements

Considerable work has been done by McCULLOUGH (1961, 1966) on the effect on the utilization of other feedstuffs, concentrates or hay, given at the same time with silage. An increase in the concentrate and hay levels decreased the intake of silage and the effect of the concentrate was more pronounced than that of hay. Similar results have been obtained with concentrates by other investigators (MATHER et al. 1960, BROWN et al. 1963, MURDOCK and HODGSON 1967). WELLMANN (1966) found that adding from 3 to 9 % of carbohydrate-rich concentrate increased the silage intake. NORDFELDT (1966) tried to find the most favourable relative quantities of silage, concentrate and hay in the ration. If the herbage was silage or hay alone, the best results in milk production were obtained when the proportion of concentrates was 60 %. WILKINS (1970) showed in experiments with sheep that dried grass pellets may be a useful supplements to silage rations.

The most suitable proportions of hay and silage in feeding have been widely investigated (HILLMAN et al. 1958, PRESTHEGGE 1959, BROWN et al. 1963, WALDO et al. 1965, 1969, DIJKSTRA 1965, 1970, CAMPLING 1966, THOMAS et al. 1969, PAPENDICK and BRUHN 1970). The consumption by cows of silage and hay prepared at the same time from the same raw material has been shown to be about the same. WALLIN (1968) found that the rumen digestion was the same with hay and silage when they were the only herbage in rations for cows. WALDO et al. (1966) found that nitrogen retention was less and the amounts of rumen ammonia greater when feeding silage than when feeding hay.

Effect of carbohydrate supplements on the utilization of roughage

Attempts have been made to improve the utilization of roughage by ruminants by adding different carbohydrates to the rations. Although the value of carbohydrate supplements has been accepted, it is not yet definitely known which of the more or less soluble carbohydrates employed, and what proportion of them, best promote the efficient utilization of the basic feed.

Digestibility

It was known as early as the last century that the addition of sugar and molasses to the diet of the ruminant depressed the digestibility of crude fibre (BARNETT and REID 1961). Similar observations on the digestibility of crude fibre and also of other feed components have been reported by BRIGGS and HELLER (1940, 1943), MITCHELL and HAMILTON (1940), HAMILTON (1942), SWIFT et al. (1947) and MARTIN Jr. and WING (1966), who added soluble carbohydrates to diets of different composition. In experiments with dairy cows WILLIAMS (1925) found that the digestibility of crude protein was clearly depressed by the addition of molasses amounting to 15 and 25 % of the concentrate mixture in a ration containing hay and maize silage. The effect on the digestibility of other nutrients was variable. On the other hand, KOMKRIS et al. (1956) reported that the digestibility of organic matter and N-free extract increased with the level of molasses.

Starch has also been found to have a varied effect on the digestibility of a roughage diet. The experiments of BURROUGHS et al. (1950 a) showed that the addition of 1.8 kg of starch to a ration of roughage fed to steers reduced the digestibility of crude fibre from 60 to 13 %. CHAPPELL and FONTENOT (1968) replaced cellulose in a purified sheep ration with a 1: 1 mixture of glucose and maize starch at levels ranging from 0 to 48 % and found that the digestibility of cellulose was significantly reduced when the levels of these readily available carbohydrates exceeded 32 %. Dry matter and energy digestibilities were higher, though not always significantly so, in rations containing 8 % or more readily available carbohydrates. KANE

et al. (1959) noticed that the addition of 2.7 kg starch to an alfalfa ration fed to dairy cows had no effect on the digestibility of the alfalfa when an adaptation time of 20 days was allowed before commencing the trial. When no adaptation period was given, the starch decreased the digestibility of the dry matter, protein and N-free extract.

ELLIS and PFANDER (1958) used varied cellulose and nitrogen levels in a semi-purified diet fed to lambs. The rations were adjusted to supply one of three levels of cellulose (21.4, 31.4 or 41.6 %) and one of three levels of nitrogen (1.65, 2.05 or 2.45 %). Increasing the cellulose level depressed linearly the digestibility of organic matter, N-free extract and total digestible nutrients, and increased linearly cellulose and ether extract digestibility. Apparent nitrogen digestibility was not significantly affected. Maximum digestibility was observed with rations containing 2 % of nitrogen. SMITH et al. (1966) found that dry matter and energy digestibilities decreased with increasing levels of cellulose on purified diets for calves.

The effect of readily available carbohydrates on the action of rumen micro-organisms has been studied both *in vivo* and *in vitro*. The results have suggested that rumen microbes are highly sensitive to changes in sugar concentration, and that at some levels carbohydrate supplements may in fact stimulate their activity. HOFLUND et al. (1948) found that 0.1—0.2 % of glucose promoted cellulose digestion *in vitro*, while higher levels depressed its digestibility. *In vivo* experiments with sheep showed that cellulose digestibility was improved by supplements bringing the level of sucrose to 1 and 3 %, and depressed when its level was raised to 9 %. BURROUGHS et al. (1950 b) showed small amounts of molasses to have a stimulating effect on cellulose digestion *in vitro*. ARIAS et al. (1951) and BELASCO (1956) obtained similar results with starch. Arias postulated the need for small amounts of readily available energy to promote cellulose digestion. How great this amount should be for maximum cellulose digestion and also for maximum roughage utilization is not yet known. EL-SHAZLY et al. (1961) supposed that the inhibition of cellulose digestion by starch was due primarily to competition for nutrients between the cellulolytic and amylolytic groups of rumen bacteria, the main nutrient being nitrogen.

Nitrogen retention

The effect of added carbohydrates on dietary N utilization, measured as N retention, has been studied in many experiments. Faecal N losses were greatest when soluble carbohydrates were included in the diets (OLTJEN and PUTNAM 1966), which explains why the addition of sugar decreased the apparent digestibility but not the true digestibility of protein of hay or hay and concentrate (HAMILTON 1942, FONTENOT et al. 1955, SYRJÄLÄ 1971 b). HEAD (1953) noticed that N retention was not decreased by the addition of starch to the ration, although the digestibility of N-containing material was depressed. Similar results have been reported by MONRO (1951), DROR et al. (1969), DU PLESSIS and MERWE (1969). With increasing levels of readily available carbohydrates in the diet urinary N showed a decreasing trend (CHAPPELL and FONTENOT 1968), whereas each increase of cellulose increased the daily urinary N excretion (ELLIS and PFANDER 1958). FONTENOT et al. (1955) found that increasing additions of sugar produced progressive increase in the estimated (Thomas-Mitchell) biological value of the nitrogen of rations containing different levels of protein.

The observations that readily available carbohydrates can increase N retention and depress apparent digestibility of dietary protein would appear to be related to the finding that an increase in the rate of ruminal ammonia formation from nitrogen-rich material is accompanied by a decrease in the utilization of nitrogen.

Rumen fermentation products

Ammonia production

Ammonia is produced in the rumen by the metabolism of nitrogenous compounds. Its

concentration in the rumen varies from 0 to 130 mg/100 ml (JOHNS 1955) and represents a balance between utilization by rumen bacteria, metabolism in the rumen wall, absorption into the portal vein and passage into the omasum (TILLMAN and SIDHU 1969). Many nutritional factors have been shown to affect the ruminal ammonia concentration. CHALMERS and SYNGE (1954) have demonstrated with nitrogen balance experiments that the more soluble proteins produce more ammonia in the rumen and are not utilized so well by ruminants. Certain processing of dietary protein, for example heating (CHALMERS et al. 1954, SHERROD and TILLMAN 1962, 1964, LITTLE et al. 1963, GLIMP et al. 1967, HUDSON et al. 1970) and formaldehyde treatment (FERGUSON et al. 1967, REIS and TUNKS 1969, FAICHNEY and WESTON 1971, HUGHES and WILLIAMS 1971), can promote increased nitrogen utilization by reducing the rate of the degradation of the proteins and thus the ammonia production in the rumen. Similar results were obtained when soluble proteins were given directly into the abomasum of the animal (REIS and SCHINCKEL 1961, COLEBROOK and REIS 1969, ØRSKOV et al. 1970).

The addition of readily available carbohydrates to the diet has also been found to depress ammonia formation in the rumen (MCDONALD 1952, ANNISON et al. 1954, ANNISON 1956), the extent of the depression being observed to depend on the sources of the carbohydrates. LEWIS and MCDONALD (1958) found that levan and starch were more effective in this respect than either glucose or xylan, and that cellulose had only a slight effect in reducing the concentration of ammonia. The effect of varying the amounts of carbohydrate added, has, however, received less attention. The decreased ammonia level obtained when starch or sugar (PHILLIPSON et al. 1959, KURILOW 1965) were added may be partly due to an increase in the numbers of bacteria that can utilize ammonia nitrogen. REIS and REID (1959) found in *in vitro* experiments that conversion of ammonia into bacterial protein increased as the result of the addition of glucose.

VFA production

The principal products of rumen fermentation are the volatile fatty acids. Their importance as a source of energy for ruminant animals is well recognized. Many experiments have shown that they provide 50—75 % of the energy absorbed from the feed (BLAXTER 1961).

Considerable research has been devoted to the dietary factors which affect the amounts of VFA resulting from ruminal fermentation and the relative proportions of these individual acids both *in vivo* and *in vitro* (BARNETT and REID 1961, HUNGATE 1966). Early work by PHILLIPSON (1942) demonstrated that the level of acids in the rumen was directly related to the nature of the diet and to the ingestion of food.

Studies of the effect of different types and levels of supplementary carbohydrates on the production of rumen VFA and their relative amounts have given varied results. When PHILLIPSON and MCANALLY (1942) introduced various pure carbohydrates into the rumen of sheep, they found an increase in the concentration of VFA, the rate of their formation being dependent on the nature of the carbohydrates. Thus glucose, fructose and sucrose were fermented very rapidly, in 3—4 hours, starch more slowly and cellulose more slowly still. Similar fermentation rates have also been reported for starch and cellulose by BELASCO (1956). The supplementation of a purified sheep diet with a mixture of glucose and starch tends to increase the total rumen VFA content (CHAPPELL and FONTENOT 1968). MCDONALD (1948, 1952) and LEWIS and MCDONALD (1958) demonstrated an increase in the VFA produced from starch when small amounts of casein were also added. However, no effect on the rumen VFA content was noticed by KELLOGG and OWEN (1969), when different sucrose additions were made to the hay and grain rations of dairy cows, or by KOMKRIS et al. (1965), when molasses was added to a roughage diet. KRJUKOV (1965) added different amounts of sugar to rations for steers and found that the VFA production was highest, 8.15—13.35 mmoles/100 ml, with 3 g sugar/kg live

weight, while 5 and 10 g of sugar had the opposite effect. KURILOV et al. (1966) also noticed that in dairy cows small amounts of sucrose (1.2 kg) stimulated rumen fermentation, whereas with 1.9 kg the effect was quite the reverse.

Widely differing results concerning the relative amounts of the individual VFA in the rumen have been obtained in numerous experiments with different levels of mono- and disaccharides, sugar-beet and its products, starch and cellulose (GRAY and PILGRIM 1952, LAMPILA and POIJÄRVI 1959, REID and MILLS 1963, KRJUKOV 1965, LAMPILA 1966, SMITH et al. 1966, 1969, CHAPPELL and FONTENOT 1968, WELLER et al. 1968, SUTTON 1968, 1969, KELLOGG 1969, BOLDUAN et al. 1971). However, it is generally accepted that readily available carbohydrates tend to increase the proportion of propionic acid, and fibre-containing materials the proportion of acetic acid (BLAXTER 1962). ØRSKOV and OLTJEN (1967) studied the effect of different types of carbohydrates, varying from simple monosaccharides to the more complex polysaccharides, on the production of VFA in the rumen with purified diets for cattle. The molar percentages of the individual VFA in the rumen fluid were:

	Acetic	Propionic	Butyric	Isovaleric	Valeric
wood pulp	73.7	18.3	4.8	1.4	0.8
starch	60.4	24.7	10.4	0.9	2.7
sucrose ..	49.6	23.2	20.2	0.7	4.4
glucose ..	38.0	22.3	25.8	1.0	10.4

The production of individual VFA has usually been studied by examining the composition of the mixture of these acids in the rumen fluid. The absorption of different acids from the rumen, can, however, differ markedly, as various studies have shown (HUNGATE 1966). For this reason the composition of the mixture has not been thought to be fully indicative of the rates of formation of the individual acids. It has commonly been observed that the VFA produced *in vitro* have a greater proportion of propionic acid than the VFA produced *in vivo*, in which the proportion of acetic acid is greatest. (BARNETT and REID 1961, ELSDEN 1945, ELSDEN et al. 1945).

EXPERIMENTAL PROCEDURES

The present investigations consisted of two main experiments. Both in Exp. I and in Exp. II the effect of different carbohydrate supplements on the utilization of the experimental silages was studied. Exp. II also included a comparative study of different ensiling preservatives.

Experimental feeds

The grass and its conservation

The grass for the experimental silage in Exp. I was harvested from second year sward in which meadow fescue predominated. A basic fertilizing mixture was applied in spring comprising 37 kg P, 62 kg K and 5 kg N per hectare, together with 115 kg N per hectare. The grass material used was from the first cutting, performed on 10 June 1969, when the grass was about 35—40 cm high and before the ears had formed on the meadow fescue.

In Exp. II the grass for all the silages was also from second year sward. The fertilizing in spring consisted of 26 kg P, 50 kg K and 120 kg N per hectare, and after the first cutting 78 kg N was applied per hectare. The grass material used was from the second cutting, performed on 14 August 1970, when the first ears of the timothy became visible. The botanical composition of the fresh material was:

	Exp. I	Exp. II
Meadow fescue	86.4 %	17.6 %
Timothy	11.5 »	42.0 »
Red clover	0.8 »	22.7 »
Couch grass	—	12.1 »
Other weeds	1.3 »	5.6 »

The chemical composition of the grass was (See Appendix 1):

	Exp. I	Exp. II
Dry matter	17.94 %	17.18 %
In dry matter		
Ash	9.56 %	10.83 %
Organic matter	90.44 »	89.17 »
Crude protein	23.19 »	17.24 »
True protein	15.61 »	13.45 »
Crude fat	3.69 »	4.35 »
N-free extract	42.92 »	43.26 »
Crude fibre	20.64 »	24.32 »
Crude carbohydrates	63.56 »	67.58 »

The analyses were carried out according to the standard procedures described by PALOHEIMO (1969).

The grass was chopped and the preservatives added during the harvesting. The preservatives and their amounts were as follows:

Exp. I

AIV II solution ..... 4.4 1/1000 kg grass

Exp. II

AIV I solution ..... 4.2 »
Formic acid ..... 3.8 »
Viher solution ..... 4.7 »

AIV II: 80 % formic acid (86 %)
2 % orthophosphoric acid (85 %)
AIV I: 25 % formic aicd (86 %)
20 % hydrochloric acid (37 %)
Viher solution: 26 % formic acid (86 %)
70 % formalin (37 % formaldehyde)

In Exp. I the grass was ensiled in a round wooden tower silo (5 × 12.6 m^2 = 63 m^3). In Exp. II it was preserved on the ground in three stack-like silos (2 × 4 m^2) surrounded with black polythene plastic film (0.15 mm in thickness). The film was sealed with a hot iron and the air removed with a tractor compressor. The effluent was led out through a rubber hose. Each stack contained about 4 000 kg fresh grass. Under vacuum conditions they were 0.5—0.6 m high. The stacks were covered with straw bales in winter to protect them from freezing.

Carbohydrate supplements used in feeding

Sugar, starch and cellulose were used as supplemental energy sources. The sugar was pure sucrose and the starch powder of pure potato starch. The cellulose was α-cellulose, pure sulphite cellulose from the wood industry.

The average chemical composition of the cellulose preparation during the experiments was:

	Exp. I	Exp. II
Dry matter	90.03 %	88.11 %
In dry matter		
Ash	0.18 %	0.24 %
Organic matter	99.81 »	99.76 »
Crude protein	0.30 »	0.19 »
Crude fat	0.15 »	0.04 »
N-free extract	14.19 »	9.44 »
Crude fibre	85.15 »	90.09 »
Crude carbohydrates	99.34 »	99.53 »
Cellulose	92.41 »	92.61 »

The cellulose determination was made according to the method of SALO (1965 b). The average dry matter percentage of the starch powder was 83.17 in Exp. I and 80.93 in Exp. II. The dry matter percentage of the sucrose was about 100.

Experimental design and rations

A Latin-square design was used in both experiments. A 7 × 7 Latin square was used for Exp. I with 7 rams in 7 periods of 3 weeks. The diets also numbered 7 (Fig. 1). In Exp. II the material was assigned to 9 small (3 × 3) Latin squares comprising 9 animals, 9 periods and 21 diets (Fig. 2). The syllables in the squares are the abbreviations of the names of the ex-

Carbohydrate levels

Periods	CHO[1] 0 %	Sucrose 15 %	Sucrose 30 %	Starch 15 %	Starch 30 %	Cellulose 15 %	Cellulose 30 %	Time 1970
1	Ee	Ju	Aa	Si	Tu	Ti	La	20/2 — 12/3
2	Aa	Ee	Si	Tu	Ti	La	Ju	13/3 — 2/4
3	Si	Tu	La	Ee	Aa	Ju	Ti	3/4 — 23/4
4	Ti	La	Ju	Aa	Ee	Tu	Si	24/4 — 14/5
5	La	Si	Ee	Ti	Ju	Aa	Tu	15/5 — 4/6
6	Tu	Aa	Ti	Ju	La	Si	Ee	5/6 — 25/6
7	Ju	Ti	Tu	La	Si	Ee	Aa	26/6 — 16/7

[1] CHO = carbohydrate

Fig. 1. Design of Exp. I.

perimental animals. The arrangement was decided by drawing lots.

The mean composition of the experimental diets was:

Exp. I

0 % level: 4.0 kg silage (AIV II)
15 % levels: 3.4 kg silage and 140 g sucrose
» » 166 g starch
» » 158 g cellulose
30 % levels: 2.8 kg silage and 280 g sucrose
» » 332 g starch
» » 316 g cellulose

Exp. II

0 % levels: 5.0 kg silage (AIV I, formic acid or Viher solution)
15 % levels: 4.2 kg silage and 140 g sucrose
» » 173 g starch
» » 158 g cellulose
30 % levels: 3.4 kg silage and 280 g sucrose
» » 346 g starch
» » 316 g cellulose

The quantity of feed was restricted sufficiently to ensure that nothing was left uneaten. The carbohydrate supplements represented 0 %,

Carbohydrate levels

Periods	0 %	15 %	30 %	0 %	15 %	30 %	0 %	15 %	30 %	Time
1	Ee	Ju	Aa	Si	Tu	Ti	La	To	Ii	1970
2	Aa	Ee	Ju	Ti	Si	Tu	Ii	La	To	6/11 — 26/11
3	Ju	Aa	Ee	Tu	Ti	Si	To	Ii	La	27/11 — 17/12
	AIV I solution Sucrose			Formic acid Starch			Viher solution Cellulose			18/12 — 7/1
4	Ee	Ju	Aa	Si	Tu	Ti	La	To	Ii	1971
5	Aa	Ee	Ju	Ti	Si	Tu	Ii	La	To	8/1 — 28/1
6	Ju	Aa	Ee	Tu	Ti	Si	To	Ii	La	29/1 — 18/2
	Formic acid Cellulose			Viher solution Sucrose			AIV I solution Starch			19/2 — 11/3
7	Ee	Ju	Aa	Si	Tu	Ti	La	To	Ii	1971
8	Aa	Ee	Ju	Ti	Si	Tu	Ii	La	To	12/3 — 1/4
9	Ju	Aa	Ee	Tu	Ti	Si	To	Ii	La	2/4 — 22/4
	Viher solution Starch			AIV I solution Cellulose			Formic acid Sucrose			23/4 — 13/5

Fig. 2. Design. of Exp. II.

15 % and 30 % of the dry matter of the total diet. The mean amount of dry matter eaten by the animals on the diets was 947 g in Exp. I and 928 g in Exp. II. As the silage was the only source of nitrogen in the ration, it was also possible to obtain three different levels of nitrogen in the investigation.

Experimental animals and their feeding

The digestibility and nitrogen balance experiments and the investigations of rumen fluid and blood were carried out with Finnish landrace rams, furnished with permanent rumen fistulas. At the time of fistulation the animals were nearly two years old, in good condition and health. The rumen fistulas of the majority of the rams were made according to the procedure of DOUGHERTY (1955), with a small modification in the dimensions of the cannulae. The cannulae used were made of silicone rubber. The fistulas of two rams, Topias and Iivari were made according to the method of HECKER (1969). The cannulae used in this method are of rubber and, unlike the cannulae of silicone rubber, very soft and light.

The animals remained healthy during the experiments. At the time of fistulation they were injected against tetanus and a week before the beginning of the experimental periods they were treated for parasites. Two rams, Juhani and Timo, were replaced with the rams Juhani II and Timo II after the fourth period of Exp. I, because their fistulas were broken. Otherwise the fistulas remained in good condition, the outflow of rumen fluid was insignificant, and could be avoided by cleaning the fistulas when necessary.

The animals were weighed four times in each period, on the two first and the two last days of the collection period, before the morning feeding. The average live weights of the rams during the periods were:

Exp. I

Eero	60.8 kg	(58.3—63.8 kg)
Juhani	69.1 »	(67.0—71.2 »)
Juhani II	62.4 »	(60.8—64.9 »)
Aapo	57.1 »	(55.0—60.2 »)
Simeon	56.8 kg	(54.9—59.4 »)
Tuomas	59.3 »	(58.0—62.2 »)
Timo	59.2 »	(53.5—62.4 »)
Timo II*	75.1 »	(72.3—78.3 »)
Lauri	61.0 »	(57.0—65.1 »)

Exp. II

Eero	63.4 kg	(61.9—65.4 kg)
Juhani II	62.6 »	(60.2—64.3 »)
Aapo II*	75.3 »	(73.2—77.9 »)
Simeon	62.7 »	(61.9—63.6 »)
Tuomas	64.3 »	(62.7—66.5 »)
Timo	61.8 »	(58.2—63.5 »)
Lauri	67.0 »	(62.9—71.0 »)
Topias	52.0 »	(48.6—55.2 »)
Iivari	50.4 »	(47.1—52.5 »)

*Timo II (Exp. I) = Aapo II (Exp. II)

During the experiments the animals were kept in individual cages with a net bottom and funnel for the collection of urine.

Feeding took place twice a day, at 8.30 a.m. and 3 p.m. At each feeding time half of the daily ration was given. The carbohydrate supplements were given first, mixed with small amounts of silage if necessary. Cellulose was never eaten unless mixed well with the silage.

The whole ration was generally consumed within an hour from the beginning of the feeding. Any food residue was removed and weighed once a day before the beginning of the morning feeding, except on the days when the rumen samples were taken, when it was removed also at the end of the morning feeding, at 10 a.m., and given back together with the evening feed. After they had eaten their food ration, the animals were offered a mineral mixture, containing 80 % commercial product (Kultalypsy) and 20 % NaCl. Kultalypsy contains 10.0 % **P**, 23.5 % Ca, 12.9 % NaCl, 2.0 % Mg plus trace

elements of Fe, Cu, Co, Zn and J and vitamins A, D_3 and E.

The animals had free access to water. During the collection periods the amount of water drunk was determined each day by weighing the amounts given and left.

Sampling and analyses

Determination of chemical composition and quality of silage

Silage for the experiments was taken from the silo and the stacks twice a week and the doses for the experimental animals were thus weighed out for 3 or 4 days at a time. The samples for the analyses were taken at the same time, once a week during the preliminary period of 14 days and twice a week during the collection period of 7 days. Dry matter and pH were determined each time.

The pH values were measured on the silage effluent with a Beckman meter Model 76. Dry matter was determined by drying the fresh sample in an oven at 103—105 °C for about 18 hours. At this temperature, however, volatile acids and bases are lost, as has been shown by various experiments concerning the dry matter determination of silage (McDONALD and DEWER 1960, DEWER and McDONALD 1961, BRAHMAKSHATRIYA and DONKER 1971), in which distillation with toluene has given good results. In the present work, a corrected value was used for the dry matter of silage. The estimate of the correction was based on the observation that 80 % of the acetic acid and all the other volatile acids are lost during drying at this high temperature (JARL and HELLEDAY 1948, PRESTHEGGE 1959, ULVESLI and BREIREM 1960).

Some of the fresh silage samples were predried at 60—65 °C for about one day, and ground in the Wiley mill through a 1-mm-mesh sieve. The ground samples from each experimental period (4 samples altogether) were mixed together. The food analysis was made on this combined sample according to standard procedures (PALOHEIMO 1969). The mineral and trace elements were determined with the atomic absorption spectrophotometer Varian Techtron Model 1000 by the metho dof HECKMAN (1967), except phosphorus, which was determined colorimetrically by the method of TAUSSKY and SHORR (1953).

Besides the pH, other properties used as criteria of the quality of silage are the VFA, lactic acid, and sugar contents and the different N-fraction concentrations. These values were obtained once in every experimental period from a cold water extract of the fresh silage samples. A Waring blender was used in the extraction. The VFA were determined by the gas chromatographic method described by HUIDA (unpubl.) and the lactic acid colorimetrically by the method of BARKER and SUMMERSON (1941). The gas chromatograph apparatus used was a Perkin-Elmer Model F 11 and the integrator a Perkin-Elmer Model D 26. The water-soluble sugars were determined by the method of SALO (1965 b) and expressed as glucose. The ammonia nitrogen was determined colorimetrically by the method of McCULLOUGH (1967) and soluble nitrogen by the Kjeldahl method.

Digestibility experiments

Digestibility experiments were carried out by the quantitative collection method. The preliminary period always lasted 14 days and the collection period 7 days. Before the beginning of the collection period the animals were provided with faeces-collecting harnesses. The faeces were removed from the bag once a day, in the morning before the feeding, weighed daily and pre-treated by grinding coarsely. Ten % samples of the daily feaces were taken for the dry matter determination. These samples were pre-dried at 60—65 °C, combined and ground in the Wiley mill through

a 1-mm-mesh sieve. The analyses were carried out according to standard procedures. Crude protein was also determined on the fresh faeces samples for the dry matter correction, because the dry matter in the standard food analyses was determined at 103—105 °C and ammonia is lost at that temperature.

Nitrogen balance experiments

Besides the faeces, the urine excreted in the collection period was also collected, being led through the funnel under the experimental cage into a plastic pail.

In Exp. II, 50—100 ml of 10 N H_2SO_4 was added to the pails to keep the pH of the urine under 3 and thus prevent NH_3 losses. The excreted urine was weighed daily. Ten % samples of the daily urine amounts were combined and used for the determinations. To preserve the urine until all the samples were obtained, a small amount of thymol was added, and the collection bottle was kept at 0 °C. The nitrogen determinations were made by the Kjeldahl method.

Rumen fluid investigations

The pH, ammonia and VFA were determined on rumen samples taken three times in each of the last three days of every experimental period:

1) in the morning before feeding, at 8.15 a.m.
2) 2.5 hours after the beginning of feeding, at 11 a.m.
3) 5.5 hours after the beginning of feeding, at 2 p.m.

Sixty-three rumen fluid samples were obtained for each of the diets of Exp. I except two (0 % carbohydrate and 30 % cellulose levels), for each of which there were 54 samples. In Exp. II 81 rumen fluid samples were obtained for each of the 0 % level diets and 27 samples for each of the other diets.

Samples of the rumen content were taken through the fistula with a silicone tube 8 mm in diameter. The tube was pushed to the bottom of the rumen and, as it was lifted slowly up, rumen fluid was sucked up into it and transferred to a 75-ml plastic bottle. This operation had to be repeated 6—8 times before the bottle was completely full. The samples were thus rather representative of the rumen fluid, containing only small amounts of solid material.

The sample bottles were immediately placed in ice water and transported to the laboratory. The pH values were measured as soon as possible, usually 20 min after sampling. The samples were always taken for the pH determinations in the order in which they had been obtained, and as both operations took about the same time, less than two minutes, the interval between the sampling and pH measurement was the same for each rumen sample. The pH measurements were made with a Beckman meter Model 76. Immediately afterwards the samples were centrifuged for 10 min at 2000 r.p.m. in order to separate the plant material. The ammonia and VFA determinations were made on the supernatant. Ammonia was determined colorimetrically immediately after centrifuging according to a modification of the method of McCULLOUGH (1967).

When the supernatant was removed with a pipette for the ammonia determination, 5 ml was also taken for the V F A determination. This sample was first treated with 1 ml of 35 % formaldehyde (in Exp. I) or with 0.5 ml of saturated mercuric chloride (in Exp. II) and made basic with 2 ml of 1 N NaOH, and then freeze-dried and kept at —18 to —20 °C until the VFA determinations were performed some months later. The VFA determinations were made by the gas chromatographic method (HUIDA, unpubl.) The preparation of the samples for the gas chromatography was as follows: The dried sample was mixed with 10 drops of concentrate H_3PO_4 and diluted with 40 ml of 5 % formic acid. It was mixed well in a shaker and left to settle for at least two hours, after which the supernatant was subjected to gas chromatographic analysis. The following acids were determined: acetic acid, propionic acid, butyric acid, isovaleric acid and valeric acid.

Blood analyses

The blood samples for the analyses were taken from the jugular veins of the rams only in Exp. II. They were taken twice in every experimental period, at the beginning and at the end of the collection period, before the morning feeding. About 10 ml of blood were led into tubes containing 150—200 i.u. heparin, and transported in ice water to the laboratory. There analyses were immediately started for: haematocrit, haemoglobin, glucose, urea, ammonia and mineral and trace elements.

The haematocrit values of the blood samples were determined by centrifuging the blood in capillary tubes closed at one end, in a microhaematocrit centrifuge of Heraeus-Christ Type 912. The centrifuging time was 5 min and the speed 15 000 r.p.m. A Hawskley Reader was used in reading the values.

Haemoglobin was determined colorimetrically using a spectrophotometer of Turner Model 350, wavelength 540 mμ, and a cyanmethemoglobin standard (Acuglobin). Ten μl blood was used in 5 ml of 0.1 % NH_3 solution.

Glucose was determined by the method of SOMOGYI (1945) as modified by NELSON (1944), ammonia by the method of McGULLOUGH (1967) and urea by the method of CHANEY and MARBACH (1962). All these three are colorimetric methods.

The mineral and trace elements were determined directly on plasma by the atomic absorption method (see p. 220).

RESULTS AND DISCUSSION

Chemical composition and quality of the experimental silages

The chemical composition of the dry matter is the same in the raw materials and the corresponding silages (Table 1, Appendix 1). However, the amount of N-free extract was greater in the raw materials than in the silages, while that of crude fat was smaller, as has also been noted in many other experiments (WATSON and NASH 1960). This is due to the fact that during the silage fermentation soluble carbohydrates, primarily sugars, are decomposed to fatty acids, which are dissolved in ether. In Exp. II the average sugar content of the dry matter of the fresh grass was 9.20 %, whereas the sugar contents of silages made from this material were as follows: AIV I silage 0.75 %, formic acid silage 3.10 % and Viher solution silage 1.45 %. The higher sugar ($P < 0.01$ or $P < 0.05$) and lower VFA ($P < 0.01$ or $P < 0.05$) contents in the formic acid silage, compared with the others (Table 2, Appendix 2), show that the fermenta-

Table 1. The mean chemical composition of the different silages.

Exp.	Added preservative	Dry matter	% of dry matter							
			Ash	Organic matter	Crude protein	True protein	Crude fat	N-free extract	Crude fibre	Crude carbo-hydrates
I	AIV II	23.67	8.21	91.78	22.23	8.04	7.29	37.25	25.00	62.25
II	AIV I	18.46^{ad}	10.57^{ade}	89.42^{ade}	18.31^{ad}	12.59^{ad}	5.57^{ad}	38.42^{ad}	27.11^{ad}	65.53^{ad}
	Formic acid	18.95^{be}	10.10^{bd}	89.89^{bd}	18.15^{ad}	12.77^{ad}	5.38^{bd}	39.91^{be}	26.44^{be}	66.35^{bd}
	Viher solution	18.29^{ad}	10.68^{ae}	89.31^{ae}	19.65^{be}	15.01^{be}	5.13^{ce}	38.29^{ad}	26.22^{be}	64.52^{ce}
	SE of means[1]	0.15	0.11	0.11	0.11	0.12	0.05	0.25	0.13	0.18

[1] SE = standard error

Statistical analysis applied only to results of Exp. II. The Tukey test (STEELE and TORRIE 1960) was used for testing the differences between the averages. Different index letters in a vertical column show that there are significant differences between the averages at the 95 % (a—c) and 99 % (d—e) levels of confidence.

Table 2. Data used as criteria of the quality of the different silages.

Exp.	Added preservative	pH	% of fresh silage (20 % dry matter)								% of total N	
			Acetic acid	Propionic acid	Butyric acid	Valeric acid	Lactic acid	Sugars as glucose	NH_3-N	Total N	NH_3-N	Soluble N
I	AIV II	4.06	0.39	—	—	—	1.51	0.36	0.04	0.67	6.2	62.7
II	AIV I	4.55^{ade}	0.76^{ad}	0.04^{ad}	+	+	1.45	0.15^{ad}	0.03	0.58^{ad}	5.3	34.5^{ad}
	Formic acid	4.41^{ad}	0.33^{be}	0.00^{be}	—	—	1.44	0.62^{be}	0.02	0.59^{ad}	4.1	32.7^{ab}
	Viher solution ..	4.83^{be}	0.59^{ade}	0.01^{be}	—	+	1.11	0.29^{ade}	0.03	0.65^{be}	4.5	29.1^{be}
	SE of means	0.06	0.06	0.00			0.10	0.08	0.00	0.01	0.46	1.10

Meaning of index letters same as in Table 1.

tion of the soluble carbohydrate fraction has been less in this silage than in the AIV I and Viher solution silages.

The amount of true protein and the proportion of NH_3-N and soluble N in the total N reflect the degradation of crude protein during silage fermentation. This degradation advanced far in the AIV II silage, but less in the silages of Exp. II (Tables 1 and 2). A contributory factor in the case of AIV II may be that Exp. I was continued until late in the summer. In Exp. II the Viher solution silage contained more true protein ($P < 0.01$) and less soluble N in the total N than the AIV I and formic acid silages made from the same material. The proportion of true protein in the crude protein was 76.4 % in the Viher solution silage, 68.8 % in the AIV I silage and 70.4 % in the formic acid silage. These findings can be due to the fact that Viher solution contains formaldehyde, which has been shown to protect proteins against degradation (Ferguson et al. 1967). Poutiainen and Huida (1970) have obtained similar results for true protein when they compared the chemical composition of silages made with different preservatives: AIV I and AIV II solutions, formic acid and Viher solution. The total amount of crude protein in the Viher solution silage of Exp. II was also higher than in the AIV I and formic acid silages ($P < 0.01$). This can be at least partly explained by the finding that the effluent of the Viher solution silage contained 0.69 % crude protein, whereas in the others the proportions were 0.97 % and 0.92 %, respectively. The lower value of the Viher solution silage may be an effect of the formaldehyde treatment. The ensilage technique employed made it impossible to measure the total amount of effluents.

The amounts of inorganic constituents of the silages in Exp. II were about the same (Table 3). They were determined on the samples of periods 4—6.

The quality of all the experimental silages was fairly good. The pH values were rather high in all except the AIV II silage and the amounts of butyric acid find in some samples were very small (Appendix 2). The mean proportion of NH_3-N in the total N was under 8 % (4.1—6.2 %), which is the maximum allowed for silage of good quality by Breirem and Ulvesli (1960) and Wieringa (1966). The quality of the silages of Exp. II changed during ensilage only in respect of the pH, the differences in it being the only statistically significant ones between the different experimental periods ($P < 0.001$), when tested by the least-square variance analysis.

Besides the quality and composition of the end product, the extent of the losses associated

Table 3. Inorganic constituents of different silages in Exp. 11, g/kg dry matter

	Ca	Mg	K	Na	P	Zn	Mn	Cu	Fe
AIV I	6.0	2.0	31.0	0.3	4.3	0.03	0.08	0.01	0.45
Formic acid	6.1	2.1	32.0	0.3	4.1	0.03	0.08	0.01	0.31
Viher solution ..	6.5	2.2	32.0	0.2	3.9	0.03	0.08	0.01	0.40

with it should also be considered in an evaluation of the ensiling method. In Exp. II the percentages of dry matter lost from the raw material owing to ensiling and spoiling were as follows:

Preservative	Effluent and fermentation losses	Spoiled	Total losses
AIV I	9 %	22 %	31 %
Formic acid	12 %	12 %	24 %
Viher solution	16 %	20 %	36 %

The effluent and fermentation losses were smallest in the AIV I silage. JARL (1948) obtained a value of 18.4 % of the dry matter for AIV silage and 26.5 % for formic acid silage, and ULVESLI et al. (1965) also obtained lower losses for AIV silage than for formic acid silage. It should be remembered that, even with the same method, the losses can vary greatly from year to year with the quality of the grass and other conditions (ULVESLI and SAUE 1965). The high value for spoiling in the AIV I and Viher solution silages is at least partly due to the fact that these silages became heated and moulded on the cut surface more readily than formic acid silage. The exceptionally mild winter in 1970—71 also probably promoted this spoiling.

The results show, that the ensiling of high-moisture grass in polythene-covered and vacuum-compressed stacks can produce silage of satisfactory quality. LANCASTER (1966) arrived at similar conclusions in experiments with different ensiling methods.

Effect of sucrose, starch and cellulose supplements on the utilization of silage

Digestibility

The digestibility percentages and the feeding values are calculated only for the silage and not for the whole diet. The digestibility of the sugar and starch supplements is taken as 100 %, since it is assumed that they are digested and absorbed in the alimentary tract of the animals (HUNGATE 1966, TOPPS et al. 1968). This is, in fact, roughly the case, since only small amounts of sugar and starch, 0.2—0.3 % of the dry matter, were found in the faeces of the animals on these diets. The digestibility values of the N-free extract and crude fibre of the cellulose supplements are taken to be 71 % and 91 %, respectively (POIJÄRVI 1941) and the other components of the

Table 4. F-values of least square variance analysis for digestibility, N balance and feeding values of silages in Exp. I and Exp. II. The numbers of degrees of freedom are indicated in parentheses.

	Experiments[1] F (1, 106)	Animals[1] F (8, 106)	Periods[1] F (8, 106)	Carbohydrates[1] F (6, 106)	Silages[2] F (2, 44)	Carbohydrate × silage[2] F (12, 44)
Digestibility, %						
Dry matter	411.16***	3.62***	3.33**	36.16***	8.73***	1.50
Organic matter	400.04***	3.21**	1.33	35.40***	8.91***	1.03
Crude protein	472.26***	1.93	1.98	53.53***	13.48***	0.94
Crude fat	208.45***	1.35	1.85	0.87	0.47	0.78
N-free extract	178.16***	1.81	3.59***	29.52***	1.12	0.98
Crude fibre	271.07***	5.28***	6.29***	17.85***	9.47***	1.82
Crude carbohydrates ..	301.19***	3.69***	1.19	30.00***	4.68*	1.07
N balance, g/day	24.83***	2.41*	1.81	3.74**	1.91	0.93
Biological value	39.94***	3.51**	2.38*	23.85***	1.87	0.81
kg/f.u.[3]	1 810.55***	1.47	0.54	13.99***	37.51***	0.93
DM kg/f.u.[4]	404.23***	2.69*	1.26	26.45***	10.94***	1.02
DCP g/f.u.[5]	609.04***	0.19	4.54***	14.90***	21.05***	0.55
DCP % in DM	1 463.51***	1.48	7.06***	38.77***	2.88	0.53

***P < 0.001
**P < 0.01
*P < 0.05

[1] from Exp. I and Exp. II
[2] from Exp. II
[3] 1 feed unit (f.u.(= 0.7 starch unit
[4] DM = dry matter
[5] DCP = digestible crude protein

Table 5. Digestibility, N balance and feeding values of silage in different carbohydrate diets in Exp. I

	Carbohydrate	Sucrose		Starch		Cellulose		SE of means
	0 %	15 %	30 %	15 %	30 %	15 %	30 %	
Digestibility, %								
Dry matter	78.1^{a}	76.4^{ab}	73.8^{bc}	77.3^{a}	71.6^{c}	79.2^{a}	78.3^{a}	0.59
Organic matter	80.8^{a}	79.1^{ab}	76.9^{b}	79.9^{ab}	74.4^{c}	81.9^{a}	81.4^{a}	0.58
Crude protein	80.5^{a}	77.6^{ab}	73.1^{c}	77.9^{ab}	70.2^{d}	78.7^{ab}	75.2^{bc}	0.80
Crude fat	80.2^{a}	79.8^{ab}	80.3^{a}	79.3^{ab}	76.1^{b}	79.4^{ab}	80.5^{a}	0.74
N-free extract	79.9^{ab}	78.4^{ab}	76.4^{bc}	79.2^{ab}	73.1^{c}	81.7^{a}	81.5^{a}	0.87
Crude fibre	82.7^{bc}	81.4^{c}	80.7^{c}	82.7^{bc}	79.7^{c}	85.7^{ab}	87.1^{a}	0.58
Crude carbohydrates	81.0^{ab}	79.6^{b}	78.1^{bc}	80.6^{ab}	75.7^{c}	83.3^{a}	83.7^{a}	0.65
N balance, g/day	3.57	3.84	4.37	2.94	2.01	2.43	2.87	0.45
Biological value	35.6^{c}	42.5^{bc}	53.1^{a}	38.6^{c}	43.0^{bc}	37.9^{c}	49.3^{ab}	1.79
kg/f.u.	5.08^{bc}	5.16^{bc}	5.30^{ab}	5.11^{bc}	5.49^{a}	4.98^{c}	5.01^{c}	0.04
DM kg/f.u.	1.20^{b}	1.22^{ab}	1.25^{a}	1.21^{ab}	1.30^{c}	1.18^{b}	1.19^{b}	0.01
DCP g/f.u.	217.3^{a}	210.7^{ab}	203.6^{bc}	209.7^{ab}	202.7^{bc}	206.4^{abc}	196.7^{c}	2.13
DCP % in DM	18.1^{a}	17.3^{abc}	16.3^{cd}	17.3^{ab}	15.6^{d}	17.5^{ab}	16.6^{bcd}	1.96

Statistical analysis: The Tukey test (STEELE and TORRIE 1960) was applied to the differences between the averages. Different index letters in a horizontal row show that there are significant differences between the averages at the 99 % level of confidence.

cellulose are assumed to be completely digestible. This does not correspond completely to the actual situation, but the indigestible parts of these components represent so small a proportion of the whole diet that they may be disregarded in the calculations of the digestibility coefficients (see p. 218).

The results of Exp. I and Exp. II are mainly expressed and statistically handled separately, because such significant differences were found between the two experiments (Table 4), although the different carbohydrate supplements affected the utilization of silage in the same way. The united results are shown only in Figs. 3—6.

The results of Exp. I (Table 5) are the averages of trials carried out with seven animals, except for the diets containing only silage (0 % carbohydrate) and 30 % cellulose supplements, where they are from only six animals. The fistulas of two animals on these diets broke during the experimental period and the animals stopped eating. The loss of appetite was probably caused by the admission of oxygen into the rumen (HOFLUND et al. 1948, HUNGATE 1966). The missing values were taken into consideration when calculating the results (STEEL and TORRIE 1960, p. 150), whereas the change of animals during the experiment was not taken into account.

The digestibility coefficients in Exp. I are fairly high. In the diets where sucrose, starch and cellulose constituted 15 % of the dry matter of the whole diet, the digestibility values of the different silage components do not differ markedly from those in the diet consisting entirely of silage. In the 15 % cellulose diet all the digestibility percentages except those of crude protein and crude fat are higher than in the 0 % carbohydrate and 15 % sucrose and starch diets. The significant differences in the digestibility values of dry matter and organic matter ($P < 0.05$) and crude carbohydrates ($P < 0.01$) are only between the 15 % cellulose and sucrose diets, whereas the digestibility of crude fibre in the 15 % cellulose diet differs significantly from the values of the 0 % carbohydrate and 15 % starch ($P < 0.05$) and sucrose ($P < 0.01$) diets.

In the diets where 30 % of the dry matter of the whole diet consisted of sucrose, starch and cellulose, the digestibility coefficients of the different components of the silage are lower than at the 15 % level. This is especially clear in the 30 % starch diet. The differences in the digestibility coefficients between the 0 % carbo-

hydrate and 30 % starch diets are significant ($P < 0.05$ or $P < 0.01$) for all the components. The 30 % sucrose addition depressed all the digestibility coefficients except that of crude fat, as compared with the 0 % carbohydrate diet, the differences being significant ($P < 0.01$) for dry matter, organic matter and crude protein. The 30 % cellulose addition decreased only the digestibility of crude protein ($P < 0.01$), whereas the digestibility of all the other components of the silage increased, as compared with those in the 0 % carbohydrate diet, the difference being significant ($P < 0.01$) in the case of crude fibre.

A comparison of the diets containing 30 % carbohydrate supplements reveals that the digestibility coefficients of all the silage components are lowest for the diet which contained 30 % starch. Further the diet with 30 % sucrose has lower digestibility values than that with 30 % cellulose. The digestibility coefficients in the 30 % cellulose diet differ significantly ($P < 0.01$) from those in the 30 % sucrose and starch diets for all the components except crude protein and crude fat, whose values differ only from those in the 30 % starch diet. In the 30 % starch diet the digestibility coefficients for organic matter, crude protein and crude fat are significantly lower ($P < 0.01$) than those in the 30 % sucrose diet.

A comparison of the diets with 15 % and 30 % levels of the same carbohydrate shows that in the sucrose diets the digestibility coefficients are significantly lower ($P < 0.01$) at the 30 % level than at the 15 % level only in respect to crude protein. In contrast, in the starch diets they are lower ($P < 0.05$ or $P < 0.01$) for all the components except crude fat. In the cellulose diets they do not differ significantly ($P > 0.05$) for any of the components of the silage.

The effects of the different carbohydrate supplements on the digestibility, N balance and feeding values of the silages in Exp. II are shown both for all the silages together (Table 6) and separately for each silage (Table 7). The results were united for the AIV I, formic acid and Viher solution silage diets at the same level of the same carbohydrate supplement, because no significant interactions were found between the silages and carbohydrate supplements (Table 4). The results in Table 6 are the averages of 27 trials at the 0 % carbohydrate level and 9 trials at each of the 15 % and 30 % levels of sucrose, starch and cellulose. In Table 7 they are the averages of 3 trials.

In contrast to the position in Exp. I, the 15 % sucrose and starch supplements in Exp. II (Table 6) significantly decreased the digestibility of the dry matter, organic matter, crude protein and crude carbohydrates ($P < 0.01$) and N-free extract ($P < 0.05$ or $P < 0.01$) of silage, compared with the values of the diet containing only silage. In the 15 % cellulose diet only the digestibility of crude protein was significantly lower ($P < 0.01$), although a slight decrease took place in the values of all the other components. Sucrose decreased about all the digestibility coefficients of silage most, followed by starch and then cellulose. The differences between these carbohydrates at the 15 % levels are, however, statistically significant ($P < 0.05$) only for crude protein in the sucrose and cellulose diets.

The 30 % carbohydrate supplements depressed the digestibility coefficients of silage more than the 15 % carbohydrate supplements, except those for crude fat, crude fibre and crude carbohydrates in the 30 % cellulose diet and for crude fat in the 30 % starch diet. The differences are significant ($P < 0.01$) between the 0 % carbohydrate and 30 % sucrose diets for the digestibility coefficients of all the components except crude fat, and between the 0 % carbohydrate and 30 % starch diets for all the components except crude fat and crude fibre. At the 30 % cellulose level they are significantly lower for crude protein ($P < 0.01$) and dry matter ($P < 0.05$) and higher for crude fibre ($P < 0.05$).

A comparison of the digestibility coefficients of the different carbohydrate diets at the 30 % levels shows that, as at the 15 % levels, sucrose decreased digestibility most, followed by starch and then cellulose, though there are small ex-

Table 6. Digestibility, N balance and feeding values of silages in different carbohydrate diets in Exp. II.

	Carbo-hydrate 0 %	Sucrose 15 %	Sucrose 30 %	Starch 15 %	Starch 30 %	Cellulose 15 %	Cellulose 30 %	SE of means 0 % diets	SE of means Other diets
Digestibility, %									
Dry matter	71.0^{a}	66.8^{bc}	62.9^{d}	67.8^{b}	64.0^{cd}	69.4^{ab}	68.7^{ab}	0.37	0.65
Organic matter	74.1^{a}	70.2^{bc}	66.0^{d}	71.1^{b}	67.7^{cd}	72.5^{ab}	72.3^{ab}	0.36	0.63
Crude protein	71.0^{a}	62.4^{bc}	56.5^{d}	66.0^{b}	58.8^{cd}	66.7^{b}	62.4^{bc}	0.54	0.93
Crude fat	71.8	73.1	71.9	71.7	72.6	71.1	71.5	0.39	0.67
N-free extract	74.7^{a}	71.8^{ab}	67.5^{cd}	71.0^{bc}	66.7^{d}	73.4^{ab}	72.6^{ab}	0.41	0.71
Crude fibre	76.0^{ab}	72.8^{bc}	69.6^{c}	74.5^{b}	74.2^{b}	75.4^{ab}	79.1^{a}	0.49	0.85
Crude carbohydrates	75.2^{a}	72.2^{bc}	68.3^{d}	72.5^{bc}	69.8^{cd}	74.3^{ab}	75.2^{ab}	0.35	0.61
N balance, g/day	2.39	2.49	3.00	2.03	2.18	1.56	1.38	0.25	0.44
Biological value	43.0^{c}	52.0^{ab}	58.4^{a}	47.1^{bc}	54.3^{ab}	46.8^{bc}	56.6^{a}	1.02	1.77
kg/f.u.	7.18^{c}	7.55^{abc}	7.97^{a}	7.45^{abc}	7.82^{ab}	7.43^{bc}	7.43^{bc}	0.06	0.10
DM kg/f.u.	1.33^{d}	1.41^{bc}	1.48^{a}	1.39^{bcd}	1.46^{ab}	1.37^{cd}	1.37^{cd}	0.01	0.01
DCP g/f.u.	177.0^{a}	165.0^{bc}	157.3^{c}	171.4^{ab}	160.1^{bc}	169.3^{abc}	158.6^{bc}	1.53	2.65
DCP % in DM	13.3^{a}	11.7^{bc}	10.6^{d}	12.3^{b}	11.0^{cd}	12.4^{b}	11.6^{bc}	0.10	0.18

Meaning of index letters same as in Table 5.

Table 7. Digestibility, N balance and kg/feed unit of AIV I, formic acid and Viher solution silages in different carbohydrate diets in Exp. II, expressed as absolute and relative values.

	Silage	Sucrose 0 % Abs.	Sucrose 0 % Rel.	Sucrose 15 % Abs.	Sucrose 15 % Rel.	Sucrose 30 % Abs.	Sucrose 30 % Rel.	Starch 0 % Abs.	Starch 0 % Rel.	Starch 15 % Abs.	Starch 15 % Rel.	Starch 30 % Abs.	Starch 30 % Rel.	Cellulose 0 % Abs.	Cellulose 0 % Rel.	Cellulose 15 % Abs.	Cellulose 15 % Rel.	Cellulose 30 % Abs.	Cellulose 30 % Rel.
Digestibility, %																			
Organic matter	AIV I	73.9	100	70.3	95	66.4	90	73.7	100	71.2	97	69.4	94	75.0	100	73.4	98	72.4	97
	Formic acid	74.1	100	70.6	95	66.0	89	74.9	100	71.8	96	66.2	88	76.5	100	75.3	98	73.5	96
	Viher solution	72.7	100	69.7	96	65.6	90	74.8	100	70.2	94	67.3	90	71.7	100	68.8	96	71.0	99
Crude protein	AIV I	71.6	100	63.2	88	55.6	78	71.5	100	66.9	94	61.5	86	72.1	100	68.2	95	62.6	87
	Formic acid	71.6	100	62.2	87	68.3	81	71.8	100	67.1	93	57.3	80	73.9	100	70.0	95	64.4	87
	Viher solution	68.3	100	61.8	90	55.5	81	70.6	100	64.0	91	57.6	82	67.7	100	61.8	91	60.2	89
Crude fibre	AIV I	74.8	100	72.3	97	68.0	91	75.7	100	74.6	99	74.5	98	78.2	100	78.8	101	82.7	106
	Formic acid	76.2	100	75.2	99	70.9	93	75.7	100	75.0	99	72.2	95	78.7	100	78.5	100	78.1	99
	Viher solution	75.3	100	70.9	94	69.8	93	78.8	100	73.8	94	76.0	96	70.4	100	69.0	98	76.4	109
N balance, g/day	AIV I	2.63	100	2.03	77	1.45	55	3.05	100	2.68	88	2.62	86	2.63	100	1.39	53	0.80	30
	Formic acid	3.53	100	3.30	93	5.52	156	2.32	100	2.31	100	1.60	69	2.02	100	1.84	91	0.83	41
	Viher solution	1.66	100	2.13	128	2.03	122	1.32	100	1.10	83	2.31	175	2.33	100	1.46	63	2.51	108
Kg/f.u.	AIV I	7.22	100	7.60	105	7.85	109	7.16	100	7.43	104	7.61	106	7.27	100	7.43	102	7.51	103
	Formic acid	6.98	100	7.31	105	7.83	112	6.90	100	7.19	104	7.81	113	6.85	100	6.97	102	7.13	104
	Viher solution	7.42	100	7.75	104	8.23	111	7.25	100	7.73	107	8.05	111	7.56	100	7.88	104	7.64	101

ceptions in the case of crude fat and N-free extract. It should be mentioned here that in Exp. I starch depressed the digestibility of silage more than sucrose at the 30 % level, whereas at the 15 % level the depression caused by sucrose was slightly greater. The digestibility coefficients of silage are higher ($P < 0.01$) in the 30 % cellulose diet than in the 30 % sucrose and starch diets for all the components except crude protein, whose value is higher ($P < 0.01$) only compared with that of the 30 % sucrose diet, and crude fat, whose value is slightly lower than in the 30 % sucrose and starch diets. The differences between the 30 % sucrose and starch diets are significant ($P < 0.01$) only in the case of crude fibre, the value being lower in the former diet.

A comparison of the diets with 15 % and 30 % levels of the same carbohydrate shows that in the sucrose and starch diets the digestibility coefficients at the 30 % level are significantly ($P < 0.01$) lower than at the 15 % level for all the components except crude fat and crude fibre in the sucrose diets, and crude fat, crude fibre and crude carbohydrates in the starch diets. In the cellulose diets they differ significantly ($P < 0.05$) only in the cases of crude protein and crude fibre, the former being higher and the latter lower at the 15 % level than at the 30 % level.

The relative values in Table 7 are calculated separately for each Latin square (3×3) (see Fig. 2) on the basis of the corresponding values at the 0 % carbohydrate level. The effect of the different carbohydrate supplements on the values reflecting the utilization of AIV I, formic acid and Viher solution silages was about the same, as may be seen from the absolute and relative values (Table 7, Appendix 3) and the F-values of the analysis of variance (Table 4). In the 15 % cellulose diets there are some differences between the digestibility values of the AIV I, formic acid and Viher solution silages, the values of the Viher solution silage being lower than those of the others. In the case of crude protein the differences are especially high, but since similar differences also exist in the 0 % carbohydrate diets, these cannot be attributed entirely to the influence of the cellulose supplements. The effect of the various preservatives on the utilization of silage are examined later in this paper (Table 17).

On the average (see also Figs. 3—5) the sucrose and starch supplements depressed the digestibility of all the components of the silage, the decrease generally being greater at the higher level of these readily available carbohydrates. This agrees with the results of experiments where large amounts of sugar (MITCHELL and HAMILTON 1940, HAMILTON 1942, WOODS et al. 1956, SYRJÄLÄ 1971 b) and starch (BURROUGHS et al. 1949, 1950 a) were added to diets of hay or hay and concentrates. This depression of digestibility may be due to the fact that readily fermentable sucrose and starch were utilized at the expense of the digestion of the components of the basic diet.

It is known that when there is a change in the type of food entering the rumen, the microorganisms in the rumen show a change in their total number and in the relative proportions of the species (QUIN 1943, ELSDEN 1945, GALL et al. 1951). Thus with an increase in the proportion of sucrose or starch in the ration, the sucrose- or starch-digesting organisms probably increase in relative number (HUNGATE et al. 1952, KROGH 1959, 1961). It has further been shown (OXFORD 1964) that many of the rumen bacteria digesting polysaccharides can use mono- and disaccharides, too. From this it follows that the utilization of fibrous feed is depressed, if sugars are available in large amounts. If the amounts of readily available carbohydrate supplements were smaller than those used in these experiments, it is possible that they might improve the digestibility of the roughage diet by increasing the number of rumen microorganisms or their activity, but not being their whole energy source. It has been shown that small amounts of sucrose (HOFLUND et al. 1948) and starch (ARIAS et al. 1951, BELASCO 1956) can enhance the digestibility of cellulose. Thus digestibility was improved in the experiments of CHAPPELL and FONTENOT (1968) when glucose

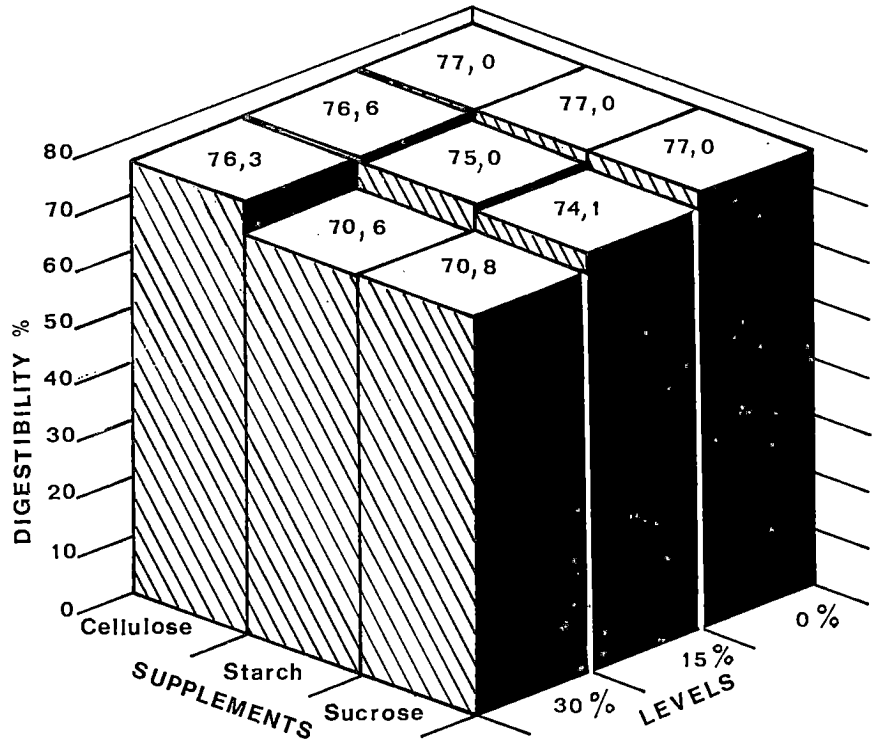


Fig. 3. Digestibility of organic matter of silage in different carbohydrate diets in Exp. I and Exp. II.

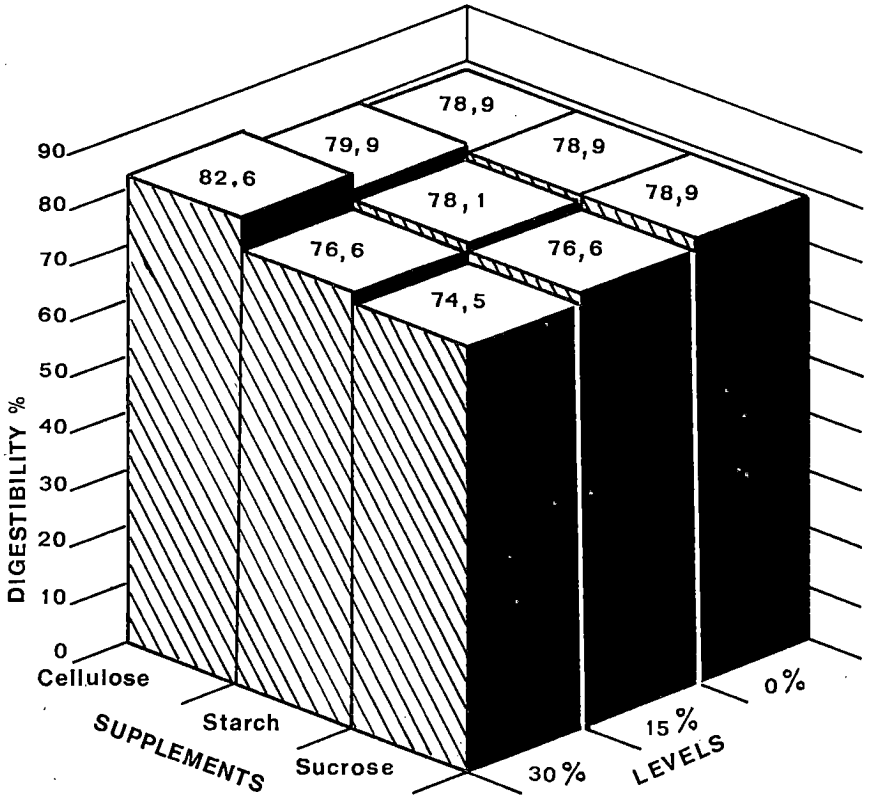


Fig. 4. Digestibility of crude fibre of silage in different carbohydrate diets in Exp. I and Exp. II.

and maize starch replaced about 8 % of the cellulose in a purified ration for sheep, but decreased when the amount of these readily available carbohydrates exceeded 32 %.

The additions of cellulose did not greatly change the digestibility of the components of silage except that of crude protein, which decreased in the same way as at the corresponding sucrose and starch levels, and that of crude fibre, which increased, especially at the 30 % cellulose level. This may at least partly be due to the fact that cellulose ferments more slowly in the rumen than readily available carbohydrates (PHILLIPSON 1942, PHILLIPSON and MCANALLY 1942). The silage is thus probably better able to compete with cellulose as the energy source for the rumen microbes than with sucrose and starch. In comparisons of the effects of the different carbohydrate supplements on the digestibility coefficients of the silage components, it should be noted that when they were calculated, the N-free extract and crude fibre components of the cellulose supplements were not assumed to be completely digestible. It is possible that the digestibility coefficients of POIJÄRVI (1941) used for the cellulose preparation are too low, and that the components of the silage containing these crude carbohydrates have received too favourable digestibility values, especially in the diets with the higher cellulose supplements. In numerous experiments with sulphite cellulose, HVIDSTEN (1946) obtained a digestibility coefficient of 71 % for N-free extract, the same as that reported by POIJÄRVI (1941), and 95 % for crude fibre, which is 4 %-units higher than the value of Poijärvi. The chemical composition of the sulphite cellulose preparation was about the same in those investigations as in the present ones, too.

It is not possible to suggest a completely satisfactory explanation for the contradiction between the results obtained in Experiments I and II with the 30 % sucrose and starch supplements. In Exp. I the digestibility coefficients were higher with the sucrose than with the starch supplements, whereas in Exp. II the situation was the opposite. The stage of growth of the raw materials of the silages, which was earlier in Exp. I than in Exp. II (Table 1), may be partly responsible. The degradation of the silage in Exp. I can be assumed to have been more quickly completed in the rumen than in Exp. II, as the sucrose would be degraded more rapidly than the starch (PHILLIPSON 1942, PHILLIPSON and MCANALLY 1942). This is also shown by the fact that the pH values of the rumen fluid samples taken after feeding were lower in Exp. I than in Exp. II (Tables 12 and 13). However, this explanation can only be accepted with certain reservations; the silages in the two experiments were made from the crops of different years, and the botanical composition of the raw materials and the methods of preservation were not the same. These differences between the conditions of Exp. I and Exp. II are the main reason why the results of these two experiments are treated separately in this paper.

Nitrogen retention

The different carbohydrate supplements influence the retention of nitrogen by the animal in different ways. Both in Exp. I (Table 5) and in Exp. II (Table 6) the N balance increased with the addition of sucrose and was greatest at the higher level of the supplement, whereas it decreased with the starch and cellulose supplements (see also Fig. 6). However, the differences between the diets are statistically significant ($P < 0.05$) only in the case of the 30 % sucrose and starch diets in Exp. I.

It is notable that while all the carbohydrate supplements decreased the apparent crude protein digestibility of silage, the N balance was decreased only by the starch and cellulose supplements, sucrose supplements tending to increase it. The different effect of sucrose may perhaps partly be ascribed to the different rates of fermentation of the carbohydrates. The rumen N metabolism of sheep on silage is more intense and more quickly completed than that of animals on a hay and straw ration (TANCUROV 1971). It is possible that, unlike sucrose, cellulose and even starch do not become available

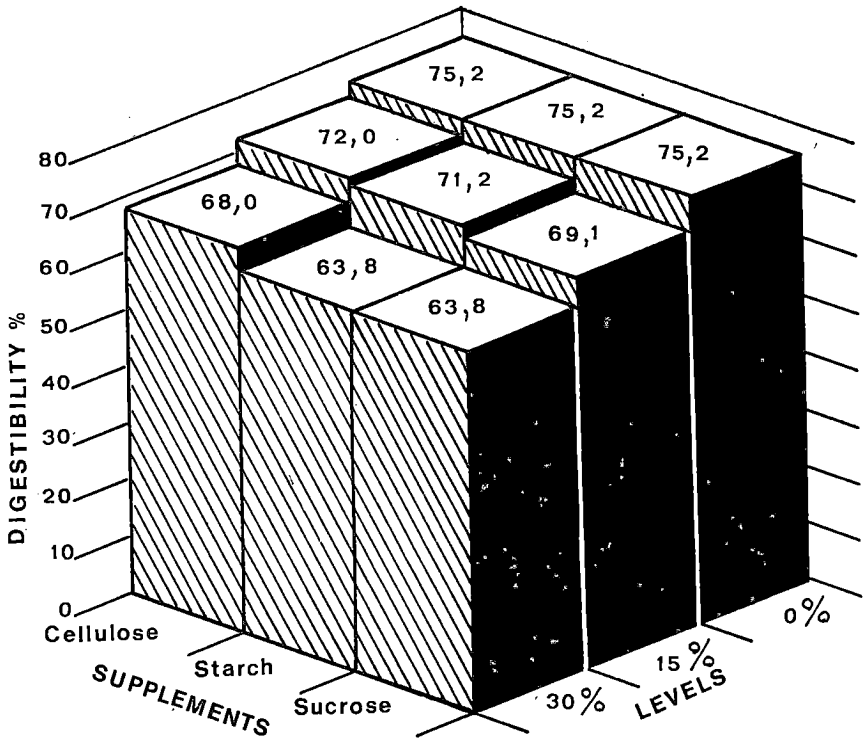


Fig. 5. Digestibility of crude protein of silage in different carbohydrate diets in Exp. I and Exp. II.

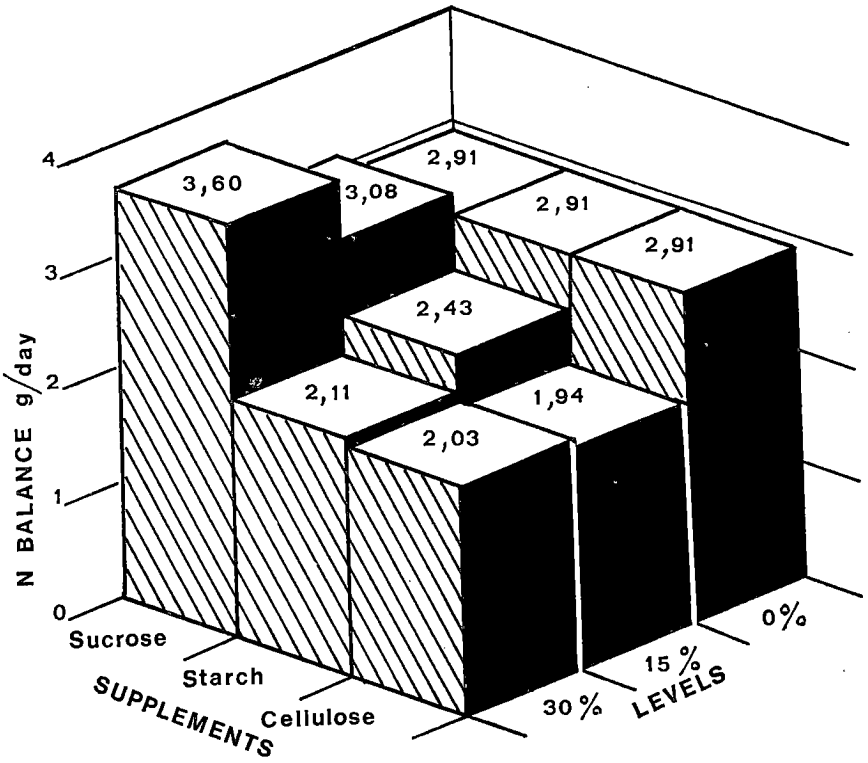


Fig. 6. N balance of the sheep on different carbohydrate diets in Exp. I and Exp. II.

for the rumen microbes sufficiently quickly when the silage is being degraded and ammonia released. Thus they are probably not able to compete as effectively with the components of silage for the role of the energy source of microbial protein synthesis. The fact that N utilization is better with sucrose than with starch and cellulose on these silage diets is also shown by the finding that sucrose can reduce the ammonia concentration in the rumen more effectively than starch or cellulose, which will be dealt with later in this paper (Tables 12 and 13).

With other roughage diets, however, the effect of starch on N utilization has been found to be the reverse. In experiments where starch was added to a hay diet for sheep (HEAD 1953, DROR et al. 1969), N utilization was not decreased, although the digestibility of protein was depressed. Starch has been found to improve N retention in fresh frozen clover and lucerne diets (DU PLESSIS and MERVE 1969), and in a semi-purified cellulose diet (CHAPPELL and FONTENOT 1968). DROR et al. (1969) supposed that the extent of N utilization with starch supplements depends on the nature of the roughage diet and on the energy: protein ratio. In experiments where different carbohydrates were examined in relation to urea utilization, starch was found to promote utilization best, while the least favourable effect was apparently that of cellulose. Starch is also superior to molasses or simple sugars (REID 1953, HELMER and BARTLEY 1971). As an explanation of the superiority of starch, it has been suggested that the sugars are absorbed or passed from the rumen or degraded too rapidly to be of much use to the micro-organisms, whereas cellulose is not hydrolyzed sufficiently rapidly to become available at the time when it is needed by the bacteria. The present investigations show, however, that sucrose can be of use to the rumen micro-organisms when grass silage is fed.

ELLIS and PFANDER (1958) found with a semi-purified diet for lambs that the N balance decreased with an increase in the proportion of cellulose. They suggested that protein was being catabolized to compensate for reduced total digestible nutrient intake. However, it is unlikely that this is the explanation of the decreases in the N balances with the cellulose supplements in the present silage experiments. At the 15 % and 30 % carbohydrate levels the animals received digestible energy in excess of their maintenance requirement and also in greater quantity than on the diet consisting entirely of silage as will be seen later (Table 9). Nor can the lower amount of crude protein in the diets containing carbohydrate supplements be the reason for the depressed N balance, because even the diets containing 30 % carbohydrate supplements had rather high crude protein contents (Table 8), which were in excess of the animals' requirements (Table 9 and p. 234). It should be remembered that, unlike the starch and cellulose supplements, the sucrose supplements did not depress the N balances, but rather increased them, although the crude protein levels of these diets were the same.

Table 8. Average crude protein content of different diets.

Diets	Exp. I		Exp. II	
	g	% of DM	g	% of DM
0 % carbohydrate	210.5	22.2	173.7	18.7
15 % »	179.0	18.9	147.7	15.9
30 % »	147.0	15.5	121.7	13.1

Other feeding values

In this paper the discussion of »feeding values» will primarily treat the values of the protein and energy available for animals in grass silage feeding.

The biological value of the protein is estimated with the formula of Mitchell (MAYNARD and LOOSLI 1962, p. 396):

$$\frac{\text{N intake} - (\text{faecal N} - \text{metabolic N}) - (\text{urinary N} - \text{endogenous N})}{\text{N intake} - (\text{faecal N} - \text{metabolic N})} \times 100$$

where metabolic N = 5 g/kg dry matter eaten and endogenous N 0.146 kg × live weight$^{0.75}$

All the carbohydrate supplements used in these experiments (Tables 5 and 6) improved the biological value of the silage and the value rose with the elevation in the level of the carbohydrates. The effect of sucrose was the greatest. In Exp. I, however, only the biological values of the 30 % sucrose and cellulose diets differed significantly ($P < 0.01$) from those of the 0 % carbohydrate diet, whereas in Exp. II those of the 15 % sucrose and 30 % starch diets also differed significantly ($P < 0.01$). As in the case of digestibility and N balance, it must be remembered that these results can be affected by the amount of protein in the diet. The biological value of protein has been shown to increase when the amount of protein in the diet decreases (Boas Fixsen 1935, Blaxter and Wood 1951). It is thus better to compare only diets with the same levels of carbohydrates because they also contain the same amounts of protein.

At the 15 % carbohydrate levels in Exp. I, the biological values of protein do not differ significantly ($P > 0.05$) from each other, but at the 30 % levels sucrose diet has a higher value ($P < 0.01$) than the starch diet. The value of the corresponding cellulose diet does not differ significantly ($P > 0.05$) from the other two. In Exp. II there are no significant differences ($P > 0.05$) between the different carbohydrate supplements at the same levels, but the biological value of protein was again highest with the sucrose supplements.

Further data reflecting the effects of the different carbohydrate supplements on the value of silages fed to sheep are provided in the four lowest rows in Tables 5 and 6. The energy values of the experimental silages are calculated on the basis of their chemical composition and digestibility. The coefficients used for the digestible nutrients were obtained from NJF tables of feedstuffs (Anon. 1969), and are 0.94 for crude protein and 1.00 for crude fat, N-free extract and crude fibre. Value number 80 is used in calculating the energy value for silage. A feed unit (f.u.), which is equal to 0.7 of a starch unit, is used as the measure of the energy content of the feed.

The silages used in these experiments were of rather good quality (Table 2), especially in Exp. I, as has also been shown by the results of the digestibility trials. Only 5.08 kg of the silage of Exp. I is needed to make up a f.u. and its bulk is 1.20 kg dry matter/f.u. At the 15 % levels the sucrose and starch supplements increased these figures only slightly, whereas at the 30 % levels they were significantly higher ($P < 0.05$ or $P < 0.01$). In contrast, the cellulose supplements decreased them slightly, which means that in Exp. I cellulose had a more favourable effect on the energy value and bulk of silage than sucrose and starch. The silages of Exp. II having lower dry matter contents and digestibility coefficients, about 2 kg more are needed for a f.u. than in Exp. I. The effect of the sucrose and starch supplements on the amount per f.u. was similar to that in Exp. I, but the effect of cellulose was different: the cellulose supplements did not decrease the amount, but slightly increased it. All the carbohydrate supplements decreased the bulk of the silages in Exp. II, the effect of the sucrose and starch supplements being significant ($P < 0.05$ or $P < 0.01$) at both levels.

The content of digestible crude protein (DCP) was higher in the silage of Exp. I than in Exp. II, but the effect on it of the carbohydrate supplements was about the same in both experiments. At all the 30 % carbohydrate levels, and also at the 15 % sucrose level in Exp. II, the DCP amounts decreased so much that the differences from the 0 % carbohydrate diets were significant ($P < 0.01$).

The average daily amounts of DCP and energy received by the animals on the different diets are presented in Table 9. The average f.u. values of the silage in the different diets varied from 0.18 to 0.20 in Exp. I and from 0.12 to 0.14 in Exp. II. When the digestible nutrients of silage are multiplied by the coefficients of metabolizable energy (ME) (Anon. 1969),

Table 9. Average daily amounts of digestible crude protein and energy per sheep received from different diets.

Diets	Exp. I			Exp. II		
	DCP g	f.u.	ME Mcal	DCP g	f.u.	ME Mcal
0 % carbohydrate	169.5	0.79	2.60	123.3	0.70	2.25
15 % sucrose	138.9	0.86	2.69	92.2	0.75	2.32
30 % »	107.5	0.93	2.75	68.8	0.81	2.37
15 % starch	139.4	0.87	2.69	97.5	0.75	2.32
30 % »	103.2	0.91	2.69	71.6	0.84	2.40
15 % cellulose	140.9	0.85	2.61	98.5	0.76	2.22
30 % »	110.5	0.90	2.56	75.9	0.82	2.24

which are 4.3 for crude protein, 5.0 for crude fat, 3.7 for N-free extract and 2.9 for crude fibre, a Mcal value of 3.25 x f.u. is obtained. A f.u. value of 1.43 and a Mcal value of 3.61 (ibid.) are used for the dry matter of sucrose and starch. The corresponding values for cellulose are obtained in the same way as those of silage, using the coefficients for grain products in the NJF tables and value number 95. Thus 1 kg of the dry matter of cellulose contains 1.20 f.u. and 2.65 Mcal ME.

The daily DCP and energy amounts received by the animals were higher than the maintenance requirements for an adult sheep weighing 60—70 kg (Poijärvi 1948, Anon. 1965, Kellner and Becker 1971), which are on the average 55 g DCP and 0.6 f.u. This was also indicated by a slight increase in the live weight of most of the experimental animals (Table 10).

Table 10. Average change (kg) in live weight of animals on different diets.

Exp.	Carbohydrate 0 %	Sucrose 15 %	Sucrose 30 %	Starch 15 %	Starch 30 %	Cellulose 15 %	Cellulose 30 %
I	1.5	1.3	1.4	1.0	0.7	2.1	1.0
II	— *	— 0.6	0.6	0.7	0.6	0.8	— 0.5

* is disregarded, because the animals has silage *ad libitum* on the 10 first days of every preliminary period, in contrast to the other diets.

Table 11. F-values of least square variance analysis for pH, ammonia nitrogen and volatile fatty acids of the rumen fluid of sheep in Exp. I and Exp. II.

	Experiments [1]	Animals [1]	Periods [1]	Sampling times [1]	Carbohydrates [1]	Silages [2]	Carbohydrate [2] × silage
pH	67.62	14.11	28.27	324.84	32.62	11.36	1.13 NS
NH_3-N, mg/100 ml	98.80	4.14	3.77	552.10	119.61	25.73	2.69
Total VFA, mmoles/100 ml	144.61	22.64	6.29	742.44	23.42	19.85	2.87
Acetic acid, molar %	759.90	13.10	4.88	446.70	68.82	2.48 NS	3.00
Propionic acid »	281.84	24.13	2.18	86.24	13.32	0.29 NS	3.77
Butyric acid »	116.97	2.81	7.11	143.42	74.04	0.90 NS	8.01
Isovaleric acid »	52.46	3.20	6.17	71.72	30.46	5.98	0.49 NS
Valeric acid »	488.34	2.62	4.49	278.70	14.80	3.72	1.52 NS
Ratio acetic: propionic	531.77	23.28	5.11	182.04	23.39	0.97 NS	2.67
» acetic: butyric	107.38	2.54	6.23	97.17	43.55	0.62 NS	2.28
» propionic: butyric	0.78 NS	6.12	4.36	10.18	18.05	0.00 NS	2.20
	F(1, 1 105)	F(8, 1 105)	F(8, 1 105)	F(2, 1 105)	F(6, 1 105)	F(2, 690)	F(12, 690)
$P < 0.001$	10.83	3.27	3.27	6.91	3.74	6.91	2.74
$P < 0.01$	6.63	2.51	2.51	4.61	2.80	4.61	2.18
$P < 0.05$	3.84	1.94	1.94	3.00	2.10	3.00	1.75

The values not followed by NS are statistically significant

[1] from Exp. I and Exp. II
[2] from Exp. II

Rumen fermentation

The results concerning rumen fermentation are also presented and treated separately for Exp. I and Exp. II, except in Figs. 7—9 and Table 16. This is done because of the great differences between these results (Table 11), which are probably attributable to the differences between the silages used, as in the case of digestibility (see p. 229).

As the samples from the rumen were taken on the three last days of every experimental period and there were 7 periods in Exp. I, the values in Table 12 are the averages of 21 samples in all the diets except in the 0 % carbohydrate and 30 % cellulose diets, where they are based on 18 samples. The missing values are taken into consideration in the statistical treatments of the results (STEEL and TORRIE 1960, p. 324).

The results in Exp. II are shown combined for all the silages (Table 13) and also separately for each silage (Table 14). The values in the former case are the averages of 81 samples in the 0 % carbohydrate diet and of 27 samples in each of the diets containing carbohydrate supplements. In the latter case they are the averages of 27 samples, since there were three sampling times (Appendix 4). Each Latin square is kept separate in the calculations and tests of the results concerning the effect of the different carbohydrate supplements on rumen fermentation with different silage diets (Table 14). This is done because the results relating to rumen fermentation processes can vary considerably with the animal and especially the period in an experiment lasting some time (Table 11). In a 5 × 5 Latin square experiment, MOIR and SOMERS (1957) found significant differences between sheep and periods with regard to pH, ammonia and total VFA.

pH values

The pH values of the rumen fluid samples in Exp. I (Table 12) and Exp. II (Table 13) agree in most cases, although they are slightly higher throughout Exp. II than in Exp. I.

The 15 % sucrose and starch supplements had about the same effect on the pH of the rumen fluid, and changed it only slightly compared with pure silage. However, with the 15 % starch diet the pH of samples taken 5.5 hr after feeding remained about the same as in the 2.5 hr samples, whereas with the 15 % sucrose diet it had increased. The situation was the same at the 30 % levels: the starch supplements kept the pH low for a longer time than the sucrose supplement (Fig. 7). This is at least partly attributable to the fact that starch is fermented slower in the rumen than sucrose (PHILLIPSON 1942, PHILLIPSON and MCANALLY 1942, CZERKAWSKI and BRECKENRIDGE 1969). The 30 % sucrose and starch supplements decreased the pH more strongly than the 15 % diets in the samples taken 2.5 and 5.5 hr after feeding, so that it differed significantly ($P < 0.05$) from that of the diets containing silage alone. It is noteworth that the effects of the 15 % and 30 % cellulose supplements differed from those of the sucrose and starch. Cellulose fermentation in the rumen was slow and probably continued throughout the day, because the sampling time had only a slight effect on the pH with these supplements. In spite of these differences between the carbohydrate diets and sampling times, the pH values on all the diets were between 6.1 and 6.9 and can be kept optimal for normal feeding (ANNISON and LEWIS 1962).

A comparison of the effect of different carbohydrate supplements on the pH values with AIV I, formic acid and Viher solution silages (Table 14, Appendix 4) does not reveal any notable differences between silages with the same carbohydrate supplement. The pH values obtaining with the silages at the 0 % carbohydrate levels are examined in more detail later in this paper (Table 18).

Ammonia concentration

Both in Exp. I (Table 12) and in Exp. II (Table 13) the ammonia concentrations in the rumen samples are lower at every sampling time on diets containing carbohydrate supple-

Table 12. pH, ammonia nitrogen and volatile fatty acids in the rumen fluid of sheep on different carbohydrate diets in Exp. I.

	Sampling time	Carbohydrate 0 %	Sucrose 15 %	Sucrose 30 %	Starch 15 %	Starch 30 %	Cellulose 15 %	Cellulose 30 %	SE of means
pH		6.71^{a}	6.72^{a}	6.72^{a}	6.66^{a}	6.66^{a}	6.48^{b}	6.44^{b}	0.03
NH_3-N, mg/100 ml		15.3^{a}	11.4^{b}	7.9^{c}	13.4^{ab}	10.1^{bc}	10.2^{bc}	9.9^{bc}	0.74
Total VFA, mmoles/100 ml	Before	6.79^{cd}	6.40^{d}	6.24^{d}	7.09^{bc}	6.58^{cd}	7.90^{b}	8.61^{a}	0.15
Acetic acid, molar %	feeding	72.2^{ab}	69.8^{bc}	70.0^{abc}	69.8^{abc}	68.5^{c}	72.3^{abc}	72.0^{a}	0.65
Propionic acid »		18.1	19.6	20.0	19.1	19.0	17.9	19.4	0.58
Butyric acid »		8.0^{ab}	8.8^{ab}	8.6^{ab}	8.5^{ab}	10.0^{a}	8.6^{ab}	7.9^{b}	0.49
Isovaleric acid »		1.4^{ab}	1.2^{abc}	0.9^{bc}	1.6^{a}	1.7^{a}	0.8^{cd}	0.3^{d}	0.12
Valeric acid »		0.4	0.5	0.5	1.0	0.7	0.4	0.3	0.14
Ratio acetic: propionic		4.01	3.59	3.62	3.71	3.61	4.07	3.80	0.12
» acetic: butyric		9.13^{ab}	8.32^{ab}	8.17^{b}	8.24^{ab}	7.07^{b}	9.40^{ab}	10.29^{a}	0.23
» propionic: butyric		2.28	2.31	2.34	2.27	1.95	2.29	2.69	0.15
pH		6.43^{a}	6.30^{ab}	6.21^{b}	6.32^{ab}	6.09^{c}	6.27^{b}	6.26^{b}	0.03
NH_3-N, mg/100 ml		55.6^{a}	38.7^{cd}	29.4^{e}	44.4^{bc}	31.3^{de}	50.5^{ab}	40.4^{cd}	1.73
Total VFA, mmoles/100 ml	2.5 hr	11.22^{a}	10.51^{ab}	9.93^{b}	10.97^{ab}	10.40^{ab}	11.62^{a}	11.07^{a}	0.26
Acetic acid, molar %	after the	58.4^{b}	54.5^{c}	52.2^{c}	60.0^{b}	59.2^{b}	60.0^{b}	62.7^{a}	0.57
Propionic acid »	beginning	20.8^{b}	24.6^{a}	22.7^{ab}	21.9^{ab}	20.7^{b}	22.5^{ab}	22.1^{ab}	0.73
Butyric acid »	of feeding	14.6^{bc}	16.3^{b}	21.0^{a}	12.7^{cd}	14.9^{bc}	12.5^{bcd}	11.0^{d}	0.87
Isovaleric acid »		3.8^{a}	2.7^{bc}	1.7^{d}	3.3^{ab}	3.0^{abc}	2.9^{abc}	2.3^{cd}	0.17
Valeric acid »		2.4	2.0	2.4	2.2	2.2	2.1	1.9	0.14
Ratio acetic: propionic		2.84^{abc}	2.45^{c}	2.48^{bc}	2.79^{abc}	2.93^{a}	2.73^{abc}	2.95^{ab}	0.10
» acetic: butyric		4.15^{b}	4.17^{b}	2.80^{c}	4.88^{b}	4.25^{b}	5.29^{ab}	5.94^{a}	0.24
» propionic: butyric		1.48^{bc}	2.14^{ab}	1.30^{c}	1.80^{abc}	1.52^{bc}	2.05^{ab}	2.17^{a}	0.15
pH		6.55^{a}	6.50^{a}	6.42^{ab}	6.41^{ab}	6.15^{c}	6.31^{b}	6.30^{b}	0.03
NH_3-N, mg/100 ml		33.5^{a}	22.7^{bc}	12.8^{d}	23.4^{bc}	12.5^{d}	28.9^{ab}	20.6^{c}	1.55
Total VFA, mmoles/100 ml	5.5 hr	8.66^{abc}	8.41^{c}	8.26^{c}	8.68^{bc}	8.94^{abc}	9.53^{ab}	9.53^{a}	0.18
Acetic acid, molar %	after the	65.9^{ab}	62.6^{c}	60.6^{c}	65.8^{b}	65.1^{b}	67.0^{ab}	68.0^{a}	0.60
Propionic acid »	beginning	19.7	21.9	20.2	19.7	18.3	20.2	20.9	0.71
Butyric acid »	of feeding	11.2^{bc}	12.7^{b}	16.2^{a}	11.2^{bc}	13.2^{b}	10.1^{bc}	9.2^{c}	0.63
Isovaleric acid »		1.9^{a}	1.3^{b}	0.8^{c}	2.1^{a}	1.8^{a}	1.5^{ab}	1.0^{bc}	0.12
Valeric acid »		1.3^{b}	1.4^{b}	2.3^{a}	1.2^{b}	1.5^{b}	1.2^{b}	0.8^{b}	0.14
Ratio acetic: propionic		3.35^{ab}	3.06^{b}	3.22^{ab}	3.41^{ab}	3.70^{a}	3.39^{ab}	3.33^{ab}	0.13
» acetic: butyric		5.97^{b}	5.68^{b}	3.99^{c}	6.04^{b}	5.44^{b}	7.07^{ab}	7.59^{a}	0.30
» propionic: butyric		1.78^{abc}	2.17^{ab}	1.44^{c}	1.83^{abc}	1.55^{bc}	2.17^{abc}	2.37^{a}	0.15
pH		6.56^{a}	6.50^{a}	6.45^{ab}	6.46^{ab}	6.30^{c}	6.36^{bc}	6.33^{c}	0.03
NH_3-N mg/100 ml		34.8^{a}	24.3^{bc}	16.7^{c}	27.0^{ab}	18.0^{c}	29.9^{ab}	23.6^{bc}	1.86
Total VFA, mmoles/100 ml		8.89^{abc}	8.44^{c}	8.14^{c}	8.91^{abc}	8.64^{bc}	9.68^{abc}	9.74^{a}	0.23
Acetic acid, molar %		65.5^{abc}	62.3^{cd}	60.9^{d}	65.2^{abc}	64.3^{bc}	66.5^{ab}	67.6^{a}	0.77
Propionic acid »	Average	19.5^{b}	22.0^{a}	20.9^{ab}	20.2^{ab}	19.4^{b}	20.2^{ab}	20.8^{ab}	0.44
Butyric acid »		11.3^{b}	12.6^{b}	15.2^{a}	10.8^{bc}	12.7^{b}	10.4^{bc}	9.4^{c}	0.55
Isovaleric acid »		2.4^{a}	1.7^{bc}	1.1^{d}	2.3^{a}	2.2^{ab}	1.7^{ab}	1.2^{cd}	0.13
Valeric acid »		1.3^{b}	1.3^{ab}	1.7^{a}	1.4^{ab}	1.5^{ab}	1.2^{b}	1.0^{b}	0.12
Ratio acetic: propionic		3.40^{ab}	3.03^{b}	3.11^{ab}	3.30^{ab}	3.41^{a}	3.40^{ab}	3.36^{ab}	0.09
» acetic: butyric		6.42^{b}	6.06^{bc}	4.99^{c}	6.39^{b}	5.59^{bc}	7.25^{b}	7.94^{a}	0.31
» propionic: butyric		1.85^{bc}	2.21^{ab}	1.70^{c}	1.97^{bc}	1.67^{c}	2.17^{abc}	2.41^{a}	0.10

Statistical analysis performed separately for each sampling time. The Tukey test (STEELE and TORRIE 1960) was applied to the differences between the averages. Different index letters in a horizontal row show that there are significant differences between the averages at the 95 % level of confidence.

Table 13. pH, ammonia nitrogen and volatile fatty acids in the rumen fluid of sheep on different carbohydrate diets in Exp. II.

	Sampling time	Carbohydrate	Sucrose		Starch		Cellulose		SE of means	
		0 %	15 %	30 %	15 %	30 %	15 %	30 %	0 % diets	Other diets
pH	Before feeding	6.80^{a}	6.79^{ab}	6.85^{a}	6.75^{ab}	6.82^{a}	6.65^{bc}	6.56^{c}	0.02	0.03
NH_3-N, mg/100 ml		23.4^{a}	15.5^{c}	8.6^{d}	20.7^{b}	15.7^{c}	19.4^{b}	13.9^{c}	0.41	0.71
Total VFA, mmoles/100 ml		8.42^{c}	8.03^{cd}	7.53^{d}	8.63^{bc}	8.20^{c}	8.95^{ab}	9.40^{a}	0.08	0.15
Acetic acid, molar %		75.5^{a}	73.7^{bc}	72.6^{d}	74.3^{abc}	73.4^{bc}	75.1^{ab}	73.3^{cd}	0.24	0.42
Propionic acid »		16.1^{bc}	16.1^{bc}	16.7^{ab}	16.0^{bc}	15.5^{c}	15.4^{c}	17.6^{a}	0.16	0.27
Butyric acid »		6.4^{c}	7.9^{b}	9.3^{a}	7.8^{b}	8.5^{ab}	8.3^{b}	8.1^{b}	0.12	0.21
Isovaleric acid »		1.7^{ab}	1.9^{ab}	1.1^{ab}	1.6^{ab}	2.2^{a}	1.0^{ab}	0.8^{b}	0.18	0.31
Valeric acid »		0.3^{ab}	0.3^{ab}	0.4^{a}	0.3^{a}	0.3^{ab}	0.2^{ab}	0.2^{b}	0.03	0.04
Ratio acetic: propionic		4.73^{ab}	4.63^{abc}	4.41^{bc}	4.70^{abc}	4.83^{a}	4.90^{a}	4.37^{c}	0.06	0.10
» acetic: butyric		12.15^{a}	9.53^{b}	8.01^{c}	9.84^{b}	8.92^{bc}	9.15^{bc}	9.31^{b}	0.17	0.30
» propionic: butyric		2.58^{a}	2.08^{bc}	1.87^{c}	2.11^{bc}	1.88^{b}	1.88^{c}	2.25^{b}	0.04	0.07
pH	2.5 hr after the beginning of feeding	6.60^{a}	6.41^{cd}	6.31^{d}	6.46^{bc}	6.38^{cd}	6.55^{ab}	6.40^{cd}	0.02	0.03
NH_3-N, mg/100 ml		34.6^{a}	23.9^{c}	15.0^{d}	29.6^{b}	20.2^{c}	30.1^{b}	25.2^{c}	0.61	1.06
Total VFA, mmoles/100 ml		10.57^{a}	11.05^{a}	10.82^{a}	10.62^{a}	10.57^{a}	10.62^{a}	11.03^{a}	0.10	0.16
Acetic acid, molar %		70.6^{a}	65.1^{b}	59.3^{c}	72.0^{a}	71.8^{a}	71.3^{a}	71.2^{a}	0.37	0.64
Propionic acid »		19.0^{bc}	18.7^{bcd}	22.9^{a}	16.9^{cd}	16.5^{d}	17.8^{bcd}	18.7^{bc}	0.30	0.52
Butyric acid »		7.8^{c}	14.2^{b}	16.4^{a}	8.2^{c}	9.0^{c}	8.7^{c}	8.5^{c}	0.25	0.43
Isovaleric acid »		1.7^{bc}	1.1^{de}	0.5^{f}	2.0^{a}	1.3^{ab}	1.5^{cd}	1.0^{e}	0.05	0.08
Valeric acid »		0.8^{ab}	0.9^{ab}	1.0^{a}	0.9^{ab}	0.8^{abc}	0.7^{bc}	0.6^{c}	0.04	0.07
Ratio acetic: propionic		3.79^{c}	3.57^{c}	2.75^{d}	4.41^{ab}	4.49^{a}	4.07^{abc}	3.92^{bc}	0.07	0.13
» acetic: butyric		9.39^{a}	4.91^{b}	4.00^{b}	11.47^{a}	8.40^{a}	8.27^{a}	8.61^{a}	0.49	0.84
» propionic: butyric		2.48^{a}	1.41^{b}	1.61^{b}	2.74^{a}	1.88^{ab}	2.06^{ab}	2.28^{ab}	0.14	0.25
pH	5.5 hr after the beginning of feeding	6.64^{a}	6.62^{ab}	6.53^{bc}	6.45^{cd}	6.36^{d}	6.61^{ab}	6.50^{bc}	0.02	0.03
NH_3-N, mg/100 ml		24.7^{a}	11.9^{d}	6.3^{e}	18.0^{bc}	9.2^{de}	20.8^{b}	16.2^{c}	0.47	0.82
Total VFA, mmoles/100 ml		9.59^{bc}	9.34^{bc}	9.26^{c}	10.15^{a}	10.14^{a}	9.69^{abc}	9.99^{ab}	0.09	0.16
Acetic acid, molar %		74.1^{a}	71.3^{b}	66.6^{c}	74.9^{a}	73.7^{a}	74.1^{a}	73.0^{ab}	0.26	0.46
Propionic acid »		17.4^{abc}	16.3^{cd}	18.6^{a}	15.1^{d}	15.4^{d}	16.7^{bcd}	17.9^{ab}	0.22	0.38
Butyric acid		7.1^{d}	11.6^{b}	13.7^{a}	8.0^{cd}	8.9^{c}	8.3^{cd}	8.3^{cd}	0.20	0.35
Isovaleric acid »		1.0^{b}	0.3^{de}	0.2^{e}	1.5^{a}	1.4^{a}	0.8^{bc}	0.6^{cd}	0.05	0.08
Valeric acid »		0.4^{bc}	0.5^{b}	0.9^{a}	0.5^{b}	0.5^{b}	0.2^{c}	0.2^{c}	0.02	0.04
Ratio acetic: propionic		4.31^{b}	4.41^{b}	3.68^{c}	5.05^{a}	5.03^{a}	4.49^{b}	4.18^{b}	0.07	0.12
» acetic: butyric		10.76^{a}	6.50^{c}	5.19^{c}	9.76^{ab}	8.78^{b}	9.04^{b}	9.21^{b}	0.18	0.32
» propionic: butyric		2.50^{a}	1.49^{d}	1.48^{d}	1.94^{c}	1.83^{c}	2.03^{bc}	2.28^{ab}	0.05	0.08
pH	Average	6.68^{a}	6.61^{ab}	6.56^{bc}	6.55^{bc}	6.52^{bc}	6.60^{ab}	6.49^{c}	0.01	0.02
NH_3-N, mg/100 ml		27.5^{a}	17.1^{cd}	10.0^{e}	22.7^{b}	15.0^{d}	23.4^{b}	18.4^{c}	0.43	0.75
Total VFA, mmoles/100 ml		9.53^{bc}	9.48^{bc}	9.20^{c}	9.80^{ab}	9.64^{abc}	9.75^{abc}	10.14^{a}	0.08	0.14
Acetic acid, molar %		73.4^{a}	70.0^{b}	66.2^{c}	73.7^{a}	73.0^{a}	73.5^{a}	72.5^{a}	0.25	0.43
Propionic acid »		17.5^{bc}	17.0^{bcd}	19.4^{a}	16.0^{de}	15.8^{e}	16.6^{cde}	18.1^{b}	0.16	0.28
Butyric acid »		7.1^{d}	11.3^{b}	13.1^{a}	8.0^{c}	8.8^{c}	8.4^{c}	8.3^{c}	0.14	0.25
Isovaleric acid »		1.4^{ab}	1.1^{bc}	0.6^{d}	1.7^{a}	1.8^{a}	1.1^{bc}	0.8^{cd}	0.07	0.12
Valeric acid »		0.5^{b}	0.6^{b}	0.7^{a}	0.6^{b}	0.5^{b}	0.4^{c}	0.3^{c}	0.02	0.04
Ratio acetic: propionic		4.28^{b}	4.20^{b}	3.61^{c}	4.72^{a}	4.78^{a}	4.49^{ab}	4.16^{b}	0.05	0.08
» acetic: butyric		10.77^{a}	6.98^{d}	5.73^{d}	10.36^{ab}	8.70^{c}	8.82^{c}	9.04^{bc}	0.20	0.34
» propionic: butyric		2.52^{a}	1.66^{c}	1.65^{c}	2.26^{ab}	1.87^{c}	1.99^{bc}	2.27^{ab}	0.05	0.09

Meaning of index letters same as in Table 12.

Table 14. pH, ammonia nitrogen and volatile fatty acids in the rumen fluid of sheep on different diets in Exp. II. The values are the averages of the different sampling times.

	Sucrose			Starch			Cellulose		
	0 %	15 %	30 %	0 %	15 %	30 %	0 %	15 %	30 %
pH									
AIV I	6.59	6.55	6.48	6.67^{ad}	6.46^{be}	6.49^{bde}	6.78^{ad}	6.73^{ad}	6.52^{be}
Formic acid	6.71	6.68	6.66	6.57^{ad}	6.48^{ab}	6.40^{be}	6.58^{ad}	6.49^{ab}	6.45^{bd}
Viher solution	6.66	6.59	6.55	6.83^{ad}	6.71^{ab}	6.67^{bd}	6.70^{ad}	6.59^{ab}	6.49^{be}
NH_3-N, mg/100 ml									
AIV I	27.0^{d}	17.6^{e}	10.0^{f}	26.6^{ad}	23.5^{ad}	15.1^{be}	27.3^{ad}	24.8^{ab}	20.7^{be}
Formic acid	27.0^{d}	19.1^{e}	10.9^{f}	28.9^{ad}	22.1^{be}	16.7^{ce}	32.4^{ad}	24.5^{be}	20.0^{ce}
Viher solution	27.3^{d}	14.5^{a}	9.0^{f}	27.7^{d}	22.6^{e}	13.3^{f}	23.8^{ad}	20.9^{ad}	14.6^{be}
Total VFA, mmoles/100 ml									
AIV I	8.89	8.89	8.78	9.23	9.83	9.80	8.95^{bd}	9.43^{ab}	9.95^{ae}
Formic acid	10.07^{ad}	10.00^{ab}	9.10^{bd}	9.99	10.14	9.92	9.75	9.78	10.29
Viher solution	9.65	9.54	9.72	9.62	9.44	9.18	9.58	10.05	10.18
Acetic acid, molar %									
AIV I	73.3^{ad}	71.7^{ad}	66.1^{be}	74.2^{abd}	74.7^{ad}	71.5^{bd}	72.8	73.7	72.5
Formic acid	72.3^{ad}	69.8^{ab}	67.7^{be}	72.6	71.6	72.7	72.8	73.6	71.7
Viher solution	72.3^{ad}	68.6^{bde}	64.7^{ce}	76.7^{ad}	74.3^{bde}	74.7^{be}	72.5	73.2	73.3
Propionic acid, molar %									
AIV I	17.5	16.5	17.2	17.5	15.7	16.7	18.5^{ad}	16.8^{be}	19.1^{ad}
Formic acid	18.2^{ab}	17.9^{bd}	19.7^{ad}	17.6^{ad}	16.6^{ab}	15.5^{be}	17.3	16.1	17.3
Viher solution	17.1^{be}	16.7^{be}	21.3^{ad}	16.0	15.7	15.3	17.8	16.9	17.9
Butyric acid, molar %									
AIV I	6.4^{d}	10.1^{e}	15.3^{f}	6.8^{be}	7.7^{be}	9.8^{ad}	6.9^{d}	8.0^{e}	7.4^{f}
Formic acid	7.6^{be}	10.8^{ad}	11.1^{ad}	7.6^{be}	9.2^{ad}	9.1^{ad}	7.7^{be}	8.7^{ade}	9.4^{ad}
Viher solution	7.9^{be}	12.9^{ad}	12.9^{ad}	5.4^{be}	7.1^{ad}	7.6^{ad}	7.7^{be}	8.6^{ad}	8.0^{bde}
Isovaleric acid, molar %									
AIV I	1.7	1.3	0.6	1.2^{bd}	1.4^{abd}	1.5^{ad}	1.3^{ad}	1.1^{ad}	0.7^{be}
Formic acid	1.4^{ad}	1.0^{ab}	0.8^{be}	1.6	2.0	2.1	1.7	1.2	1.2
Viher solution	1.5^{d}	1.0^{e}	0.3^{f}	1.5^{be}	1.7^{ab}	1.9^{ad}	1.3^{d}	0.9^{e}	0.5^{f}
Valeric acid, molar %									
AIV I	0.4^{ad}	0.4^{ad}	0.7^{be}	0.4	0.5	0.5	0.5	0.4	0.3
Formic acid	0.5	0.6	0.7	0.5	0.7	0.5	0.4	0.3	0.4
Viher solution	0.6	0.7	0.8	0.5	0.5	0.5	0.6^{ad}	0.4^{be}	0.3^{be}
Ratio acetic: propionic									
AIV I	4.28^{ab}	4.46^{ad}	3.93^{bd}	4.35^{bd}	4.93^{ad}	4.53^{ab}	4.02^{bd}	4.43^{ade}	3.86^{be}
Formic acid	4.03^{ad}	3.95^{ab}	3.57^{bd}	4.22^{ad}	4.41^{ade}	4.88^{be}	4.28	4.65	4.27
Viher solution	4.34^{ad}	4.20^{ad}	3.33^{be}	4.86	4.83	4.95	4.12	4.38	4.34
Ratio acetic: butyric									
AIV I	11.68^{d}	7.64^{e}	5.07^{f}	11.22^{ad}	10.02^{ad}	7.68^{be}	10.64^{ad}	9.23^{be}	9.97^{ade}
Formic acid	10.27^{ad}	7.61^{be}	6.65^{be}	9.76	10.16	8.26	9.69^{ad}	8.58^{bde}	7.97^{be}
Viher solution	9.47^{ad}	5.68^{be}	5.47^{be}	14.57^{ad}	10.89^{be}	10.16^{be}	9.62^{ad}	8.66^{bd}	9.19^{ab}
Ratio propionic: butyric									
AIV I	2.75^{d}	1.72^{e}	1.26^{f}	2.60^{ad}	2.06^{be}	1.80^{ce}	2.68^{ad}	2.10^{be}	2.62^{ad}
Formic acid	2.53^{ad}	1.91^{be}	1.92^{be}	2.34	2.47	1.74	2.27^{ad}	1.87^{be}	1.94^{be}
Viher solution	2.19^{d}	1.35^{e}	1.78^{f}	3.01^{ad}	2.26^{be}	2.06^{ce}	2.34^{ad}	2.01^{be}	2.25^{ade}

Statistical analysis performed separately for each silage diets containing different levels of the same carbohydrate supplement. The Tukey test (STEEL and TORRJE 1960) was applied to the differences between the averages. Different letters in a horizontal row show that there are significant differences between the averages at the 95 % (a—c) and 99 % (d—e) levels of confidence.

ment than without it, the differences being significant ($P < 0.01$) in most cases, especially in samples taken 2.5 hr after feeding. Further it is lower at the 30 % level than at the 15 % level of the same carbohydrate supplement. The effect of the carbohydrates at the same level is in all cases in the same order, the ammonia concentrations being lowest with the sucrose supplements, higher with the starch and highest with the cellulose supplements, although there are some variations in its degree between Exp. I and Exp. II. At the 15 % levels in Exp. II the ammonia concentrations in the rumen fluid samples are significantly lower at every sampling time ($P < 0.05$) with the sucrose supplement than with the starch and cellulose sup-

plements. The situation is about the same at the 30 % levels, except in samples taken 5.5 hr after feeding, where the differences between the sucrose and starch diets are not significant ($P > 0.05$). In Exp. I the tendency is the same, although the differences are not significant in so many cases. The ammonia concentrations with the 15 % starch supplement are clearly lower than those with the 15 % cellulose supplement, especially in Exp. I, but the differences are not significant ($P > 0.05$). However, the differences are significant ($P < 0.05$) at the 30 % levels in about all the samples taken after feeding in both experiments.

A comparison of the effect of the different carbohydrate supplements on the rumen ammonia concentration with AIV I, formic acid and Viher solution silages (Table 14, Appendix 4), reveals that it is roughly the same with all the silages. It is perhaps worth mentioning that in samples taken 2.5 hr after feeding the 30 % starch and cellulose supplements decreased the ammonia concentration more with Viher solution than with formic acid and AIV I silages.

The above results agree with those of earlier investigations of McDONALD (1948, 1952) and others (BARNETT and REID 1961), where readily available carbohydrates were also found to depress the amount of ammonia in the rumen fluid. When these results are examined, it should, however, be borne in mind that the silage was the only nitrogen source in the present experiments and that its amounts decreased when the carbohydrate levels rose. CHALMERS (1961) found that when the concentration of ammonia in the rumen fluid is determined at intervals throughout the day, it is apparent that the form of its curve closely follows that of the intake of nitrogen. SCMEKEL (1967 a) and CISZUK (1972) also found that the amount of rumen ammonia depends on the amount of N in the ration. It is therefore better in this study to compare the effect of the different carbohydrates at the same level on the ammonia concentration in the rumen, because then the N content in the diets is the same. Figs. 7 and 8 show clearly the effects of the carbohydrates at the same levels and Fig. 7 also the considerable variation with the sampling time.

Since the extent of ammonia production in the rumen can be correlated with the utilization of dietary protein (CHALMERS and SYNGE 1954), it can be supposed that in these experiments sucrose had the best effect on the utilization of the dietary nitrogen, being followed by starch and then cellulose. The observation that the sucrose supplement improved N utilization on the silage diets more than the starch and cellulose supplements can be attributed to differences in the rates at which those carbohydrates are fermented in the rumen (PHILLIPSON 1942, PHILLIPSON and McANALLY 1942), and the intensity of rumen N metabolism of sheep on silage diets (TANCUROV 1971), discussed earlier in this paper in connection with the N balance (p. 230). In the experiments of LEWIS and McDONALD (1958), where the sheep were on hay diets, starch reduced the concentration of ammonia in the rumen slightly more than sugars and cellulose.

It is generally accepted that the higher the ammonia concentration in the rumen the more it may be absorbed through the rumen epithelium, converted to urea in the liver and excreted in the urine, thus depressing the utilization of dietary nitrogen (BARNETT and REID 1961). A proportion of the urea formed in the liver, can, however, return to the rumen in saliva or via the bloodstream. Dietary carbohydrates have been found to improve the utilization of this recycled urea (HOUPT 1959, SOMERS 1961, PACKETT and GROVES 1965). The rate of ammonia absorption is influenced by both the concentration gradient (LEWIS et al. 1957, HOGAN 1961) and the pH of the rumen fluid (COOMBE et al. 1960, HOGAN 1961, BLOMFIELD et al. 1963), although PILGRIM et al. (1969) did not find any effect of changes in pH between 6.2 and 6.9 on the ammonia absorption. An increase in pH causes the NH_4^+ ions to be converted to NH_3, which is rapidly absorbed from the rumen. A decrease in the pH of the rumen fluid produced by carbohydrate fermentation

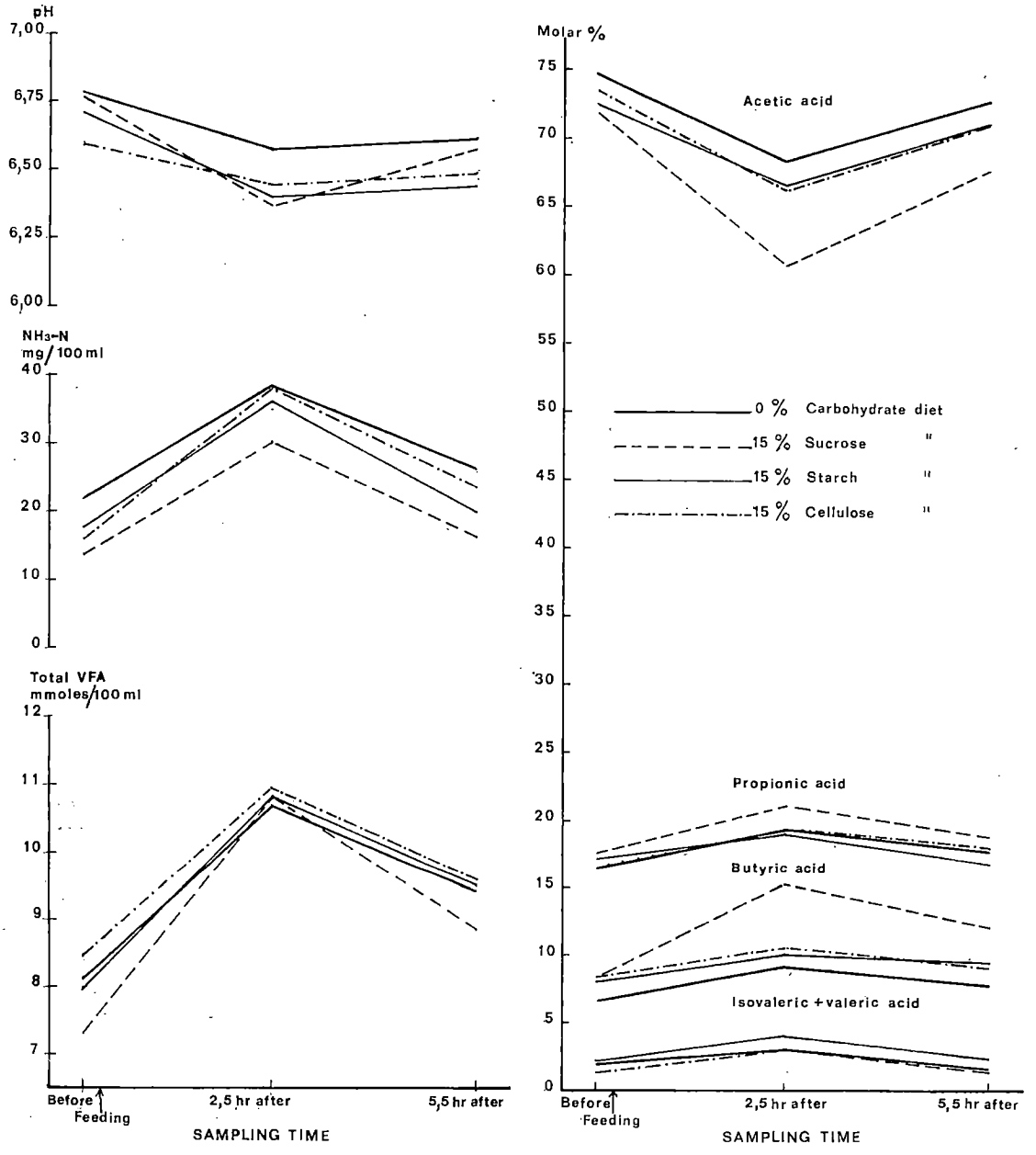


Fig. 7 a. pH, NH_3 -N and VFA in the rumen fluid of sheep on the 0 % and 15 % carbohydrate diets in Exp. I and Exp. II (Appendix 7).

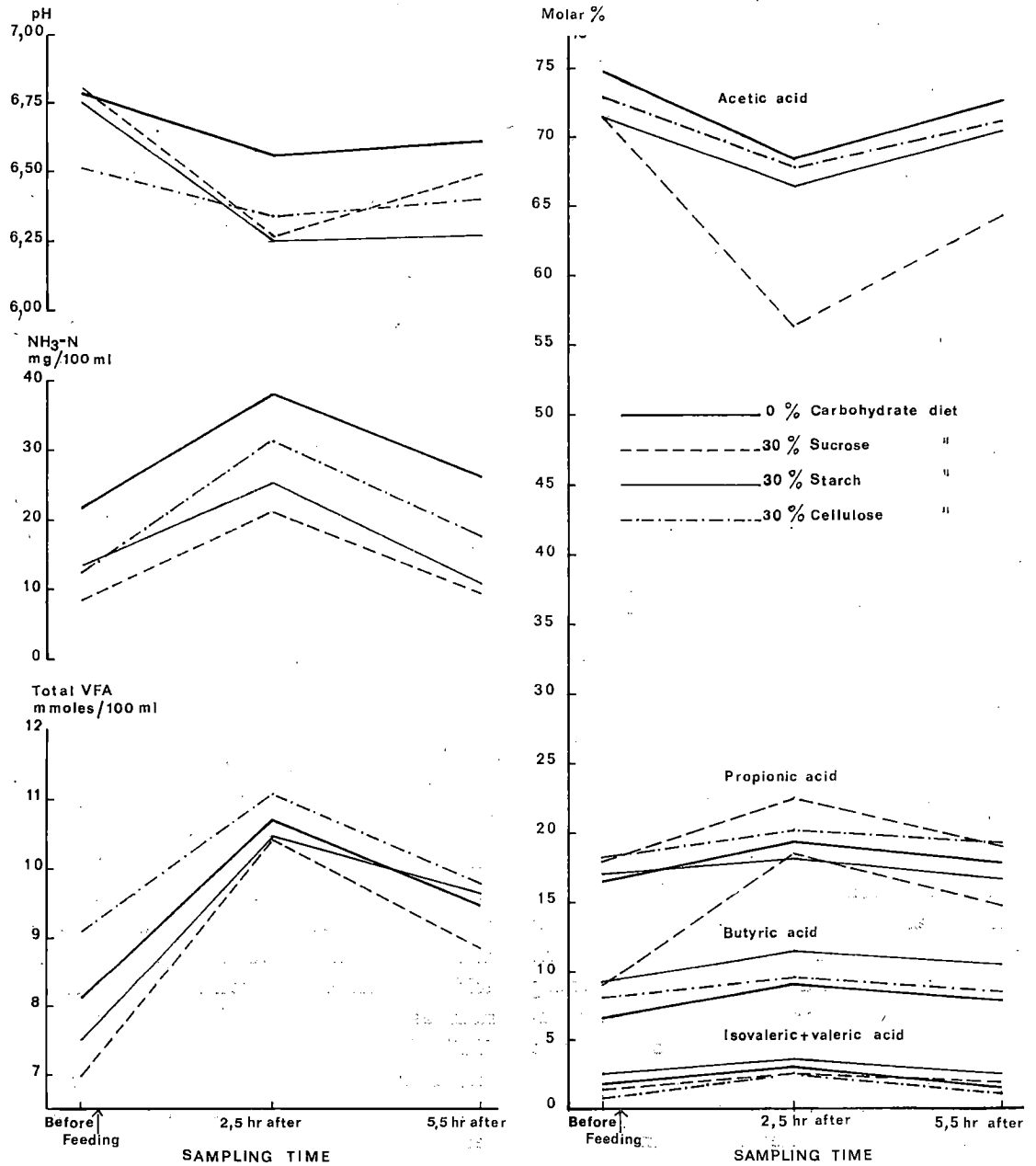


Fig. 7 b. pH, NH_3 -N and VFA in the rumen fluid of sheep on the 0 % and 30 % carbohydrate diets in Exp. I and Exp. II (Appendix 7).

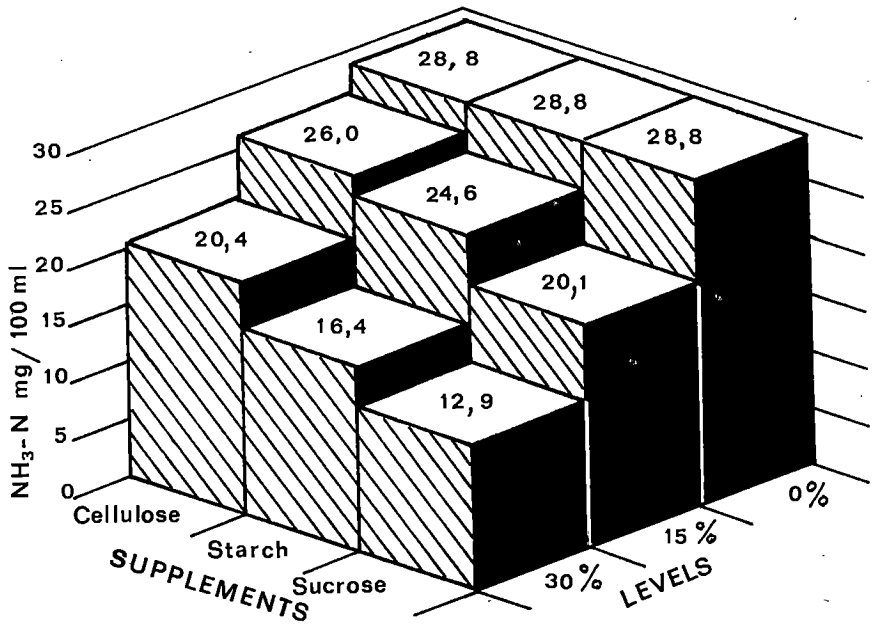


Fig. 8. NH_3 -N in the rumen fluid of sheep on different carbohydrate diets in Exp. I and Exp. II. The values are the averages of the different sampling times.

will thus decrease the rate of ammonia absorption and increase its conversion to microbial protein. The function of carbohydrates in this conversion is to make energy and carbon skeletons available for microbial synthesis.

When the ammonia concentration of the rumen fluid is used as a criterion of dietary protein utilization, it must be borne in mind that its concentration in the rumen fluid at any one time is the result of many factors acting simultaneously. It does not give any direct indication of the total quantity of ammonia evolved from the protein, nor any measure of the rate of evolution or absorption. The most that can be said is that high ammonia concentrations indicate that the deamination of the protein has exceeded the capabilities of the micro-organisms to use the degraded products for synthesizing their own protein (CHALMERS 1961). The use of the concentration of ammonia in the rumen as a measure of the quality of dietary protein has the advantages that the results are obtained in a shorter time and less material is required than in an investigation of the nitrogen balance.

VFA concentration

The total amount of VFA per volume unit of the rumen fluid was not determined separately, but was taken as being the sum of the amounts of acetic, propionic, butyric, isovaleric and valeric acids, which were determined by gas chromatographic analyses and expressed as mmoles/100 ml of rumen fluid. Besides these acids, the rumen fluid can contain other VFA, such as caproic acid (ØRSKOV and OLTJEN 1967). However, their amounts are not high and their omission from the calculation of the total amount of VFA cannot give rise to significant errors.

Lactic acid, the intermediate stage in the production of VFA, was also disregarded in the analyses of the rumen samples, although it is present in the rumen (PHILLIPSON 1942, BALCH et al. 1955), especially with rations containing abundant sugar and starch (PHILLIPSON and MCANALLY 1942, HUNGATE et al. 1952, BRIGGS et al. 1957), and under certain conditions can lower the pH considerably. Since lactic acid is fermented into fatty acids very rapidly, it

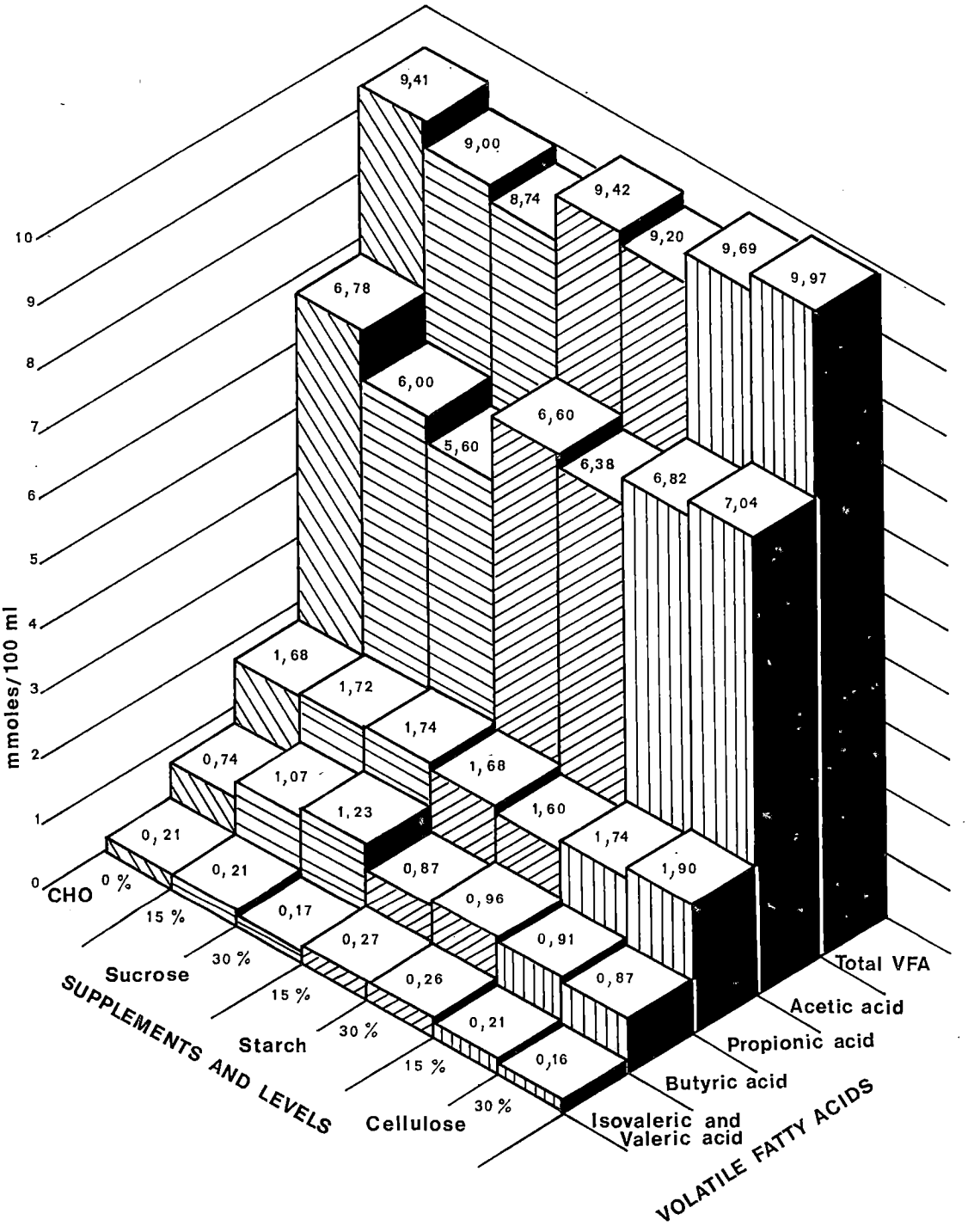


Fig. 9. VFA in the rumen fluid of sheep on different carbohydrate diets in Exp. I and Exp. II. The values are the averages of the different sampling times (Appendix 7).

Table 15. Distribution of energy of VFA mixture among different acids in different carbohydrate diets. The results are the averages of different sampling times in Exp. I and Exp. II (see Appendix 5—6).

Diets	VFA mmoles/ 100 ml	Energy of VFA mixture kcal/ 100 ml	Distribution of energy among different acids (%)				Average caloric value of mixture kcal/ mole
			Acetic acid	Propionic acid	Butyric acid	Valeric [1] acid	
0 % carbohydrate	9.25	2.60	51.9	24.2	16.9	6.9	281
15 % sucrose	9.02	2.62	47.7	24.4	22.1	5.7	290
30 % »	8.74	2.60	44.6	25.4	25.4	4.6	297
15 % starch	9.41	2.63	52.1	23.2	17.5	7.2	279
30 % »	9.20	2.62	50.8	22.5	19.5	7.3	285
15 % cellulose	9.72	2.73	52.4	24.2	17.9	5.5	281
30 % »	9.97	2.76	53.3	25.7	16.7	4.3	277

[1] isovaleric acid is included.

can be detected only during a short period after feeding (BALCH et al. 1955, VUYST et al. 1969) and can almost completely disappear within 2 hr (SUTTON 1971). In the present experiments the first rumen samples were taken as much as 2.5 hr after the beginning of feeding. It can thus be assumed that most of the lactic acid had already disappeared from the rumen. In another study lactic acid could not be found in the rumen of a cow fed silage with a high lactic acid content, which also indicates that the fermentation of lactate in the rumen can be very rapid (BALCH and ROWLAND 1957).

The sucrose diets generally gave lower rumen VFA concentrations than the diets consisting entirely of silage, the depression being greater at the 30 % level than at the 15 % level. The corresponding starch supplements had a variable effect on the concentration, although some increase was found in samples taken 5.5 hr after feeding. The differences between 0 % carbohydrate and sucrose and starch diets are significant ($P < 0.05$) in only a few cases. Cellulose gave a slight increase in VFA production, it being greater at the 30 % than at the 15 % level, and the differences from 0 % carbohydrate diets being significant ($P < 0.05$) in samples taken before feeding. A comparison of the total VFA amounts at the same level of carbohydrate supplements shows that at both the 15 % and 30 % levels the concentration decreased in the same order, from cellulose to starch to sucrose, at almost every sampling time. In samples taken before feeding it is significantly higher ($P < 0.05$) with the 15 % cellulose supplement than with the 15 % sucrose supplement, and also significantly higher with the 30 % cellulose supplement than with the 30 % starch and sucrose supplements ($P < 0.05$). In Exp. II, in contrast to Exp. I, the samples taken 2.5 hr after feeding showed a slightly higher VFA concentration with sucrose than with some other supplements, though the difference was not significant ($P > 0.05$). In samples taken 5.5 hr after feeding the concentration was significantly higher ($P < 0.05$) with the 30 % cellulose than with the 30 % sucrose supplement in both experiments.

The effect of the different carbohydrate supplements on the absolute and relative amounts of the individual VFA varied. The sucrose supplements decreased the molar percentages of acetic and isovaleric acids, the differences from the 0 % carbohydrate diets being significant ($P < 0.05$) in most cases, and increased those of propionic, butyric and valeric acids. The effects of the starch and cellulose supplements on the molar proportions of the individual VFA were rather slight, although cellulose tended to increase the proportion of acetic acid in some cases. The differences between the different diets in the total and individual VFA amounts in the rumen fluid are clearly seen in Figs. 7 and 9.

The distribution of the energy of the VFA mixture among the different acids (Table 15, Appendix 5 and 6) was calculated by using the molar caloric values as follows: acetic acid 209.4 kcal, propionic acid 367.2 kcal, butyric acid 524.3 kcal and valeric acid 681.6 kcal (WEAST 1968—69, pp. D 184—189). The average molar caloric value of the VFA mixture was highest with the diets containing sucrose supplements and lowest with the diets containing cellulose supplements. This is due to the fact that with the sucrose supplements the fermentation in the rumen produced a greater proportion of acids with high molar caloric values, especially butyric acid, whereas with the cellulose supplement the proportion of acetic acid was greater. With the starch diets the caloric values of the VFA mixture lay between those of the sucrose and cellulose diets. The differences between the different diets are statistically significant in only a few cases (Appendix 5 and 6). Greater differences are found between the different sampling times, the samples taken 2.5 hr after feeding having the highest molar caloric values for the VFA mixture (see also Table 16).

The effect of the different carbohydrate supplements on the rumen fluid did not vary greatly between the AIV I, formic acid and Viher solution silages. An examination of the average amounts of VFA at the different sampling times (Table 14) shows that compared with the corresponding diets without a carbohydrate supplement they were significantly lower ($P < 0.05$) only with the 30 % sucrose supplement in the formic acid silage diet, and significantly higher ($P < 0.01$) only with the 30 % cellulose in the AIV I silage diet. The changes in the absolute and relative amounts of individual VFA on the different silage feeds were roughly similar with the same carbohydrate supplements. The differences in rumen VFA production between the silages without any carbohydrate supplement will be examined later in this paper (Table 18).

The composition and amount of the VFA mixture in the rumen fluid depends closely on the nature of the feed and its digestion in the rumen, as many studies have shown (BARNETT and REID 1961, HUNGATE 1966). In the present investigations the sucrose supplements depressed ruminal VFA formation during grass silage feeding. Similar results were obtained by KRJUKOV (1965) and KURILOV et al. (1966) with large amounts of sugar, 5—10 g/kg live weight, in roughage diets for cattle, whereas smaller amounts, 3 g/kg live weight, stimulated rumen fermentation. In contrast, KELLOGG and OWEN (1969) found that different sucrose additions had no effect on total VFA production. In other experiments cellulose and in some cases also starch supplements tended to increase the VFA production (MCDONALD 1948, 1952, CHAPPELL and FONTENOT 1968).

The proportions of the individual acids in the total VFA agree in most cases with the experiments of ØRSKOV and OLTJEN (1967) and others (BARNETT and REID 1961, HUNGATE 1966), where the proportions of acetic and isovaleric acids decreased from complex (cellulose) to simple (glucose) carbohydrate sources and those of butyric, propionic and valeric acids, increased, though not linearly in the case of propionic acid. It is likely that the proportions of butyric and higher VFA may be indicative of the rate of fermentation, because they increase with the rapidly fermented mono- and disaccharides (ØRSKOV and OLTJEN 1967). This is also supported by the experiments of LAMPILA and POIJÄRVI (1959), where they found a very high proportion of butyric acid in the VFA mixture on a diet containing fodder sugar beets. A high proportion of acetic acid has generally been associated with a high roughage diet and that of propionic acid with a high concentrate diet (HUNGATE 1966).

The amount of VFA production in the rumen with a certain diet is also dependent on how large a part of the feed is digested in the rumen. Quantitative information on rumen fermentation is difficult to obtain. There is considerable disagreement about the proportion of the digestible energy of ruminants that is fermented in the rumen and the amount that can escape

Table 16. Average total VFA amounts and proportions of individual acids in the diets of Exp. I and Exp. II.

Sampling time	Total VFA mmoles/ 100 ml	Molar % of total VFA				
		Acetic acid	Propionic acid	Butyric acid	Isovaleric acid	Valeric acid
Before feeding	7.94	73.0	17.2	8.1	1.4	0.4
2.5 hr after feeding ..	10.74	65.2	19.9	11.7	1.9	1.3
5.5 hr. after » ..	9.38	70.2	18.0	10.0	1.1	0.8
Average	9.35	69.4	18.4	9.9	1.5	0.8

rumen fermentation. Soluble sugars, such as sucrose and glucose, have been shown (SUTTON 1971) to be digested nearly completely in the rumen and it is unlikely that much of them escapes fermentation. This is also the case with large amounts of sugar. Starch is also rapidly digested and only about 5—10 % usually escapes fermentation, although the percentage can sometimes be higher. The physical structure of the grain (ØRSKOV et al. 1969) and the type of microbial population can effect the rate of starch fermentation (HUNGATE 1966). The quantity of starch passing into the abomasum has been found to increase with increasing starch intake (KARR et al. 1966). Of the digestible cellulose usually some 10—20 % escapes fermentation in the rumen (HUNGATE 1966).

The amounts of the total and individual VFA varied more widely with the sampling time than with the different diets, as was also the case with the pH values and ammonia concentrations (Table 11, Fig. 7). This was the main reason why the results of the different sampling times were generally treated separately. When the averages of all the diets are calculated (Table 16), it is seen that the molar proportion of acetic acid increased and those of propionic and butyric acids decreased between the first and second samples taken after feeding. Similar results were obtained by GRAY and PILGRIM (1951), REID et al. (1957), LAMPILA and POIJÄRVI (1959), SCHMEKEL (1967 a, 1967 c) and SAUE (1968), but in some other experiments the molar percentages of the individual fatty acids did not change much with the time elapsing between feeding and sampling (SHAW 1961). The variation with sampling time of the relative amounts of the individual VFA can be primarily associated with the different rates at which these acids are absorbed from the rumen. It has been shown in many experiments (BARNETT and REID 1961, ANNISON and LEWIS 1962) that under the normal slightly acid conditions existing in the rumen, butyric and propionic acids tend to be absorbed at a faster rate than acetic acid, but not in greater quantity. The absorption and production of the rumen VFA is a complex process, which has been shown to be closely dependent on the pH of the rumen contents (BARNETT and REID 1961, ANNISON and LEWIS 1962, LAMPILA 1964).

Effect of preservatives on the utilization of silage

The results examined in this section are only from Exp. II and thus relate to the silages prepared with AIV I, formic acid and Viher solution preservatives.

Digestibility, nitrogen retention and other feeding values

The results on the left-hand side of Table 17 were obtained with diets consisting entirely of silage, and are thus the averages of 9 trials. The results on the right-hand side relate to the carbohydrate diets as well, thus being the averages of 27 trials.

Formic acid silage gave the highest digestibility coefficients for all the components, except crude fat, being followed by AIV I silage

Table 17. Digestibility, N balance and feeding values of AIV I, formic acid and Viher solution silages.

	Diets containing only silage				Diets also containing carbohydrate supplements			
	AIV I	Formic acid	Viher solution	SE of means	AIV I	Formic acid	Viher solution	SE of means
Digestibility, %								
Dry matter	70.9	72.1	70.0	0.57	68.3	68.9	67.0	0.70
Organic matter	74.2	75.1	73.1	0.56	71.7	72.1	70.2	0.68
Crude protein	71.7^{ade}	72.5^{ae}	68.9^{bd}	0.56	65.9	66.3	63.1	1.20
Crude fat	72.6	72.0	70.9	0.56	72.3	72.0	71.5	0.39
N-free extract	74.2	75.7	74.2	0.74	71.8	72.5	71.4	0.74
Crude fibre	76.2	76.8	74.8	0.71	75.5	75.6	73.4	0.68
Crude carbohydrates	75.1	76.1	74.5	0.63	73.3	73.7	72.3	0.63
N balance, g/day	2.78	2.63	1.78	0.40	2.14	2.59	1.87	0.26
Biological value	44.7	44.5	39.8	1.44	50.4	50.4	47.3	1.58
kg/f.u.	7.22^{ade}	6.91^{bd}	7.42^{ae}	0.06	7.46^{ade}	7.22^{bd}	7.73^{ce}	0.07
DM kg/f.u.	1.33^{ab}	1.31^{ad}	1.36^{bd}	0.01	1.38	1.37	1.41	0.01
DCP g/f.u.	175.1^{ab}	172.3^{ad}	183.6^{bd}	2.13	165.7^{ad}	163.9^{ad}	174.7^{be}	1.99
DCP % in DM	13.1	13.2	13.5	1.52	12.1	12.0	12.4	2.28

Statistical analysis performed separately for diets containing only silage and for diets also containing carbohydrate supplements. The Tukey test (STEELE and TORRIE 1960) was applied to the differences between the averages. Different index letters in a horizontal row show that there are significant differences between the averages at the 95 % (a—c) and 99 % (d—e) levels of confidence.

and then Viher solution silage. The differences between these silages are, however, small, being significant only in the case of crude protein, whose digestibility is significantly lower in Viher solution silage than in both formic acid ($P < 0.01$) and AIV I ($P < 0.05$) silage.

The N balance with diets consisting entirely of silage is highest on AIV I silage feeding, lower on formic acid, and lowest on Viher solution silage feeding. With diets containing carbohydrate supplements the N balance decreases from formic acid to AIV I to Viher solution silages. On the whole, it seems that the carbohydrate supplements had a slightly more adverse effect on the N balance with AIV I than with formic acid silage, whereas with Viher solution silage their effect was slightly beneficial.

The biological value of the different silages decreases in the same order as the N balance, although it is higher in diets with carbohydrate supplements than without them (Table 6). When these results are evaluated, it should be remembered that the differences between the different silages are not significant ($P > 0.05$). However, the differences between the other feeding values of the different silages were significant in many cases, formic acid silage giving the best results, followed by AIV I and then Viher solution silage.

POUTIAINEN and HUIDA (1970) obtained similar results when comparing the digestibility of grass silages prepared with different preservatives. The digestibility of crude protein in Viher solution silage was about 4 %-units lower than in AIV I and formic acid silages ($P < 0.05$). The other digestibility coefficients were also lower, but not significantly so. The N balance was slightly higher, though not significantly so ($P < 0.1$), with Viher solution silage, in contrast to the results of the present experiments, where it was slightly lower. The effect of the formaldehyde of the Viher solution in decreasing the solubility of protein (FERGUSON et al. 1967, REIS and TUNKS 1969) probably had no importance for N retention in the present experiment. It seems that the amounts of formaldehyde in the preservative giving optimal N retention by animal probably lie within a fairly narrow range, because different experiments have given varied results. In the present experiments, the proportion of formaldehyde was about 0.8 % of the dry matter of fresh grass.

Numerous digestibility trials have been car-

Table 18. pH, ammonia nitrogen and volatile fatty acids in the rumen fluid of sheep on AIV I, formic acid and Viher solution silage diets.

	Sampling time	Diets containing only silage				Diets also containing carbohydrate supplements			
		AIV I	Formic acid	Viher solution	SE of means	AIV I	Formic acid	Viher solution	SE of means
pH		6.78	6.77	6.85	0.03	6.75^{ab}	6.71^{bd}	6.81^{ae}	0.02
NH_3-N, mg/100 ml		21.2^{bd}	25.3^{ae}	23.7^{ade}	0.66	17.0^{bd}	19.9^{ae}	17.7^{ab}	0.46
Total VFA, mmoles/100 ml		8.00^{bd}	8.84^{ae}	8.41^{ab}	0.13	8.17^{ae}	8.77^{bd}	8.39^{ade}	0.10
Acetic acid, molar %	Before	75.4	75.3	75.8	0.36	74.4	74.2	74.4	0.27
Propionic acid »	feeding	16.4^{ad}	16.2^{ab}	15.7^{bd}	0.21	16.3	16.1	16.1	0.17
Butyric acid »		6.2	6.4	6.6	0.16	7.5	7.6	7.9	0.16
Isovaleric acid »		1.7	1.8	1.6	0.27	1.6	1.7	1.3	0.18
Valeric acid »		0.2	0.3	0.3	0.05	0.2	0.3	0.3	0.03
Ratio acetic: propionic		4.64	4.71	4.85	0.08	4.63	4.69	4.68	0.06
» acetic: butyric		12.30	12.14	12.02	0.34	10.37	10.20	9.84	0.24
» propionic: butyric		2.68	2.59	2.49	0.06	2.27	2.21	2.13	0.05
pH		6.61^{ade}	6.50^{be}	6.68^{ad}	0.03	6.46^{ad}	6.43^{a}	6.54^{bd}	0.02
NH_3-N, mg/100 ml		34.6^{ab}	36.8^{ad}	32.3^{be}	1.04	28.5^{ad}	29.1^{a}	24.9^{bd}	0.95
Total VFA, mmoles/100 ml	2.5 hr	10.14^{ad}	11.08^{be}	10.50^{ade}	0.14	10.43^{ad}	11.06^{be}	10.66^{ad}	0.09
Acetic acid, molar %	after the	70.8^{ab}	69.2^{bd}	71.9^{ae}	0.58	69.4	68.3	69.9	0.59
Propionic acid »	beginning	19.5^{ad}	19.4^{ab}	18.2^{bd}	0.40	18.6	19.0	18.5	0.36
Butyric acid »	of feeding	7.4^{ad}	8.7^{be}	7.4^{ad}	0.17	9.9	10.2	9.4	0.42
Isovaleric acid »		1.5^{bd}	1.9^{ae}	1.7^{ab}	0.07	1.3^{ad}	1.7^{be}	1.4^{ad}	0.07
Valeric acid »		0.8	0.8	0.9	0.07	0.8	0.9	0.8	0.04
Ratio acetic: propionic		3.70^{ab}	3.62^{bd}	4.06^{ad}	0.12	3.86^{ab}	3.67^{bd}	4.00^{ad}	0.09
» acetic: butyric		9.74^{ad}	7.99^{be}	10.44^{ad}	0.32	8.05	7.83	8.73	0.54
» propionic: butyric		2.66^{ad}	2.24^{be}	2.53^{ad}	0.05	2.11	2.18	2.18	0.15
pH		6.65	6.60	6.66	0.03	6.55	6.53	6.58	0.02
NH_3-N, mg/100 ml		25.0^{ab}	26.1^{ad}	22.8^{bd}	0.81	18.7^{ad}	18.1^{ab}	15.3^{bd}	0.88
Total VFA, mmoles/100 ml	5.5 hr	8.94^{be}	9.90^{ad}	9.94^{ad}	0.12	9.32^{be}	9.85^{ad}	9.95^{ad}	0.09
Acetic acid, molar %	after the	74.8^{ad}	73.1^{be}	74.5^{ade}	0.37	73.3	72.4	73.0	0.38
Propionic acid »	beginning	17.6	17.6	17.0	0.28	16.9	16.9	16.9	0.25
Butyric acid »	of feeding	6.6^{ae}	7.8^{bd}	7.0^{ade}	0.21	8.8	9.2	8.7	0.32
Isovaleric acid »		0.8^{bd}	1.0^{ad}	1.1^{ad}	0.06	0.7^{bd}	1.0^{ae}	0.9^{ab}	0.06
Valeric acid »		0.3^{be}	0.4^{ad}	0.4^{ad}	0.03	0.4^{bd}	0.4^{ab}	0.5^{ad}	0.03
Ratio acetic: propionic		4.32	4.20	4.42	0.10	4.44	4.38	4.43	0.08
» acetic: butyric		11.50^{ad}	9.59^{be}	11.20^{ad}	0.31	9.30^{ad}	8.29^{bd}	9.33^{ad}	0.28
» propionic: butyric		2.69^{ad}	2.31^{be}	2.52^{ab}	0.06	2.14	1.94	2.11	0.06
pH		6.68^{ab}	6.62^{bd}	6.73^{ae}	0.02	6.59^{ade}	6.56^{ad}	6.64^{be}	0.01
NH_3-N, mg/100 ml		26.9^{ab}	29.4^{ad}	26.3^{bd}	0.78	21.4^{ade}	22.4^{ad}	19.3^{be}	0.57
Total VFA, mmoles/100 ml		9.03^{be}	9.94^{ad}	9.62^{ad}	0.13	9.31^{be}	9.89^{ad}	9.66^{ad}	0.08
Acetic acid, molar %	Average	73.7^{ab}	72.6^{bd}	74.1^{ae}	0.35	72.4	71.6	72.4	0.29
Propionic acid »		17.8^{ad}	17.7^{ad}	17.0^{bd}	0.22	17.3	17.4	17.2	0.17
Butyric acid »		6.7^{ad}	7.6^{be}	7.0^{ad}	0.13	8.7	9.0	8.7	0.19
Isovaleric acid »		1.4	1.6	1.4	0.10	1.2^{ad}	1.5^{bd}	1.2^{ad}	0.07
Valeric acid »		0.4	0.5	0.5	0.04	0.5	0.5	0.5	0.02
Ratio acetic: propionic		4.22^{ab}	4.17^{bd}	4.44^{ad}	0.07	4.31	4.25	4.37	0.05
» acetic: butyric		11.18^{ad}	9.91^{be}	11.22^{ad}	0.23	9.24	8.77	9.30	0.22
» propionic: butyric		2.67^{ae}	2.38^{bd}	2.51^{cd}	0.04	2.17	2.11	2.14	0.06

Meaning of index letters same as in Table 17.

ried out under various conditions with silages preserved by different methods (WATSON and NASH 1960, SAUE 1968, BURSTEDT et al. 1971), but even a partial review of them would take too much space in this study.

Rumen fermentation

The values for the diets containing only silage (Table 18) are the averages of 27 rumen samples taken at each sampling time and those for the diets containing also carbohydrate supplements are the averages of 81 samples.

The pH values of the rumen fluid are lowest with formic acid silage, differing significantly from those with Viher solution ($P < 0.01$) and AIV I ($P < 0.05$) silages in samples taken 2.5 hr after feeding. It should be mentioned that the pH of the silage samples increased in the same order as that of the rumen fluid samples: from formic acid to AIV I to Viher solution (Table 2).

The ammonia concentration in the rumen fluid is lowest with Viher solution silage in samples taken 2.5 hr and 5.5 hr after feeding, higher in AIV I and highest in formic acid silage, the differences being significant ($P < 0.01$ or $P < 0.05$) between Viher solution and formic acid silages. In samples taken before feeding they are, however, lower with AIV I silage than with formic acid ($P < 0.01$) and Viher solution silage ($P < 0.05$). The lowest mean ammonia concentration with Viher solution silage can be attributed to the protein-protecting effect of formaldehyde. In this silage the crude protein was less decomposed (Tables 1 and 2) than in the other silages. Its degradation in the rumen was thus lower and ammonia was released slower than with formic acid and AIV I silages. This explanation is supported by the fact that the dry matter of the Viher solution silage contained more crude protein (Table 1) than that of the other silages, and the fact that the rumen ammonia level generally increases with increasing crude protein content of the feed (SCHMEKEL 1967 a). But the final value for the animal of this effect of formaldehyde is difficult to assess, because in spite of the lowered rumen ammonia content N retention was not better with Viher solution silage, but even lower than with AIV I and formic acid silages.

These results agree with those obtained by SAUE (1970), when he compared the ammonia concentrations in the rumen fluid of sheep fed with grass silages preserved by formic acid, formalin and combinations of the two substances. The ammonia concentration decreased when the proportion of formalin increased. In samples taken 2 hr after feeding it was:

	NH_3-N mg/100 ml
Without preservative	36.6
Formic acid	26.4
1 formalin: 2 formic acid	19.8
2 formalin: 1 formic acid	17.2
Formalin	14.3

LAMPILA (1960) found almost the same mean ruminal ammonia contents in a cow fed with hay, concentrates and silages prepared with AIV acid, Calcifor salt and without preservatives. With AIV salt the rumen ammonia concentration was 24—32 % higher than with the other three silages, probably owing to the ammonium content of this preservative. SCHMEKEL (1967 c) found that the silage preservative caused only small differences in the rumen ammonia content of sheep. The content varied more widely with the amounts of silage consumed and the sampling time. In his experiments the silage was prepared with $NaHSO_4$, $Na_2S_2O_5$, Kofa, malt-cereal and without preservatives.

There are only a few experiments concerning the effect of different silage preservatives on the rumen ammonia production, but more attention has been paid to the effect of silage versus artificially dried grass or hay (WALDO et al. 1966, SCHMEKEL 1967a, SAUE 1968, CISZUK 1972). In most of the experiments the rumen ammonia content was higher with silage than with dried grass or hay made from the same material. This has been shown to result from differences in the solubility of the crude protein. The protein is denatured in the drying processes, especially in high temperature drying (HENK and LAUBE 1968). The higher amount of soluble

Table 19. Distribution of energy of VFA mixture among different acids in different silage diets at 0 % carbohydrate levels. The results are the averages of different sampling times.

Diets	VFA mmoles/ 100 ml	Energy of VFA mixture kcal/ 100 ml	Distribution of energy among different acids (%)				Average caloric value of mixture kcal/mole
			Acetic acid	Propionic acid	Butyric acid	Valeric[1] acid	
AIV I	9.03^{be}	2.41^{be}	57.5	24.6	13.2	4.6	267
Formic acid ..	9.94^{ad}	2.70^{ad}	55.7	24.1	14.9	5.3	272
Viher solution	9.62^{ad}	2.57^{ab}	57.9	23.4	13.7	5.0	268

[1] isovaleric acid is included.
Meaning of index letters same as in Table 1.

carbohydrates in hay can also be responsible for the lower ammonia content.

The total VFA amounts in the rumen fluid were highest with formic acid silage, lower with Viher solution silage and lowest with AIV I silage. The differences between the formic acid and AIV I silages were significant ($P < 0.01$) at every sampling time. The relative proportions of the individual acids in the total VFA varied with the different silages, especially in the samples taken 2.5 hr and 5.5 hr after feeding. The proportion of acetic acid was highest with Viher solution silage, lower with AIV I and lowest with formic acid silages. That of propionic acid decreased from AIV I to formic acid to Viher solution, and that of butyric acid from formic acid to Viher solution to AIV I. The carbohydrate supplements tended to lower the differences between these silages in the relative amounts of the individual VFA in the rumen fluid.

No differences ($P > 0.05$) were found between the AIV I, formic acid and Viher solution silages in the distribution of the energy of the VFA mixture among the different acids (Table 19), or in the average molar caloric value of the VFA mixture. The energy of the VFA mixture per unit volume of the rumen fluid is significantly higher ($P < 0.01$) in animals on formic acid silage feeding than in those on AIV I silage feeding, as was also the case with the VFA content.

As in the case of ammonia, there are very few investigations concerning rumen VFA production with silages preserved by different methods. Those which exist (ORTH 1961, SCHMEKEL 1967 c) do not deal with any of the preservatives used in the present experiments. Schmekel found that rumen digestion, and consequently VFA production, differed with the preservatives used in the preparation of the silage, but varied more greatly with the amounts of feed consumed.

Silage intake and water consumption

The intake of the silages was measured in Exp. II during the ten first days of the preliminary periods with animals receiving silage alone. The average daily consumption of silage dry matter was 1 073 g per animal. The intake did not differ ($P > 0.05$) between the silages, but varied with the animals (Table 20). It also varied from day to day.

Many experiments have been performed on the effect of the ensiling method on the intake of silage by ruminants (WATSON and NASH 1960)

Table 20. Voluntary intake of silage, DM g/day.

Sheep	AIV I	Formic acid	Viher solution	Average
Eero	946	1 128	1 108	$1\,061^{ab}$
Juhani	1 007	1 182	—	$1\,095^{ab}$
Aapo	1 204	1 429	—	$1\,317^{a}$
Simeon	1 454	1 023	1 232	$1\,236^{a}$
Tuomas	1 187	884	1 245	$1\,105^{ab}$
Timo	532	730	865	709^{b}
Lauri	1 087	1 179	919	$1\,062^{ab}$
Topias	1 111	1 482	1 012	$1\,202^{ab}$
Iivari	997	978	952	976^{ab}
Average	1 058	1 113	1 048	1 073

Meaning of index letters same as in Table 1.

and the results have been variable. In some cases silage preservative did not have any important effect (OSLAGE and OSLAGE 1958); in some cases it had (MCCARRICK et al. 1965, SCHMEKEL 1967 b). Besides the raw material used, factors with a more pronounced effect on silage consumption are the dry matter content and the acids and other fermentation products in silage. A high dry matter content has been shown to increase the consumption of silage (MCCULLOUGH 1961, THOMAS et al. 1961), whereas far advanced fermentation, in respect of both the nitrogen fraction and the carbohydrates, generally decreases it (MOORE et al. 1960, THOMAS et al. 1961, GORDON et al. 1964, SAUE 1968). The degree of fermentation depends closely on the success of ensiling.

No differences were found in the consumption of drinking water between the different silages used in Exp. II, but the least squares variance analysis revealed significant differences between the animals ($P < 0.001$), periods ($P < 0.05$) and carbohydrate supplements ($P < 0.01$). Some differences in average water consumption were also found between the different carbohydrate diets (Table 21). Consumption was greatest with diets containing sucrose and cellulose supplements and smallest with starch supplements.

Table 21. Daily average water consumption on different diets in Exp. II, g/animal.

Diets	Drinking water	Total
0 % carbohydrate	184^{b}	4 256
15 % sucrose	194^{ab}	3 614
30 % »	529^{a}	3 298
15 % starch	142^{b}	3 595
30 % »	65^{b}	2 900
15 % cellulose	335^{ab}	3 774
30 % »	218^{ab}	3 025

Meaning of index letters same as in Table 1.

The results of the present investigations contradict those of AXELSSON and KIVIMÄE (1955), and SCHMEKEL (1967 b), who found that water consumption is influenced by the ensiling preservative. However, there are large individual variations in their data, as in the present results. The preservatives used in their experiments were of both organic and inorganic origin.

Composition of blood of sheep on different silage and carbohydrate feeds

The results concerning the blood haematological criteria, glucose, urea and ammonia in sheep on different carbohydrate diets (Table 22) are the averages of 51 samples with the 0 % carbohydrate diet and of 17 samples with each of the other diets. As calculated for the different silages (Table 23), they are the averages of 17 samples with the diets consisting only of silage and of 51 samples with the diets also containing carbohydrate supplements. For the inorganic constituents of plasma (Table 24), the results are the averages of 18 samples, because they were determined only in periods 4—6.

Before examining the effect of different diets

Table 22. Haematological criteria and blood glucose, urea and ammonia concentrations of sheep on different carbohydrate diets in Exp. II.

Diets	Haematocrit	Hb g/100 ml	Glucose mg/100 ml	Urea-N mg/100 ml	NH_3-N mg/100 ml
0 % carbohydrate ..	35^{b}	15.0	49.3	9.9^{a}	0.15
15 % sucrose	35^{b}	14.7	49.6	8.3^{b}	0.13
30 % »	36^{ab}	14.9	49.9	7.3^{bc}	0.14
15 % starch	37^{a}	15.7	47.4	9.0^{ab}	0.15
30 % »	37^{a}	15.6	48.6	7.6^{bc}	0.16
15 % cellulose	36^{ab}	15.3	47.3	8.3^{b}	0.15
30 % »	35^{ab}	15.1	45.7	6.4^{c}	0.14
SE of means: 0 % diet	0.27	0.14	0.79	0.23	0.01
other diets	0.47	0.24	1.37	0.40	0.01

Meaning of index letters same as in Table 1.

Table 23. Haematological criteria and blood glucose, urea and ammonia concentrations of sheep on different silage diets.

Diets	Haematocrit	Hb g/100 ml	Glucose mg/100 ml	Urea-N mg/100 ml	NH_3-N mg/100 ml
At 0 % carbohydrate levels					
AIV I	35^{ab}	15.3	48.7	9.2	0.15
Formic acid	36^{ad}	15.1	49.3	10.0	0.15
Viher solution	34^{be}	14.6	50.0	10.4	0.16
SE of means	0.40	0.20	1.17	0.38	0.01
At all carbohydrate levels					
AIV I	36	15.2	48.5	8.0^{bd}	0.14
Formic acid	36	15.2	49.7	8.4^{ab}	0.15
Viher solution	36	15.1	47.3	9.1^{ad}	0.15
SE of means	0.29	0.14	0.79	0.28	0.01

Meaning of index letters same as in Table 1.

on the blood composition, it should be mentioned that the differences were more significant between the animals and periods than between the different carbohydrates and especially between the different silages (Table 25). Also the interaction carbohydrate × silage was not very significant. Statistically significant differences between the different carbohydrate diets (Table 22) and between the different silages (Table 23) were found only in the case of haematocrit and the urea content. Haematocrit is higher ($P < 0.05$) with starch diets than with 0 % carbohydrate and 15 % sucrose diets, and it is also higher ($P < 0.01$) with formic acid than with Viher solution silage. The blood urea follows the rumen ammonia concentration (Table 13), as regards the different carbohydrate diets, being lower with diets containing carbohydrate supplements than with a diet of silage alone (see p. 235). At all the 30 % carbohydrate levels the urea content is significantly lower ($P < 0.01$) than that of 0 % carbohydrate diet, whereas at the 15 % levels it is lower ($P < 0.05$) only in the sucrose and cellulose diets. The situation is not so clear as regards the different silages. The blood urea content is highest with Viher solution silage, lower with formic acid and lowest with AIV I silage, the differences being significant ($P < 0.05$) between Viher solution and AIV I silage, in diets also containing carbohydrate supplements. In contrast, the rumen ammonia content was lowest with Viher solution silage.

The blood glucose concentration showed no significant differences between the different diets, although the starch and cellulose supplements tended to give lower values than the sucrose supplement. The differences in the inorganic constituents of blood plasma with different silage diets were also rather small, being

Table 24. Inorganic constituents of blood plasma of sheep on different silage diets in Exp. II, mg/100 ml.

Diets	Ca	Mg	K	Na	P	Zn	Cu	Fe
At 0 % carbohydrate levels								
All silages	11.2	2.4	27.1	352.4	5.8	0.08	0.06	0.15
At all carbohydrate levels								
AIV I	11.6	2.7^{ad}	20.5	355.2	6.3^{ad}	0.09	0.05^{ad}	0.16
Formic acid	11.3	2.5^{ab}	27.6	347.4	4.8^{bd}	0.09	0.06^{bd}	0.15
Viher solution	11.2	2.4^{bd}	26.0	352.8	5.6^{ab}	0.09	0.06^{ab}	0.13
SE of means	0.18	0.07	4.43	4.41	0.27	0.009	0.003	0.009

Meaning of index letters some as in Table 1.

Table 25. F-values of least variance analysis for haematological criteria and blood glucose, urea and ammonia concentrations of sheep in Exp. II. The numbers of degrees of freedom are indicated in parentheses.

	Animals F (8, 44)	Periods F (8, 44)	Carbohydrates F (6, 44)	Silages F (2, 44)	Carbohydrate × silage F (12, 44)
Heamatocrit	14.30***	3.68**	3.31*	0.09	2.43*
Hb, g/100 ml	8.29***	6.00***	2.64*	0.10	2.20*
Glucose, ml/100 ml	5.32***	6.82***	1.60	3.19	1.08
Urea-N »	5.64***	19.71***	15.22***	5.88**	1.23
NH_3-N »	3.33**	9.74***	1.19	1.86	0.86

***P < 0.001
**P < 0.01
*P < 0.05

statistically significant ($P < 0.05$) only in the case of Mg, P and Cu.

The ammonia absorbed from the digestive tract of the animal is converted to urea in the liver (McDONALD 1948) and gives a certain blood urea level. In many experiments the blood urea concentration has been found to correlate with the rumen ammonia concentration and is used as a measure of ammonia loss from the rumen and thus also as a measure of feed protein utilization (LEWIS 1957, TAGARI et al. 1964, ABOU AKKADA and OSMAN 1967, CISZUK 1972). It must, however, be borne in mind that some ammonia absorption takes place in other parts of the digestive tract than the rumen (McDONALD 1948), and thus this correlation is not always very clear. Although the daily variations in blood urea concentration are generally not as great as in rumen ammonia concentration (LEWIS 1957, CISZUK 1972), similar factors influence their concentrations, e.g. protein intake and quality, and the presence of readily available carbohydrates given as a supplement to the diet (McDONALD 1952, ANNISON et al. 1954, ANNISON 1956, LEWIS 1957, PRESTON et al. 1965, ABOU AKKADA and OSMAN 1967, CISZUK 1972).

The results of the present investigations agree with those of earlier ones. The lower blood urea concentration with different carbohydrate diets is primarily due to the different protein intake, although the carbohydrate supplement itself can have a decreasing effect. The lower rumen ammonia concentration and higher blood urea concentration with Viher solution than with other silages can be attributed to differences in the solubility of the protein of the silages. Being less soluble, the protein of Viher solution silage is also degraded less in the rumen, as is shown by the lower rumen ammonia content (Table 18). But its degradation probably continues to a greater extent in the lower parts of the digestive tract than that of the AIV I and formic acid silages, and the ammonia released and absorbed there gives a higher blood urea concentration in the animals fed with this silage. This protein degradation of Viher solution silage in the abomasum or in the intestine is not, however, sufficiently great to compensate for its lower degradation in the rumen, as the digestibility coefficients show (Table 17).

Although there are some differences between the different diets in the concentration of the blood constituents determined, about all the values fall within the normal ranges (RAUEN 1964, pp. 341—362). They also show that, as far as they are concerned, the nutritional status of the animals was good on these silage and carbohydrate feeds.

GENERAL CONSIDERATIONS

The investigations reported in this paper concern the effect of sucrose, starch and cellulose supplements at varied levels on the utilization by ruminants of grass silage prepared with different preservatives. Special attention was given to the utilization of crude protein.

The sheep was chosen as the experimental animal, because its smaller size made it more suited than the cow for the present experimental conditions. An added advantage of using sheep was that information was also obtained on their feeding and nutrition with silage-based diets. Experiments of this kind have not previously been performed in Finland and only rarely in other countries. However, the results of these investigations which primarily concern nutritional physiology, may also be applied to other ruminants.

The investigations consisted of two main experiments, in which the Latin square design was applied. In Exp. I a 7 × 7 Latin square and in Exp. II 9 small (3 × 3) Latin squares were used. The experiments comprised mainly digestibility and balance trials based on the quantitative collection method, analyses of rumen content and blood investigations. They were all performed on the same permanently rumen-fistulated adult rams. The collection of the different samples and the determinations were not found to interfere with each other in any case or to disturb the welfare of the animals. HAYES et al. (1964) has also shown that the fistulation technique does not affect the total digestion of the animal. A dorsally located fistula does not greatly weaken the rumen wall and has only a very slight influence on absorption (SCHMEKEL 1967 a). Differences have been found in the composition of the rumen fluid at different levels in the rumen (HOGAN 1964, DAVEY 1965, LAMPILA 1955, 1965, LAMPILA and POUTIAINEN 1966), but the sampling technique adopted here may be assumed to have minimized the errors caused by such differences.

The rumen samples were taken three times daily: in the morning before feeding and 2.5 hr and 5.5 hr after the beginning of feeding. Even with so few sampling times, it is possible to obtain a rather representative picture of the fermentation processes in the rumen. Experiments where the rumen samples were analysed at regular intervals during the day have shown that in animals on grass silage feeds the pH, ammonia and VFA concentration in the rumen fluid have their extreme values when 1—3 hours have elapsed after feeding (LAMPILA 1960, HUNGATE 1966, SCHMEKEL 1967 a, 1967 c, SAUE 1968).

The carbohydrate supplements substituted in these experiments for 15 % and 30 % of the dry matter of the daily rations, represent on the average 2—3 g and 5 g per kg live weight. Rather high supplements were chosen in order that their effect on the utilization of silage could be clearly seen. It has been shown that sugar supplements given to sheep and cattle at the rates of 2—3 g and 3—5 g, respectively, per kg live weight per day increased the utilization of hay and concentrate feeds by stimulating the action of the rumen microbes, whereas given at higher rates they had the opposite effect (KRJUKOV 1965, KURILOV 1965, 1972). However, the situation may be different in the case of silage owing to the fact that during ensiling the sugars and fructosans disappear completely, or nearly so. These changes, due primarily to fermentation, affect not only the carbohydrate fraction, but also the nitrogenous substances of grass. The extent of their degradation and thus also their solubility, depending primarily on the ensiling method used, may differ in different silages. Consequently, in this study special attention was paid to the comparison of the effects of the carbohydrate supplements, with their different rates of degradation in the rumen.

Even at the 15 % levels, the sucrose and starch supplements proved to be too large, if their effect on the utilization of silage is judged only from its digestibility coefficients. These supplements generally decreased the digestibility values, by roughly similar amounts. This effect

increased with a rise in their level. The situation was not the same in the case of cellulose, which did not decrease the digestibility of silage components, while also failing to increase it to any great extent.

The digestion in the rumen, as reflected by the VFA concentration of the rumen fluid, was also found to differ with the carbohydrate diets, but not very significantly. The sucrose supplements generally decreased the concentration of total VFA, the effect of the starch supplements was almost nil, and the cellulose supplements increased it. The VFA concentrations and especially the relative amounts of different acids in the mixture varied widely with the sampling time. The sucrose supplements decreased the proportions of acetic and isovaleric acids, but increased those of propionic, butyric and valeric acids in the total VFA mixture, when compared with diets consisting entirely of silage. The effects of the starch and cellulose supplements were rather slight, especially that of the starch supplements, although the cellulose supplements tended to increase the proportion of acetic acid in some cases.

The composition of the VFA mixture can influence its energy content, because the various fatty acids have different molar caloric values, which increase with the number of carbon atoms in the molecule (WEAST 1968—69, pp. D 184—189). Consequently, if the production of acetic acid increases in the fermentation in the rumen, as with cellulose supplements, the molar caloric value of the VFA mixture decreases. With sucrose supplements, the production of butyric acid increases, and the value also tends to increase.

The composition of milk also depends on the rumen fatty acid composition. The butterfat content of milk has been shown to increase with a high level of acetic acid and/or a low level of propionic acid (BLAXTER 1962, VAN SOEST 1963). The sucrose diets of the present experiments could thus decrease, and the cellulose diets increase, the fat content of milk, if used for dairy cattle.

The pH values of the rumen fluid of sheep lay between 6.1 and 6.9 on all the diets and can be kept optimal for normal feeding (ANNISON and LEWIS 1962).

Many criteria were used in the present study to assess the utilization of the nitrogenous substances of silage:

— digestibility of crude protein
— N balance
— biological value of protein
— rumen fluid ammonia concentration
— blood urea and ammonia concentrations.

As regards the effect of different carbohydrate supplements, it should be remembered that the utilization of crude protein is closely dependent on its content in the ration, as has been shown by earlier investigations (BOAS FIXEN 1935, BLAXTER and WOOD 1951, CHALMERS 1961, SCHMEKEL 1967a, CISZUK 1972). Thus in the present experiments at least the biological value of protein could be expected to increase and the ammonia concentration of the rumen fluid and the urea concentration of the blood to decrease, when the carbohydrate levels increased, because this involved a decrease in the crude protein content of the daily rations. Consequently, attention was concentrated on the effect of the different carbohydrate supplements at the same levels, since the crude protein content of the ration was then the same.

All the carbohydrate supplements depressed the digestibility of the crude protein of silage, the depression increasing with the carbohydrate level. A comparison of the different carbohydrate diets, generally showed that the digestibility coefficients of crude protein decreased in the following order: from cellulose to starch to sucrose, although the differences between them were small. It should be noted that the digestibility percentages used show only the apparent digestibility, but not the true digestibility of the feed. The latter would be more useful, especially in the case of crude protein (PALOHEIMO et al. 1968, SYRJÄLÄ 1967, 1971 a, 1971 b). It has been shown (HAMILTON 1942, FONTENOT et al. 1955, SYRJÄLÄ 1971 a) that soluble carbohydrates increase the metabolic nitrogen substances of

faeces. From this it follows that the apparent digestibility values will be too low, especially when the ration contains sugar or other soluble carbohydrate supplements.

The N balance and the biological value of protein were somewhat higher with the sucrose than with the corresponding starch and cellulose diets. The observation that the sucrose supplements had the most beneficial effect on the utilization of the nitrogenous compounds in silage was also supported by the finding that the ammonia concentration of the rumen fluid was clearly lower with the diets containing sucrose supplements than with the starch or cellulose supplements. This was apparent at both the 15 % and 30 % levels. In contrast, no remarkable differences were found between the different carbohydrates in the blood urea and ammonia concentrations.

The differences between the effects of the sucrose, starch and cellulose supplements on the digestibility and on the utilization of the nitrogenous components of silage appeared in this study to depend closely on the rates at which these carbohydrates are degraded in the rumen. Sucrose is degraded most rapidly, starch more slowly and cellulose most slowly (PHILLIPSON 1942, PHILLIPSON and MCANALLY 1942).

The present results point to the conclusion that even such large carbohydrate supplements can suitably be used in grass silage feeding. Although they tend to decrease the digestibility of silage, they increase the utilization of its nitrogenous components. The effect of sucrose has been shown to be more beneficial in this respect than that of starch and cellulose. Higher levels than 30 % can hardly be considered with silage feeding. How levels below 15 % affect the utilization of silage needs more investigation.

In the investigation of the effect of different preservatives on the utilization of grass silage, attention was concentrated on the preservatives now in common use in Finland: AIV I, formic acid and Viher solution. Silage preserved with AIV II, also common in Finland, was used as well, but in another year (Exp. I) than the silages prepared with those three preservatives and is accordingly not included with them in the comparison. It has also been shown (POUTIAINEN and HUIDA 1970) that AIV II gives results similar to those of formic acid when used as an ensiling preservative.

The silages in the comparison were prepared from the same raw material and ensiled in vacuum stacks surrounded with black polythene plastic film, each containing about 4 000 kg. The quality of the silages was rather good and fairly uniform. The crude protein fraction was present in a less soluble form in Viher solution silage than in AIV I and formic acid silage. The total ensiling losses were lower in the formic acid silage than in the others.

The intake and digestibility values of the different silages did not differ considerably. Only the digestibility of crude protein in the Viher solution silage was significantly lower than that in the other silages. The other values reflecting the utilization of the nitrogenous components also tended to be inferior in this silage, the rumen fluid ammonia concentration forming the exception and being lower with the Viher solution silage diets than with the other silages. The differences in N utilization between the different silages has been demonstrated to depend primarily on the formaldehyde of the Viher solution, which has a protein-protecting effect (FERGUSON et al. 1967, REIS and TUNKS 1969).

Some differences were found between different silage diets in the total VFA content of the rumen fluid. It was highest with formic acid silage, lower with Viher solution and lowest with AIV I silage. The relative proportions of the individual acids in the mixture differed only slightly. The effect of the different carbohydrate supplements also varied little with the silages.

On the whole the results of the comparison of the preservatives used showed such slight differences that it is difficult to say which of them has the most beneficial effect on the utilization of grass silage by ruminants.

The quality and the nutritive value of silage depends not only on careful ensiling but also on the raw material used. For this reason, in future

investigations it might be advisable to concentrate on the raw material of silage, for instance its botanical composition and its stage of growth at harvesting. These may also influence the effect that sucrose, starch and cellulose supplements have on the utilization of grass silage by ruminants.

REFERENCES

ABOU AKKADA, A. R. & OSMAN SAYED EL, H. 1967. The use of ruminal ammonia and blood urea as an index of the nutritive value of protein in some food-stuffs. J. Agric. Sci. 69: 25—31.

ALDER, F. E., MCLEOD, D. S.L. & GIBBS, B. G. 1969. Comparative feeding value of silages made from wilted and unwilted grass and grass/clover herbage. J. Brit. Grassl. Soc. 24: 199—206.

ANNISON, E. F. 1956. Nitrogen metabolism in the sheep. Protein digestion in the rumen. Biochem. J. 64: 705—714.

ANNISON, E. F., CHALMERS, M, I., MARSHALL, S. B. M. & SYNGE, R. L. M. 1954. Ruminal ammonia formation in relation to the protein requirement of sheep. III Ruminal ammonia formation with various diets. J. Agric. Sci. 44: 270—273.

— & LEWIS, D. 1962. Metabolism in the rumen. 184 p. London.

ANON. 1965. The nutrient requirements of farm livestock. No 2 Ruminants. Technical reviews and summaries. Agric. Res. Council, 204 p. London.

— 1969. Fodermiddeltabel. Nord. Jordbr.forskenes foren. 40 p. Gjøvik.

ARCHIBALD, J. G. & KUZMESKI, J. W. 1954. Further observations on the composition of grass silage. J. Dairy Sci. 37: 1283—1290.

ARIAS, C., BURROUGHS, W., GERLAUGH, P. & BETHKE, R. M. 1951. The influence of different amounts and sources of energy upon *in vitro* urea utilization by rumen microorganisms. J. Anim. Sci. 10: 683—692.

AXELSSON, J. 1952. Use of molasses, grains, and other additives in making grass silage. Proc. 6th Intern. Grassl. Congr. 1153—1158. Pennsylvania.

— & KIVIMÄE, A. 1955. Kofasalz und Ensilierungsphosphat als Zusatzmittel beim Silieren von Klee. Landw. Forsch. 8: 54—67.

BALCH, C. C., BALCH, D. A., BARTLETT, S., BARTRUM, M. P., JOHNSON, V. W., ROWLAND, S. J. & TURNER, J. 1955. Studies of the secretion of milk of low fat content by cows on diets low in hay and high in concentrates. VI. The effect on the physical and biochemical process of the reticulo-rumen. J. Dairy Res. 22: 270—289.

BALCH, D. A. & ROWLAND, S. J. 1957. Volatile fatty acids and lactic acid in the rumen of dairy cows receiving a variety of diets. Brit. J. Nutr. 11: 288—298.

BARKER, H. A. 1961. Fermentations of nitrogenous organic compounds. The bacteria II, 151—207. Ed. Gunsalus, I. C. and Stanier, R. V., New York.

BARKER, S. B. & SUMMERSON, W. H. 1941. The colorimetric determination of lactic acid in biological material. J. Biol. Chem. 138: 535—554.

BARLOW, C. 1965. The use of special-purpose grasses for silage production. I. A comparison of varietes. J. Agric. Sci. 64: 439—447.

BARNETT, A. J. G. 1954. Silage fermentation.. 208 p. London.

— & REID, R. L. 1961. Reactions in the rumen. 252 p. London.

BLAXTER, K. L. 1961. Energy utilization in the ruminant. Digestive physiology and nutrition of the ruminant, 183—197. Ed. Lewis, D. London.

— 1962. The energy metabolism of ruminants. 329 p. Springfield, Illinois.

— & WOOD, W. A. 1951. The nutrition of the young Ayrshire calf. 4. Some factors affecting the biological value of protein determined by nitrogen-balance methods. Brit. J. Nutr. 5: 55—67.

BELASCO, I. J. 1956. The role of carbohydrates in urea utilization, cellulose digestion and fatty acid formation. J. Anim. Sci.15: 496—508.

BLOOMFIELD, R. A., KEARLEY, E. O., CREACH, D. O. & MUHRER, M. E. 1963. Ruminal pH and absorption of ammonia and VFA. J. Anim. Sci. 22: 833.

BOAS FIXSEN, M. A. 1935. The biological value of protein in nutrition. Nutr. Abstr. Rev. 4: 447—459.

BOLDUAN, G., VOIGT, J., PIATKOWSKI, B. & STEGER, H. 1971. Einfluss der Verabreichung leicht hydrolysierbarer Kohlenhydrate auf Verdaulichkeit und Pansenfermentation bei Kühen. Arch. Tierernähr. 21: 141—149.

BRAHMAKSHATRIYA, R. D. & DONKER, J. D. 1971. Five methods for determination of silage dry matter. J. Dairy Sci. 54: 1470—1474.

BREIREM, K. & ULVESLI, O. 1954. Resultater fra ensileringsforskningen. Norg. Landbr.høgsk. Saertr. 145: 1—35.

— & ULVESLI, O. 1960. Ensiling methods. Herb. Abstr. 30: 1—8.

BRIGGS, H. M. & HELLER, V. G. 1940. The effect of adding blackstrap molasses to a lamb- fattening ration. J. Agric. Res. 60: 65—72.

— & HELLER, V. G. 1943. Effect of adding blackstrap

molasses, potassium salts, sucrose and corn syrup to a lamb-fatting ration. J. Agric. Res. 67: 359—367.

Briggs, P. K., Hogan, J. P. & Reid, R. L. 1957. The effect of volatile fat acids, lactic acid, and ammonia on rumen pH in sheep. Austr. J. Agric. Res. 8: 674—690.

Brown, L. D., Hillman, D., Lassiter, C. A. & Huffman, C. F. 1963. Grass silage vs. hay for lactating dairy cows. J. Dairy Sci. 46: 407—410.

Burroughs, W., Gall, L. S., Gerlaugh, P. & Bethke, R. M. 1950 a. The influence of casein upon roughage digestion in cattle with rumen bacteriological studies. J. Anim. Sci. 9: 214—220.

— Gerlaugh, P., Edgington, B. H. & Bethke, R. M. 1949. The influence of corn starch upon roughage digestion in cattle. J. Anim. Sci. 8: 271—278.

— Long, J., Gerlaugh, P. & Bethke, R. M. 1950 b. Cellulose digestion by rumen micro-organisms as influenced by cereal grains and protein rich feeds commonly fed to cattle using artificial rumen. J. Anim. Sci. 9: 523—530.

Burstedt, E., Ciszuk, P. & Lingvall, P. 1971. Ensileringstudier med nya konserveringsmetoder. Lantbr. högsk. försöksledarmöten, Husdjur 27, 15: 1—19.

Cameron, C. D. T. 1966. The effects of nitrogen fertilizer application rates to grass on forage yields, body weight gains, feed utilization, and vitamin A status of steers. Can. J. Anim. Sci. 46: 19—24.

Campling, R. C. 1966. The intake of hay and silage by cows. J. Brit. Grassl. Soc. 21: 41—48.

Carlson, J. R. 1963. The acceptability and feeding value of nitrogen fertilized grass silage. Norg. Landbr.høgsk. Foringsfors. Ber. 115: 1—14.

Castle, M. E. & Watson, J. N. 1969. The effect of level of protein in silage on the intake and production of dairy cows. J. Brit. Grassl. Soc. 24: 187—192.

— & Watson, J. N. 1970. Silage and milk production, a comparison between grass silage made with and without formic acid. J. Brit. Grassl. Soc. 25: 65—70.

Chalmers, M. I. 1961. Protein synthesis in the rumen. Digestive physiology and nutrition of the ruminant, 205—225. Ed. Levis, D., London.

— Cuthbertson, D. P. & Synge, R. L. M. 1954. Ruminal ammonia formation in relation to the protein requirement of sheep. I. Duodenal administration and heat processing as factors influencing fate of casein supplements. J. Agric. Sci. 44: 254—262.

— & Synge, R. L. M. 1954. Ruminal ammonia formation in relation to the protein requirement of sheep. II. Comparison of casein and herringmeal supplements. J. Agric. Sci. 44: 263—269.

Chaney, A. L. & Marbach, E. P. 1962. Modified reagents for determination of urea and ammonia. Clin. Chem. 8: 130—132.

Chappell, G. L. M. & Fontenot, J. P. 1968. Effect of level of readily-available carbohydrates in purified sheep rations on cellulose digestibility and nitrogen utilization. J. Anim. Sci. 27: 1709—1715.

Ciszuk, P. 1972. Ammoniakhalt i vommen och urinämneshalt i blodet hos får som mått på foderkvävets utnyttjande. Stencilserie 17: 1—117. Lantbr.högsk. Avd. Husdj. näringsfysiol., Uppsala.

Colebrook, W. F. & Reis, P. J. 1969. Relative value for wool growth and nitrogen retention of several proteins administered as abomasal supplements to sheep. Austr. J. Biol. Sci. 22: 1507—1516.

Coombe, J. B., Tribe, D. E. & Morrison, J. W. C. 1960. Some experimental observations on the toxicity of urea to sheep. Austr. J. Agric. Res. 11: 247—256.

Craven, J. A. 1963. The value of silage in sheep nutrition. Ann. rep. 1963. School of Agric. Univ. Durham, Newcastle 17 p.

Czerkawski, J. W. & Breckenridge, G. 1969. Fermentation of various soluble carbohydrates by rumen microorganisms with particular reference to methane production. Brit. J. Nutr. 23: 925—937.

Davey, A. W. F. 1965. Sampling the contents of the rumen of the dairy cow. N.Z.J. Agric. Res. 8: 409—411.

Dewer, W. A. & McDonald, P. 1961. Determination of dry matter in silage by distillation with toluene. J. Sci. Food. Agric. 12: 790—795.

Dijkstra, N. D. 1952. Chemical and bacteriological changes involved in making grass silage and their effect on losses in feed value. Proc. 6th Intern. Grassl. Congr. 1164—1170, Pennsylvania.

— 1965. Silagefütterung bei Milchvieh. Wirtschaftseigene Futter 11: 47—55.

— 1970. Comparison between hay dried with cold air, hay dried with warm air and wilted silage as roughage for dairy cows. Vers. Landbouwk. onderz. 735: 1—42.

Dougherty, R. W. 1955. Permanent stomach and intestinal fistulas in ruminants: some modifications and simplifications. Cor. Veter. 45: 331—357.

Dror, Y., Mayevsky, A. & Bondi, A. 1969. Some effects of starch on protein utilization by sheep. Brit. J. Nutr. 23: 727—735.

Du Plessis, G. F. & Merwe, F. J. van der 1969. Effect of carbohydrate supplementation on the nitrogen balance of sheep fed fresh frozen clover and lucerne. Agroan. 1: 155—160.

Ellis, W. C. & Pfander, W. H. 1958. The influence of varied cellulose and nitrogen levels upon ration digestibility and nitrogen balance of lambs fed semi-purified rations. J. Nutr. 65: 235—250.

Elsden, S. R. 1945. The fermentation of carbohydrates in the rumen of the sheep. J. Exp. Biol. 22: 51—62.

— Hitchcock, M. W. S., Marschall, R. A. & Phillipson, A. T. 1945. Volatile acids in the digesta of ruminants and other animals. J. Exp. Biol. 22: 191—202.

El-Shazly, K., Dehority, B. A. & Johnson, R. R. 1961. Effect of starch on the digestion of cellulose *in vitro* and

in vivo by rumen microorganisms. J. Anim. Sci. 20: 268—273.

ETTALA, E., POUTIAINEN, E., LAMPILA, M., RINNE, K. & TAKALA, M. 1971. Typpilannoituksen vaikutus laidunnurmeen ja lehmien tuotoksiin. Kehittyvä Maatalous 4:. 18—30.

FAICHNEY, G. J. & WESTON, R. H. 1971. Digestion by ruminant lambs of a diet containing formaldehyde-treated casein. Austr. J. Agric. Res. 22: 460—468.

FARRIES, E. 1966. Zum Nährwert von Weidegrass in unterschiedlichen Vegetationsstadien. Wirtschaftseigene Futter 12: 77—83.

— 1969. Zum Einfluss des Anwelkens auf die Verdaulichkeit von Silage und Heu. Wirtschaftseigene Futter 15: 52—59.

FERGUSON, K. A., HEMSLEY, J. A. & REIS, P. J. 1967. Nutrition and wool growth. The effect of protecting dietary protein from microbial degradation in the rumen. Austr. J. Sci. 30: 215—217.

FLIEG, O. 1938. Ein Schlüssel zur Bewertung von Gärfutterproben. Futterbau u. Gärfutterbereitung 1: 121—128.

FONTENOT, J. P., GALLUP, W. D. & NELSON, A. B. 1955. Effect of added carbohydrates on the utilization by steers of nitrogen in wintering rations. J. Anim. Sci. 14: 807—817.

FOX, J. B. & BROWN, S. M. 1969. The effect of fertilizer nitrogen on silage fermentation. J. Brit. Grassl. Soc. 24: 23—30.

GALL, L. S., THOMAS, W. E., LOOSLI, J. K. & HUHTANEN, C. N. The effect of purified diets upon rumen flora. J. Nutr. 44: 113—122.

GEERING, J. 1941. Über den Einfluss der Häufigkeit des Wiesenschnittes auf Pflanzenbestand, Nährstoffgehalt und Nährstoffertrag. Landw. J.buch. Schw. 55: 579—597.

GLIMP, H. A., KARR, M. R., LITTLE, C. O., WOOLFOLK, P. G., MITCHELL, G. E. JR. & HUDSON, L. W. 1967. Effect of reducing soybean protein solubility by dry heat on the protein utilization of young lambs. J. Anim. Sci. 26: 858—861.

GORDON, C. H., DERBYSHIRE, J. C., WISEMAN, H. G. & JACOBSON, W. C. Variations in initial composition of orchardgrass as related to silage composition and feeding value. J. Dairy Sci. 47: 987—992.

GRAY, F. V. & PILGRIM, A. F. 1951. Fermentation in the rumen of the sheep. II. The production and absorption of volatile fatty acids during the fermentation of wheaten hay and lucerne hay in the rumen. J. Exp. Biol. 28: 83—90.

— & PILGRIM, A. F. 1952. Origins of the volatile fatty acids in the rumen. Nature 170: 375.

HALLEY, R. J. & DOUGALL, B. M. 1962. The feed intake and performance of dairy cows fed on cut grass. J. Dairy Res. 29: 241—248.

HAMILTON, T. S. 1942. The effect of added glucose upon the digestibility of protein and fiber in rations for sheep. J. Nutr. 23: 101—110.

HARRIS, C. E. & RAYMOND, W. F. 1963. The effect of ensilage on crop digestibility. J. Brit. Grassl. Soc. 18: 204—212.

HAYES, B. W., LITTLE, C. O. & MITCHELL, G. E. JR. 1964. Influence of ruminal, abomasal and intestinal fistulation on digestion in steers. J. Anim. Sci. 23: 764—766.

HEAD, M. J. 1953. The effect of quality and quantity of carbohydrate and protein in the ration of the sheep on the digestibility of cellulose and other constituents of the ration, with a note on the effect of adding vitamins of the B-complex on the digestibility and retention of the nutrients of a hay ration. J. Agric. Sci. 43: 281—293.

HECKER, J. F. 1969. A simple rapid method for inserting rumen cannulae in sheep. Austr. Veter. J. 45: 293—294.

HECKMAN, M. 1967. Minerals in feeds by atomic absorption spectrophotometry. J. A.O.A.C. 50: 45—50.

HELMER, L. G. & BARTLEY, E. E. 1971. Progress in the utilization of urea as a protein replacer for ruminants. A review. J. Dairy Sci. 54: 25—51.

HENK, G. & LAUBE, W. 1968. Untersuchungen zur Heissluftrocknung von Grünfutter. 2. Verluste an verdaulichen Nährstoffen. Arch. Tierernähr. 18: 437—446.

HILLMAN, D., LASSITER, C. A., HUFFMAN, C. F. & DUNCAN, C. W. 1958. Effect of all-hay vs. all-silage rations on dry matter intake of lactating dairy cows; Moisture and pH as factors affecting appetite. J. Dairy Sci. 41: 720.

HOFLUND, S., QUIN, J. I. and CLARK, R. 1948. Studies on the alimentary tract of Merino sheep in South Africa. XV. The influence of different factors on the rate of cellulose digestion (a) in the rumen and (b) in ruminal ingesta as studied *in vitro*. Onderstepoort J. Veter. Sci. 23: 395—409.

HOGAN, J. P. 1961. The absorption of ammonia through the rumen of the sheep. Austr. J. Biol. Sci. 14: 448—460.

HOLMES, J. C. & LANG, R. W. 1963. Effects of fertilizer nitrogen and herbage dry matter content on herbage intake and digestibility in bullocks. Anim. Prod. 5: 17—26.

HOUPT, T. R. 1959. Utilization of blood urea in ruminants. Amer. J. Physiol. 197: 115—120.

HUDSON, L. W., GLIMP, H. A., LITTLE, C. O. & WOOLFOLK, P. G. 1970. Ruminal and postruminal nitrogen utilization by lambs fed heated soybean meal. J. Anim. Sci. 30: 609—613.

HUIDA, L. I. Quantitative determination of volatile fatty acids from silage and rumen samples. (unpubl.).

HUOKUNA, E. 1960. Grazing on herbage at different grazing stages: Its effect on a cocksfoot dominant ley and on milk production. Valt. Maatal.koetoim. Julk. 177: 1—44.

— 1968. Lypsykarjan laitumen runsas typpilannoitus. Ann. Agric. Fenn. 7: 25—32.

HUGHES, J. G. & WILLIAMS, G. L. 1971. The effect of formaldehyde treatment of protein supplements upon their in vitro fermentation and utilization by sheep. Proc. Nutr. Soc. 30: 41 A.

HUNGATE, R. E. 1966. The rumen and its microbes. 533 p. New York.

— DOUGHERTY, R. W., BRYANT, M. P. & CELLO, R. M. 1952. Microbiological and physiological changes associated with acute indigestion in sheep. Cor. Veter. 42: 421—449.

HVIDSTEN, H. 1946. Forsøk med cellulose til drøvtyggere. Norg. Landbr.høgsk. Meld. 26: 63—234.

INOUE, S. & OHYAMA, Y. 1966. Chemical quality and digestibility of grass-clover low-moisture silage. Nutr. Abstr. Rev. 36: 57.

JARL, F. 1947. Försök med melassensilering. Lantbr. högsk. Husd.förs. Medd. 64: 1—8.

— 1948. Ensileringsförsök och utfodringsförsök med ensilage. I. Stat. Husd. förs. Medd. 32: 1—96.

— 1951. Ensileringsmetoder. Stat. Husd.förs. Medd. 82: 670—685.

— & HELLEDAY, T. 1948. Ensileringsförsök och utfordringsförsök med ensilage. II. Stat. Husd.förs. Medd. 37: 1—63.

JOHNS, A. T. 1955. Pasture quality and ruminant digestion. II. Levels of volatile acids and ammonia in the rumen of sheep on a high-production pasture. N.Z.J. Sci. Technol. 37 A: 323—331.

JÄNTTI, A. & KÖYLIJÄRVI, J. 1964. Laidunnurmien typpiväkilannoituskokeiden tuloksia. Ann. Agric. Fenn. 3: 165—214.

KANE, E. A., JACOBSON, W. C. & DAMEWOOD, P. M. JR. 1959. Effect of corn starch on digestibility of alfalfa hay. J. Dairy Sci. 42: 849—855.

KAPPELLE, D. & POSTMA, C. 1952. De invloed van het vochtgehalte op enkelte eigenschappen van kuilgras. Versl. Centraal Inst. Landbouwk. Onderz. 1952, 101—112.

KARR, M. R., LITTLE, C. O. & MITCHELL, G. E., JR. 1966. Starch disappearance from different segments of the digestive tract of steers. J. Anim. Sci. 25: 652—654.

KELLNER, O. & BECKER, M. 1971. Grundzüge der Fütterungslehre. 374 p. Hamburg.

KELLOGG, D. W. 1969. Influence of sucrose on rumen fermentation pattern and milk fat content of cows fed a high-grain ration. J. Dairy Sci. 52: 1601—1604.

— & OWEN, F. G. 1969. Relation of ration sucrose level and grain content to lactation performance and rumen fermentation. J. Dairy Sci. 52: 657—662.

KOMKRIS, T., STANLEY, R. W. & MORITA, K. 1965. Effects of feed containing molasses fed separately and together with roughage on digestibility of rations, volatile fatty acids produced in the rumen, milk production, and milk constituents. J. Dairy Sci. 48: 714—719.

KORMOS, J. & CHESTNUTT, D. M. B. 1966. A study of ensiling wilted and unwilted grass at two stages of maturity. 1. Nutrient losses. Rec. Agric. Res. 15: 11—23.

KREULA, M. 1969. Rehunsäilöntämenetelmät ja uudet AIV-liuokset. Karjatalous 45: 192—194.

KRJUKOV, B. 1965. Einfluss eines verschiedenen Zuckergehaltes in der Ration auf die fermentation Vorgänge im Pansen. — IX Mendelcevskij S-RZD po Obščej i prikladmoj chimii. 1965. Nr. 3. S. 262 (Ref. Landw. Zentralbl. III 1966, p. 1985).

KROGH, N. 1959. Studies on alterations in the rumen fluid of sheep, especially concerning the microbial composition, when readily available carbohydrates are added to the food. I. Sucrose. Acta Veter. Scand. 1: 74—97.

— 1961. III. Starch. Acta Veter. Scand. 2: 103—119.

KUCHLER, L. F. & WACHTER, H. 1931. Die Sicherung der Grünfutterkonservierung in Silo durch chemisch and biologisch wirksame Zusatzmittel. Prakt. Bl. Pfl.bau. Pfl.schutz. 9: 118—133.

KURILOV, N. N. 1965. Die Umwandlung und Ausnutzung der Stickstoffsubstanzen im Pansen der Wiederkäuer. Tezisy dokladov na Simpoziume »Kormlenie plemermyeh proizvoditelej» Moskva 1965 12—13 (Ref. Landw. Zentralbl. III 1966, p. 1685).

— 1972. The glucose requirement of ruminants and the importance of readily digestible carbohydrates in the utilization of nutrients from the ration. Nutr. Abstr. Rev. 42: 701.

— MASLOBOEV A. Y.A. & SEVASTYANOVA, N. A. 1966. Level of rumen fermentation and utilization of feed N by cows with feeds rich in starch or sugar included in the ration. Trudy vses. nauchnoissled. Inst. Fiziol. Biokhim. sel'.-khoz. Zhivot. 2: 221—234. (Ref. Dairy Sci. Abstr. 39: 2182)

LAMPILA, M. 1955. Preliminary studies on the variations of pH and volatile fatty acid concentration of the rumen contents of the cow. J. Sci. Agric. Soc. Finl. 27: 142—153.

— 1960. The effect of silage prepared in different ways upon the ammonia content of the cow's rumen ingesta. J. Sci. Agric. Soc. Finl. 32: 169—175.

— 1964. Volatile fatty acids, pH and microbial activity in the rumen contents of the cow. Ann. Agric. Fenn. 3: 1—76.

— 1965. The passage of fluid, certain mineral elements, and volatile fatty acids from the reticulo-rumen of the cow. Ann. Agric. Fenn. 4: 134—144.

— 1966. The composition and caloric value of the volatile fatty acid mixture of the bovine rumen fluid on five diets. Acta Agr. Fenn. 109: 121—135.

— & POIJÄRVI, I. 1959. The formation of volatile fatty acids in the rumen contents of cows *in vivo* and *in vitro*. J. Sci. Agric. Soc. Finl. 31: 315—320.

— & POUTIAINEN, E. 1966. Systematic differences in the composition of the bovine rumen fluid between differ-

ent parts of the rumen. Ann. Agric. Fenn. 5: 279—297.

LANCASTER, R. J. 1966. Relative efficiency of silage making in polythene-covered bunkers and vacuum-compressed stacks. Proc. 10th Intern. Grassl. Congr. 560—564. Helsinki.

LESLIE, J. I., HEMKEN, R. W. & CLARK, N. A. 1968. A comparison of nitrogen fertilized grasses with a grass-legume mixture as pasture for dairy cows. Nutr. Abstr. Rev. 38: 994.

LESSARD, J. R. & MCDONALD, P. 1966. A silaca gel chromatographic procedure adapted to liquid-scintillation counting of ^{14}C labelled organic acids from plant material and silage. J. Sci. Food Agric. 17: 257—263.

LEWIS, D. 1957. Blood-urea concentration in relation to protein utilization in the ruminant. J. Agric. Sci. 48: 438—446.

— HILL, K. J. & ANNISON, E. F. 1957. Studies on the portal blood of sheep. 1. Absorption of ammonia from the rumen of the sheep. Biochem. J. 66: 587—592.

— & MCDONALD, I. W. 1958. The inter-relationships of individual proteins and carbohydrates during fermentation in the rumen of the sheep. 1. The fermentation of casein in the presence of starch or other carbohydrate materials. J. Agric. Sci. 51: 108—118.

LITTLE, C. O., BURROUGHS, W. & WOODS, W. 1963. Nutritional significance of soluble nitrogen in dietary proteins for ruminants. J. Anim. Sci. 22: 358—363.

LUKŠO, A. V. 1966. Use of sodium bisulphate, ammonium bisulphate and sodium chloride during ensiling. Nutr. Abstr. Rev. 36: 361.

MACKENZIE, D. J. & WYLAM, C. B. 1957. Analytical studies on the carbohydrates of grasses and clovers. VIII. Changes in carbohydrate composition during the growth of perennial rye-grass. J. Sci. Food Agric. 8: 38—45.

MARTIN, R. J. JR. & WING, J. M. 1966. Effect of molasses level on digestibility of a high concentrate ration and on molar proportions of volatile fatty acids produced in the rumen of dairy steers. J. Dairy Sci. 49: 846—849.

MATHER, R. E., BREIDENSTEIN, C. P., POULTON, B. R. & BONNINGTON, G. H. 1960. High levels of grass silage for milk production with no grain, medium and high grain feeding. 1. Intake, milk production and body weight changes. J. Dairy Sci. 43: 358—370.

MAYNARD, L. A. & LOOSLI, J. K. 1962. Animal nutrition. 533 p. New York.

MCCARRICK, R. B. 1969. A comparison of seven additives used in ensiling high-moisture grass/clover pastures. J. Brit. Grassl. Soc. 24: 25—30.

— MAGUIRE, M. F., POOLE, D. B. R. & SPILLANE, T. A. The nutritive values of ammonium bisulphate and molassed silages. III. Effects of level of ammonium bisulphate applied to herbage on silage quality and animal performance. Irish J. Agric. Res. 4: 135—142.

MCCULLOUGH, H. 1967. The determination of ammonia in whole blood by a direct colorimetric method. Clin. Chim. Acta 17: 297—304.

MCCULLOUGH, M. E. 1961. A study of factors associated with silage fermentation and dry matter intake by dairy cows. J. Anim. Sci. 20: 288—291.

— 1966. The nutritive value of silage as influenced by silage fermentation and ration supplementation. Proc. 10th Intern. Grassl. Congr. 235—238. Helsinki.

MCDONALD, I. W. 1948. The absorption of ammonia from the rumen of the sheep. Biochem. J. 42: 584—587.

— 1952. The role of ammonia in ruminal digestion of protein. Biochem. J. 51: 86—90.

MCDONALD, P. & DEWER, W. A. 1960. Determination of dry matter and volatiles in silage. J. Sci. Food. Agric. 11: 566—570.

— HENDERSON, A. R. & MCGREGOR, A. W. 1968. Chemical changes and losses during the ensilage of wilted grass. J. Sci. Agric. 19: 125—132.

MINSON, D. J., HARRIS, C. E., RAYMOND, W. F. & MILFORD, R. 1964. The digestibility and voluntary intake of S 22 and H 1 ryegrass, S 170 tall fescue, S 48 timothy, S 215 meadow fescue and germical cocksfoot. J. Brit. Grassl. Soc. 19: 298—305.

— RAYMOND, W. F. & HARRIS, C. E. 1960. Studies in the digestibility of herbage. VIII. The digestibility of S 37 cocksfoot, S 23 ryegrass and S 24 ryegrass. J. Brit. Grassl. Soc. 15: 174—180.

MITCHELL, H. H. & HAMILTON, T. S. 1940. The utilization by calves of energy in rations containing different percentages of protein and in glucose supplement. J. Agric. Res. 61: 847—864.

MOORE, L. A., THOMAS, J. W. & SYKES, J. F. 1960. The acceptability of grass/legume silage by dairy cattle. Proc. 8th Intern. Grassl. Congr. 701—704. Reading.

MUNRO, H. N. 1951. Carbohydrate and fat as factors in protein utilization and metabolism. Physiol. Rev. 31: 449—488.

MURDOCH, J. C. 1954. The value of wilting, lacerating and chopping of herbage for silage. Proc. Eur. Grassl. Congr. OEEC 264—266. Paris.

— 1960. The effect of pre-wilting of herbage on the composition of silage and its intake by cows. J. Brit. Grassl. Soc. 15: 70—73.

— 1964. Some factors affecting the intake of roughage by sheep. J. Brit. Grassl. Soc. 19: 316—320.

— 1965. The effect of silage made from grass at different stages of maturity on the yield and composition of milk. J. Dairy Res. 32: 219—227.

— 1967. Factors affecting the voluntary intake of silage and hay. J. Brit. Grassl. Soc. 22: 95—99.

— BALCH, D. A., HOLDSWORTH, M. C. & WOOD, M. 1955. The effect of chopping, lacerating and wilting of herbage on the chemical composition of silage. J. Brit. Grassl. Soc. 10: 181—188.

MURDOCK, F. R. & HODGSON, A. S. 1967. Milk production

response of dairy cows fed high-moisture grass silage. 1. Effect of varying levels of hay and concentrate. J. Dairy Sci. 50: 57—61.

NELSON, N. 1944. A photometric adaptation of the Somogyi method for the determination of glucose. J. Biol. Chem. 153: 375—380.

NILSSON, G. & NILSSON, P. E. 1956. The microflora on the surface of some fodder plants at different stages of maturity. Arch. Mikrobiol. 24: 412—422.

NORDFELDT, S. 1955. Ensileringsförsök. Prövning av kolhydratrika tillsatsmedel jämte salter av olika slag och AIV-vätska. Stat. Husd.förs. Medd. 58: 1—95.

— 1966. Utilization of hay and/or silage by dairy cows. Proc. 10th Intern. Grassl. Congr. 588—593. Helsinki.

NOWAKOWSKI, T. Z. 1962 Effects of nitrogen fertilizers on total nitrogen, soluble nitrogen and soluble carbohydrate contents of grass. J. Agric. Sci. 59: 387—392.

OLOFSSON, S. 1962. Tillväxt och kemisk sammansättning hos några vallgräs under våren och försommaren. Stat. Jordbr. förs.Medd. 135: 1—123.

OLTJEN, R. R. & PUTNAM, P. A. 1966. Plasma amino acids and nitrogen retention by steers fed purified diets containing urea or isolated soy protein. J. Nutr. 89: 385—391.

ORTH, A. 1961. Silage und ihre Verfütterung. 109 p. Frankfurt am Main.

O'SHEA, J. & BROWNE, D. 1964. Digestibility of grass/clover swards under various conditions. Res. Rep. Agric. Inst. Dubl., Anim. Prod. Div. 55—56.

OSLAGE, W. & OSLAGE, H. J. 1958. Über den Einfluss von AIV-Silage auf den Mineralstoffwechsel und den Säure-Basen-Haushalt von Milchkühen. Z. Tierphysiol. Tierernähr. u. Futtermittelk. 13: 33—40.

OXFORD, A. E. 1964. A guide to rumen microbiology. N. Z. Dep. Sci. Ind. Res., Bull. 160: 1—103.

PACKETT, L. W. & GROVES, T. D. D. 1965. Urea recyling in the ovine. J. Anim. Sci. 24: 341—346.

PALOHEIMO, L. 1969. Weender Analyse. Handb. Tierernährung, 164—171. Hamburg.

— SYRJÄLÄ, L. & VAINIO, K. A. 1968. Studies on the faeces. J. Sci. Agric. Soc. Finl. 40: 237—246.

PAPENDICK, K. & BRUHN, G.-A. 1970. Die Wirkung einiger Silierhilfsmittel unter Berücksichtigung einer Milchsäurebakterienkultur. Wirtschaftseigene Futter 16: 15—24.

PEDERSEN, E. J. N., FREDERIKSEN, J. H., SKOVBORG, E. B., MØLLER, E. & WITT, N. 1971. Graesser i renbestand I. Artens, kvaelstofgødskningens og slaetantallets indflydelse på graesudbytte og -valitet. Faellesudv. Stat. Planteavl. Husdyrbr.fors., Ber. 1. København.

PHILLIPSON, A. T. 1942. The fluctuation of pH and organic acids in the rumen of the sheep. J. Exp. Biol. 19: 186—198.

— DOBSON, M. J. & BLACKBURN, T. H. 1959. Assimilation of ammonia nitrogen by rumen bacteria. Nature 183: 402—404.

PHILLIPSON, A. T., & MCANALLY, R. A. 1942. Studies on the fate of carbohydrates in the rumen of the sheep. J. Exp. Biol. 19: 199—214.

PILGRIM, A. F., GRAY, F. V. & BELLING, G. B. 1969. Production and absorption of ammonia in the sheep's stomach. Brit. J. Nutr. 23: 647—655.

PLAYNE, M. J. & MCDONALD, P. 1966. The buffering constituents of herbage and of silage. J. Sci. Food Agric. 17: 264—268.

POIJÄRVI, I. 1929. Suomessa kasvaneen nurminadan (*Festuca pratensis*) ja koiranruohon (*Dactylis glomerata*) sulavaisuudesta ja rehuarvosta. Suom. Laiduntalous 3: 47—63.

— 1941. Rehuselluloosaruokinnasta. Suom. Eläinlääk.l. 10: 391—405.

— 1948. Suomalaisten lampaiden ravinnontarve. Valt. Maatal.koetoim. Tied. 214: 1—22.

— 1950. Silppuamisen merkityksestä AIV-rehua vaikeasti säilöttävästä raaka-aineesta valmistettaessa. Koetoim. ja Käyt. 6: 3.

— 1955. AIV-, Calcifor- ja Kofa-menetelmän vertailukokeita. Acta Agr. Fenn. 83: 173—183.

POUTIAINEN, E. & HUIDA, L. 1970. Eri säilöntäaineilla valmistettujen nurmisäilörehujen laatu ja sulavuus. Koetoim. ja Käyt. 27: 2.

— & RINNE, K. 1971. Korjuuasteen vaikutus säilörehun ravintoarvoon. Kehittyvä Maatalous 3: 15—28.

PRESTHEGGE, K. 1959. Forsøk med grasprodukter til storfe. Norg. Landbr.høgsk. Fcringsfors. Ber. 93: 1—237.

PRESTON, R. L., SCHNAKENBERG, D. D. & PFANDER, W. H. 1965. Protein utilization in ruminants. I. Blood urea nitrogen as affected by protein intake. J. Nutr. 86: 281—288.

QUIN, J. I. 1943. Studies on the alimentary tract of Merino sheep in South Africa VII. Fermentation in the forestomachs of sheep. Onderstepoort J. Veter. Sci 18: 91—112.

RAININKO, K. 1968. The effects of nitrogen fertilization, irrigation and number of harvestings upon leys established with various seed mixtures. Acta Agr. Fenn. 112: 1—137.

RAUEN, H. M. 1964. Biochemisches Taschenbuch II. 1084 p. Berlin.

REID, D. L. 1966. The response of herbage yields and quality to a wide range of nitrogen application rates. Proc. 10th Intern. Grassl. Congr. 209—213. Helsinki.

— JUNG, G. A. & MURRAY, S. J. 1966. Nitrogen fertilization in relation to the palatability and nutritive value of orchardgrass. J. Anim. Sci. 25: 636—645.

REID, J. T. 1953. Urea as a protein replacement for ruminants: a review. J. Dairy Sci. 36: 955—996.

— KENNEDY, W. K., TURK, K. L., SLACK, S. T., TRIMBERGER, G. W. & MURPHY, R. P. 1959. The effect of growth state, chemical composition, and physical

properties upon the nutritive value of forages. J. Dairy Sci. 42: 567—571.

Reid, R. L., Hogan, J. P. & Briggs, P. K. 1957. The effect of diet on individual volatile fatty acids in the rumen of sheep, with particular reference to the effect of low rumen pH and adaptation on high-starch diets. Austr. J. Agric. Res. 8: 691—710.

— & Mills, S. C. 1961. Studies on the carbohydrate metabolism of sheep. XII. The interpretation of changes in the levels of metabolic intermediates after intravenous injection of propionate, succinate and malate. Austr. J. Agric. Res. 12: 913—926.

Reis, P. J. & Reid, R. L. 1959. *In vitro* studies on the effect of pH and glucose on ammonia accumulation in the rumen of sheep. Austr. J. Agric. Res. 10: 71—80.

— & Schinkel, P. G. 1961. Nitrogen utilization and wool production by sheep. Austr. J. Agric. Res. 12: 335—352.

— & Tunks, D. A. 1969. Evaluation of formaldehyde-treated casein for wool growth and nitrogen retention. Austr. J. Agric. Res. 20: 775—781.

Salo, M.-L. 1965 a. The composition of pasture grasses at the University Farm Viik. J. Sci. Agric. Soc. Finl. 37: 135—147.

— 1965 b. Determination of carbohydrate fractions in animal foods and faeces. Acta Agr. Fenn. 105: 1—102.

Saue, O. 1968. The effect of different methods of grass conservation on voluntary feed intake, body weight gains and feed expenditures in lambs. Norg. Landbr.-høgsk. Foringsfors. Ber. 135:1—93.

— 1970. Ammoniakkinhold i vomosaft ved foring med høy, surfor og grasbriketter. Nord. Jordbr.forskn. 52: 447—448.

Scharrer, K., Schreiber, R. & Kühn, H. 1952. Vergleichende Silierversuche mit verschiedenen Formiaten und Oxalsäure. Landw. Forsch. 4: 59—73.

Schmekel, J. 1967 a. Rumen digestion as affected by varying levels of nitrogen fertilized herbage conserved as silage or artificially dried. Lantbr.högsk. Ann. 33: 767—783.

— 1967 b. The influence of additives on silage consumption. Lantbr.högsk. Ann. 33: 785—804.

— 1967 c. The influence of different silage additives on rumen digestion. Lantbr.högsk. Ann. 33: 805—821.

Shaw, J. C. 1961. Nutritional physiology of the rumen. 8th. Intern. Tierzuchtkongr. Hauptber. 29—56. Hamburg.

Shepherd, J. B., Hodgson, R. E. & Sweetman, W. J. 1946. The comparative feeding value of wilted alfalfa silage and alfalfa hay for dairy cows. J. Dairy Sci. 29: 551—552.

Sherrod, L. B. & Tillman, A. D. 1962. Effects of varying the processing temperatures upon the nutritive values for sheep of solvent-extracted soybean and cottonseed meals. J. Anim. Sci. 21: 901—910.

— & Tillman, A. D. 1964. Further studies on the effects of different processing temperatures on the utilization of solvent-extracted cottonseed protein by sheep. J. Anim. Sci. 23: 510—516.

Smith, G. E., Smith, W. H. & Beeson, W. M. 1966. Effects of different levels of cellulose in purified diets for calves. J. Anim. Sci. 25: 355—359.

— Schwope, L., Overholt, P. & Strasia, C. A. 1969. Ruminal VFA and minerals in sheep fed semi-purified diets. J. Anim. Sci. 28: 862.

Somers, M. 1961. Factors influencing the secretion of nitrogen in sheep saliva. 4. The influence of injected urea on the quantitative recovery of urea in the parotid saliva and the urinary excretions of sheep. Aust. J. Exp. Biol. 39: 145—156.

Somogyi, M. 1945. A new reagent for the determination of sugars. J. Biol. Chem. 160: 61—68.

Steel, R. G. D. & Torrie, J. H. 1960. Principles and procedures of statistics. 481 p. New York.

Steen, E. 1968. Inverkan av kvävegödsling på kvaliteten hos fyra vallgräs på betestadiet. Landbr.högsk. Medd. 92: 1—27.

Steenberg, V. 1948. Recent developments in silage-making in Denmark. Emp. J. Exp. Agric. 16: 155—162.

Stirling, A. 1954. Studies in silage fermentation. Proc. Eur. Grassl. Congr. OEEC 251—253. Paris.

Strickland, M. J., Wickens, R. & Hopkins, J. R. 1966. Relative production from grassland when conserved as silage, barn dried hay or field dried hay. II. Chemical analyses and digestibility data. Exp. Husb. 13: 90—97.

Sutton, J. D. 1968. The fermentation of soluble carbo hydrates in rumen contents of cows fed diets containing a large proportion of hay. Brit. J. Nutr. 22: 689—712.

— 1969. The fermentation of soluble carbohydrates in rumen contents of cows given diets containing a large proportion of flaked maize. Brit. J. Nutr. 23: 567—583.

— 1971. The rate of carbohydrate fermentation in the rumen. Proc. Nutr. Soc. 30: 36—42.

Swift, R. W., Thacker, E. J., Black, A., Bratzler, J. W. & James, W. H. 1947. Digestibility of rations for ruminants as affected by proportions of nutrients. J. Anim. Sci. 6: 432—444.

Syrjälä, L. 1967. Kettoaineiden kokonaispaljouden määrittäminen rehuista ja sonnasta sekä sulavuus eri eläinlajeilla. Lic. thesis. Dept. Anim. Husb., Univ. Helsinki. 177 p.

— 1971 a. Effect of large doses of zinc bacitracin on voluntary intake, mastication and digestibility of hay in adult ruminants. J. Sci. Agric. Soc. Finl. 43: 86—93.

— 1971 b. Effects of different sucrose levels on digestibility and mastication of hay and on yield and composition of milk in dairy cow. J. Sci. Agric. Soc. Finl. 43: 94—102.

Tagari, H., Dror, Y., Ascarelli, I. & Bondi, A. 1964. The influence of levels of protein and starch in rations of sheep on the utilization of protein. Brit. J. Nutr. 18: 333—356.

TANCUROV, G. V. 1971. Changes in the concentration of N compounds in the rumen of sheep fed on roughage and silage. Nutr. Abstr. Rev. 41: 277.

TAPPEINER, H. 1884. Untersuchungen über die Gärung der Cellulose insbesondere über deren Lösung im Darmkanale. Z. Biol. 20: 52—134.

TAUSSKY, H. H. & SHORR, E. 1953. A microcolorimetric method for the determination of inorganic phosphorus. J. Biol. Chem. 202: 675—685.

TAYLOR, M. M. & PHILLIPS, J. D. 1970. The bacterial flora of the four silages. J. Brit. Grassl. Soc. 25: 70—71.

THOMAS, J. W., BROWN, L. D., EMERY, R. S., BENNE, E. J. & HUBER, J. T. 1969. Comparisons between alfalfa silage and hay. J. Dairy Sci. 52: 195—204.

— MOORE, L. A., OKAMOTO, M. & SYKES, J. F. 1961. A study of factors affecting rate of intake of heifers fed silage. J. Dairy Sci. 44: 1471—1483.

TILLMAN, A. D. & SIDHU, K. S. 1969. Nitrogen metabolism in ruminants: rate of ruminal ammonia production and nitrogen utilization by ruminants — A Review. J. Anim. Sci. 28: 689—697.

TOPPS, J. H., KAY, R. N. B. & GOODALL, E. D. 1968. Digestion of concentrate and of hay diets in the stomach and intestines of ruminants. 1. Sheep. Brit. J. Nutr. 22: 261—280.

ULVESLI, O. & BREIREM, K. 1960. Forsøk over ensileringsmetoder. Meld. Norg. Landbr.høgsk. 39, 16: 1—75.

— FYRILEIV, E. & BREIREM, K. 1954. En sammenligning av ensileringsmetoden for grass. Landbr.høgsk. Inst. Husdyrern. Fóringslaere, Saertr. 140. Oslo.

— & SAUE, O. 1965. Sammenligning av tilsetningsmidler ved ensilering av engverkster 1953—1959. Meld. Norg. Landbr.høgsk. 44, 12: 1—39.

— SAUE, O. & BREIREM, K. 1965. Ensileringsførsok på Stend Jordbruksskole 1955—1961. Surforkontroll i Hordaland 1953—1956. Meld. Norg. Landbr.høgsk. 44, 13: 1—31.

VAN SOEST, P. J. 1963. Ruminant fat metabolism with particular reference to factors affecting low milk fat and feed efficiency. A review. J. Dairy Sci. 46: 204—216.

VIRTANEN, A. I. 1929. Uusi menettelytapa tuoreen rehun säilyttämiseksi. Valio Lab. Helsinki.

— 1933. The A.I.V.-method for the preservation of fresh fodder. Acta Chem. Fenn. 6: 13—25.

— 1952. Use of acids in making grass silage. Proc. 6th Intern. Grassl. Congr. 1147—1152. Pennsylvania.

— 1969. Tuoreen rehun säilytyksestä. Karjatalous 45: 96—98.

VIRTANEN, O. E. 1970. Viher-liuos-säilönnän perusteista. Maamiehen Lääke 3: 10—13.

VUYST, A. DE, MORDENTI, A., AUSLOOS, M. & VANBELLE, M. 1969. Effect of glucose and starch on the concentration of lactic acid in the rumen of sheep. Nutr. Abstr. Rev. 39: 430.

WAITE, R. 1957. The water-soluble carbohydrates of grasses. III. First and second year growth. J. Sci. Food Agric. 8: 422—428.

— 1958. IV. The effect of different levels of fertilizer treatment. J. Sci. Food Agric. 9: 39—43.

— & BOYD, J. 1953. II. Grasses cut at grazing height several times during the growing season. J. Sci. Food Agric. 4: 257—261.

WALDO, D. R., MILLER, R. W., OKAMOTO, M. & MOORE, L. A. 1965. Ruminant utilization of silage in relation to hay, pellets, and hay plus grain. I. Compositions, digestion, nitrogen balance, intake and growth. J. Dairy Sci. 48: 910—916.

— MILLER, R. W., SMITH, L. W., OKAMOTO, M. & MOORE, L. A. 1966. The effect of direct-cut silage, compared to hay, on intake, digestibility, nitrogen utilization, heifer growth and rumen retention. Proc. 10th Intern. Grassl. Congr. 224—228. Helsinki.

— SMITH, L. W., MILLER, R. W. & MOORE, L. A. 1969. Growth, intake, and digestibility from formic acid silage versus hay. J. Dairy Sci. 52: 1609—1616.

WALLIN, O. 1968. Sambandet mellan ensilage och mjölkkvalitet. Nutr. Abstr. Rev. 38: 1350.

WATSON, S. J. 1952. Chemical and physical changes in forage following cutting that influence their character and feeding values; and factors that affect these changes. Proc. 6th Intern. Grassl. Congr. 1112—1119. Pennsylvania.

— & NASH, M. J. 1960. The conservation of grass and forage crops. 758 p. Edinburgh.

WEAST, R. C. 1968—69. Handbook of chemistry and physics. 49th Ed., Cleveland.

WELLER, R. A., GRAY, F. V. & PILGRIM, A. F. 1968. Volatile fatty acids produced by a sheep fed pure cellulose as sole carbohydrate in its diet. Austr. J. Biol. Sci. 21: 1075—1076.

WELLMANN, U. 1966. A comparison of the dry-matter intake of silage and hay by cattle. Proc. 10th Intern. Grassl. Congr. 568—574. Helsinki.

WHITTENBURY, R., MCDONALD, P. & BRYAN-JONES, D. G. 1967. A short review of some biochemical and microbiological aspects of ensilage. J. Sci. Food Agric. 18: 441—444.

WIERINGA, G. W. 1966. The influence of nitrate on silage fermentation. Proc. 10th Intern. Grassl. Congr. 537—540. Helsinki.

WILKINS, R. J. 1970. The *ad libitum* intake and digestibility of dried grass pellets and silage by sheep. J. Brit. Grassl. Soc. 25: 125—130.

WILLIAMS, P. S. 1925. The effect of cane molasses on the digestibility of a complete ration fed to dairy cows. J. Dairy Sci. 8: 94.

WILSON, R. F. & TILLEY, J. M. A. 1964. Determination of organic acids in silage by silica gel chromatography. J. Sci. Food Agric. 15: 208—213.

WILSON, R. K. & MCCARRICK, R. B. 1967. A nutritional

study of grass swards at progressive stages of maturity. 1. The digestibility, intake, yield and chemical composition of dried grass harvested from swards of Irish perennial ryegrass, timothy and a mixed sward at nine progressive stages of growth. Irish J. Agric. Res. 6: 267—279.

WINCH, J. E., SHEARD, R. W. & MOVAT, D. N. 1970. Determining cutting schedules for maximum yield and quality of brome grass, timothy, lucerne and lucerne/grass mixtures. J. Brit. Grassl. Soc. 25: 44—52.

WOOD, W. A. 1961. Fermentation of carbohydrates and related compounds. The bacteria II, 59—149. Ed. Gunsalus, I. C. and Stanier. R. Y., New York.

WOODMAN, H. E., BLUNT, D. L. & STEWART, J. 1926. Nutritive value of pasture. I. Seasonal variations in the productivity, botanical and chemical composition, and nutritive value of medium pasturage on a light sandy soil. J. Agric. Sci. 16: 205—274.

— BLUNT, D. L. & STEWART, J. 1927. II. Seasonal variations in the productivity, botanical and chemical composition, and nutritive value of pasturage on a heavy clay soil. J. Agric. Sci. 17: 209—263.

— NORMAN, D. B. & BEE, J. W. 1928. III. The influence of the intensity of grazing on the composition and nutritive value of pasture herbage. J. Agric. Sci. 18: 266—296.

WOODS, W. R., THOMPSON, C. M. & GRAINGER, R. B. 1956. The effect of varying levels of protein and cerelose on the utilization of mature timothy hay by sheep. J. Anim. Sci. 15: 1141—1146.

ØRSKOV, E. R., FRASER, C. & CORSE, E. C. 1970. The effect on protein utilization of feeding different protein supplements via the rumen or via the abomasum in young growing sheep. Brit. J. Nutr. 24: 803—809.

— FRASER, C. & KAY, R. N. B. 1969. Dietary factors influencing the digestion of starch in the rumen and small and large intestine of early weaned lambs. Brit. J. Nutr. 23: 217—226.

— & OLTJEN, R. R. 1967. Influence of carbohydrate and nitrogen sources on the rumen volatile fatty acids and ethanol of cattle fed purified diets. J. Nutr. 93: 222—228.

MS received 11 October 1972
Printed 23 November 1972

Liisa Syrjälä
Agricultural Research Centre
Dept. of Animal Husbandry
SF-01300 TIKKURILA, Finland

Appendix 1. Chemical composition of the grasses and silages during the experimental periods.

Exp.	Added preservative	Grass or silage	Period	Dry matter	% of dry matter							
					Ash	Organic matter	Crude protein	True protein	Crude fat	N-free extract	Crude fibre	Crude carbohydrates
I	AIV II	grass silage	-	17.94	9.56	90.44	23.19	15.61	3.69	42.92	20.64	63.56
			1	23.86	8.20	91.79	21.21	7.98	7.44	37.81	25.30	63.12
			2	23.62	8.19	91.80	21.48	8.09	7.49	37.43	25.48	62.91
			3	23.89	8.59	91.40	21.64	7.67	7.32	37.36	25.06	62.43
			4	23.65	8.16	91.83	21.93	7.78	7.31	37.56	25.02	62.58
			5	23.55	7.92	92.07	22.99	8.33	7.05	37.56	24.46	62.02
			6	23.57	8.08	91.91	23.34	8.33	7.33	36.01	25.22	61.23
			7	23.57	8.33	91.66	23.00	8.08	7.18	37.02	24.45	61.47
II	AIV I	grass silage	-	16.60	11.36	88.63	17.41	13.69	4.56	40.76	25.90	66.66
			1	18.56	10.67	89.32	18.05	12.93	5.52	39.41	26.33	65.74
			2	18.30	10.70	89.29	18.11	12.33	5.61	39.14	26.42	65.56
			3	18.68	10.28	89.71	18.42	11.83	5.99	38.20	27.09	65.29
			4	18.57	10.76	89.23	18.36	12.67	5.23	38.06	27.56	65.63
			5	18.61	10.76	89.23	18.75	12.22	5.81	37.42	27.23	64.66
			6	18.96	10.15	89.84	17.98	12.12	5.62	38.48	27.75	66.24
			7	17.93	10.62	89.37	18.17	12.55	5.28	39.51	26.40	65.91
			8	17.97	10.22	89.77	18.58	13.10	5.64	38.14	27.39	65.53
			9	18.58	10.98	89.01	18.37	13.53	5.39	37.39	27.85	65.24
	Formic acid	grass silage	-	17.98	10.01	89.99	16.51	12.67	4.26	44.62	24.60	69.22
			1	18.97	10.26	89.73	18.31	13.27	5.33	40.07	26.00	66.07
			2	19.26	10.07	89.92	17.78	12.05	5.47	40.49	26.16	66.65
			3	18.87	9.93	90.06	17.96	12.16	5.63	39.97	26.50	66.47
			4	19.05	10.15	89.84	18.33	12.89	5.22	40.29	25.98	66.27
			5	18.79	10.33	89.66	18.14	12.62	5.38	39.99	26.13	66.13
			6	18.50	9.96	90.03	18.06	12.01	5.63	39.84	26.49	66.33
			7	18.76	10.24	89.75	18.40	13.09	5.37	39.43	26.53	65.97
			8	18.96	10.20	89.79	18.37	13.47	5.17	39.45	26.78	66.23
			9	19.41	9.73	90.26	18.02	13.33	5.19	39.68	27.36	67.05
	Viher solution	grass silage	-	17.15	11.12	88.89	17.80	13.98	4.24	44.39	22.46	66.85
			1	18.27	10.83	89.16	19.38	15.44	4.71	38.94	26.11	65.06
			2	18.35	10.54	89.45	19.50	14.65	5.11	39.03	25.80	64.83
			3	18.16	10.76	89.23	19.25	14.62	5.41	38.51	26.04	64.56
			4	18.13	10.35	89.64	20.29	15.68	4.93	37.94	26.46	64.41
			5	18.27	10.17	89.82	19.97	14.56	5.29	38.76	25.79	64.55
			6	18.46	10.52	89.47	19.67	14.89	5.38	38.60	25.80	64.41
			7	18.17	10.44	89.55	18.56	13.87	5.15	40.34	25.48	65.83
			8	18.23	10.90	89.09	20.42	16.01	5.09	36.15	27.41	63.56
			9	18.58	11.60	88.39	19.81	15.39	5.08	36.36	27.13	63.50

Appendix 2. Data used as criteria of the quality of the silages in different periods.

Experiment	Time of sampling	Added preservative	pH	% of fresh silage (20 % dry matter)								% of Total N	
				Acetic acid	Propionic acid	Butyric acid	Valeric acid	Lactic acid	Sugars as glucose	NH_3-N	Total N	NH_3-N	Soluble N
I	30/12 1969	AIV II	3.95	0.35	-	-	-	1.52	0.34	0.03	0.63	5.3	33.6
	05/05 1970	AIV II	3.91	0.41	-	-	-	1.69	0.35	0.04	0.68	6.2	75.6
	01/06 1970	AIV II	4.09	0.43	-	-	-	1.35	0.41	0.05	0.70	7.2	79.0
II	23/11 1970	AIV I	4.42	0.44	-	-	-	2.11	0.28	0.03	0.60	5.5	39.0
		Formic acid	4.20	0.26	-	-	-	1.40	1.55	0.03	0.60	5.1	30.1
		Viher solution	4.60	0.57	-	-	-	1.35	0.18	0.02	0.67	3.1	26.7
	14/12 1970	AIV I	4.38	0.48	0.04	-	-	1.40	0.15	0.03	0.59	5.5	32.7
		Formic acid	4.32	0.30	-	-	-	1.64	0.42	0.03	0.58	5.4	31.2
		Viher solution	4.58	0.34	-	-	-	1.25	0.52	0.02	0.67	3.2	30.7
	04/01 1971	AIV I	4.58	0.91	0.06	-	-	1.26	0.11	0.03	0.59	5.7	31.2
		Formic acid	4.25	0.27	-	-	-	1.34	0.70	0.02	0.60	3.6	32.3
		Viher solution	4.80	0.34	-	-	-	0.76	0.63	0.02	0.66	3.2	26.0
	22/01 1971	AIV I	4.51	0.85	0.04	-	-	1.60	0.19	0.02	0.53	4.0	36.6
		Formic acid	4.37	0.28	-	-	-	0.96	0.42	0.02	0.58	3.6	34.0
		Viher solution	4.72	0.45	-	-	-	1.41	0.33	0.02	0.63	3.4	27.4
	10/02 1971	AIV I	4.49	0.72	0.04	-	-	1.53	0.01	0.02	0.59	3.7	38.3
		Formic acid	4.59	0.48	-	-	-	1.76	0.47	0.02	0.57	3.9	38.7
		Viher solution	4.82	0.44	-	-	-	1.39	0.30	0.02	0.66	3.2	32.9
	05/03 1971	AIV I	4.58	0.90	0.04	0.01	0.01	1.17	0.12	0.02	0.58	3.6	29.6
		Formic acid	4.38	0.31	-	-	-	1.55	0.58	0.02	0.61	3.6	37.1
		Viher solution	4.70	0.61	-	-	-	1.36	0.18	0.03	0.64	5.0	31.7
	26/03 1971	AIV I	4.38	0.70	0.03	0.01	-	1.65	0.15	0.03	0.59	5.6	34.4
		Formic acid	4.35	0.34	-	-	-	1.66	0.45	0.02	0.64	3.3	29.9
		Viher solution	4.80	0.74	0.02	-	-	1.34	0.18	0.03	0.59	5.7	31.8
	19/04 1971	AIV I	4.90	0.92	0.04	-	-	1.22	0.13	0.04	0.58	7.5	36.2
		Formic acid	4.70	0.33	-	-	-	1.53	0.60	0.02	0.57	3.6	33.5
		Viher solution	5.30	0.95	0.04	-	-	0.65	0.17	0.05	0.65	8.3	30.3
	11/05 1971	AIV I	4.68	0.88	0.04	-	0.01	1.17	0.18	0.04	0.60	6.9	32.6
		Formic acid	4.50	0.40	-	-	-	1.19	0.35	0.03	0.59	5.2	27.5
		Viher solution	5.12	0.95	0.03	-	0.01	0.52	0.13	0.03	0.65	5.2	24.3

Appendix 3. Digestibility, N balance and feeding values of AIV I, formic acid and Viher solution silages in different carbohydrate diets in Exp. II.

	Silage	Sucrose			Starch			Cellulose		
		0 %	15 %	30 %	0 %	15 %	30 %	0 %	15 %	30 %
Digestibility, %										
Dry Matter	AIV I	70.7	66.9	63.1	71.1	68.7	66.9	71.0	69.3	67.2
	Formic acid	70.5	66.7	62.9	71.9	68.7	62.5	73.7	72.5	70.6
	Viher solution	69.7	66.9	62.7	71.0	65.9	62.5	69.3	66.2	68.3
Organic matter	AIV I	73.9	70.3	66.4	73.7	71.2	69.4	75.0	73.4	72.4
	Formic acid	74.1	70.6	66.0	74.9	71.8	66.2	76.5	75.3	73.5
	Viher solution	72.7	69.7	65.6	74.8	70.2	67.3	71.7	68.8	71.0
Grude protein	AIV I	71.6	63.2	55.6	71.5	66.9	61.5	72.1	68.2	62.6
	Formic acid	71.6	62.2	58.3	71.8	67.1	57.3	73.9	70.0	64.4
	Viher Solution	68.3	61.8	55.5	70.6	64.0	57.6	67.7	61.8	60.2
Crude fat	AIV I	72.4	72.0	72.3	72.2	71.4	72.8	73.0	72.9	71.7
	Formic acid	71.7	75.0	71.8	72.4	70.7	71.6	71.9	71.5	71.0
	Viher solution	71.6	72.2	71.6	72.0	73.0	73.4	69.2	68.8	71.8
N-free extract	AIV I	74.7	71.9	69.5	73.6	70.7	69.0	74.2	72.0	70.1
	Formic acid	74.0	70.8	65.6	76.2	72.1	65.6	76.9	76.0	75.0
	Viher solution	73.5	72.6	67.2	74.2	70.2	65.3	75.0	72.2	72.6
Crude fibre	AIV I	74.8	72.3	68.0	75.7	74.6	74.5	78.2	78.8	82.7
	Formic acid	76.2	75.2	70.9	75.7	75.0	72.2	78.7	78.5	78.1
	Viher solution	75.3	70.9	69.8	78.8	73.8	76.0	70.4	69.0	76.4
Crude carbo-hydrates	AIV I	74.7	72.1	68.9	74.5	72.3	71.3	75.9	74.9	75.4
	Formic acid	74.8	72.6	67.8	76.0	73.3	68.2	77.6	77.0	76.2
	Viher solution	74.2	71.9	68.2	76.2	71.8	69.8	73.1	70.9	74.1
N balance, g/day	AIV I	2.63	2.03	1.45	3.05	2.68	2.62	2.63	1.39	0.80
	Formic acid	3.53	3.30	5.52	2.32	2.31	1.60	2.02	1.84	0.83
	Viher solution	1.66	2.13	2.03	1.32	1.10	2.31	2.33	1.46	2.51
Biological value	AIV I	44.7	51.1	56.0	44.7	49.7	61.3	44.6	46.3	54.9
	Formic acid	47.9	56.2	63.3	44.7	49.3	50,2	40.9	47.8	53.2
	Viher solution	39.4	48.7	55.9	37.6	42.4	51.3	42.3	46.3	61.8
kg/f.u.	AIV I	7.22	7.60	7.85	7.16	7.43	7.61	7.27	7.43	7.51
	Formic acid	6.98	7.31	7.83	6.90	7.19	7.81	6.85	6.97	7.13
	Viher solution	7.42	7.75	8.23	7.25	7.73	8.05	7.56	7.88	7.64
DM kg/f.u.	AIV I	1.33	1.41	1.45	1.34	1.39	1.42	1.32	1.35	1.36
	Formic acid	1.33	1.39	1.49	1.31	1.37	1.49	1.28	1.31	1.34
	Viher solution	1.35	1.42	1.50	1.32	1.42	1.48	1.38	1.44	1.40
DCP, g/f.u.	AIV I	174.4	161.8	146.7	176.2	170.7	160.9	174.8	169.1	156.6
	Formic acid	173.8	158.1	158.5	170.1	165.5	152.9	173.0	166.5	156.6
	Viher solution	185.2	175.1	166.8	184.3	177.9	166.5	181.3	172.4	162.7
DCP % in DM	AIV I	13.0	11.5	10.1	13.1	12.3	11.3	13.3	12.5	11.5
	Formic acid	13.1	11.4	10.7	12.9	12.1	10.3	13.4	12.7	11.7
	Viher solution	13.6	12.4	11.1	13.9	12.6	11.3	13.1	12.0	11.7

Appendix 4. pH, NH_3- N and VFA in the rumen fluid of sheep on different diets in Exp. II. Sampling before feeding.

	Sucrose			Starch			Cellulose		
	0 %	15 %	30 %	0 %	15 %	30 %	0 %	15 %	30 %
pH									
AIV I	6.70	6.73	6.83	6.79	6.66	6.81	6.85	6.75	6.60
Formic acid	6.66	6.88	6.91	6.77	6.67	6.66	6.87	6.50	6.48
Viher solution	6.84	6.74	6.81	6.82	6.90	6.99	6.88	6.72	6.60
NH_3-N, mg/100 ml									
AIV I	21.6	14.9	8.9	19.4	17.6	14.0	22.5	19.8	14.6
Formic acid	25.7	17.7	10.3	28.3	21.8	17.3	22.1	19.9	15.8
Viher solution	24.7	13.8	6.7	22.4	22.7	15.8	23.9	18.3	11.3
Total VFA, mmoles/100 ml									
AIV I	7.91	7.64	7.23	8.17	8.63	8.09	7.92	8.78	9.18
Formic acid	9.26	8.49	7.67	8.42	9.18	8.84	8.82	8.71	9.54
Viher solution	8.49	7.98	7.68	8.47	8.09	7.67	8.28	9.35	9.47
Acetic acid, molar %									
AIV I	74.9	73.7	72.4	77.0	76.8	73.8	74.3	74.3	72.4
Formic acid	74.3	73.9	72.1	76.0	72.8	73.1	75.8	76.6	73.6
Viher solution	75.0	73.6	73.2	75.9	73.5	73.3	76.6	74.3	73.9
Propionic acid, molar %									
AIV I	16.4	15.8	16.0	15.4	14.9	15.2	17.5	16.1	19.6
Formic acid	16.6	17.3	18.0	15.3	16.1	14.7	16.7	14.5	16.0
Viher solution	16.0	15.2	16.2	15.1	17.0	16.6	16.1	15.7	17.2
Butyric acid, molar %									
AIV I	6.0	7.4	9.6	6.1	7.0	9.0	6.5	8.3	7.4
Formic acid	6.5	7.1	8.4	6.8	8.8	8.6	5.9	7.9	8.8
Viher solution	7.0	9.4	9.8	7.2	7.4	8.0	5.5	8.8	8.2
Isovaleric acid, molar %									
AIV I	2.4	2.8	1.5	1.3	1.2	1.7	1.5	1.1	0.5
Formic acid	2.1	1.4	1.1	1.8	1.8	3.2	1.4	0.9	1.5
Viher solution	1.6	1.5	0.5	1.6	1.7	1.9	1.5	0.9	0.5
Valeric acid, molar %									
AIV I	0.4	0.3	0.4	0.1	0.1	0.3	0.3	0.2	0.2
Formic acid	0.5	0.3	0.4	0.2	0.5	0.4	0.3	0.1	0.2
Viher solution	0.4	0.3	0.3	0.3	0.4	0.2	0.3	0.3	0.1
Ratio acetic: propionic									
AIV I	4.62	4.75	4.54	5.02	5.21	4.94	4.26	4.62	3.74
Formic acid	4.54	4.32	4.11	5.01	4.53	5.12	4.57	5.31	4.73
Viher solution	4.72	4.83	4.57	5.04	4.37	4.42	4.78	4.78	4.63
Ratio acetic: butyric									
AIV I	12.58	10.11	7.62	12.75	11.03	8.46	11.57	9.03	10.16
Formic acid	11.54	10.58	8.87	11.39	8.52	8.92	13.49	9.78	8.70
Viher solution	10.94	7.90	7.53	10.87	9.97	9.38	14.27	8.66	9.08
Ratio propionic: butyric									
AIV I	2.75	2.13	1.68	2.55	2.14	1.75	2.72	1.96	2.73
Formic acid	2.56	2.47	2.27	2.27	1.87	1.76	2.93	1.86	1.91
Viher solution	2.31	1.64	1.67	2.17	2.32	2.13	2.99	1.83	2.10

Appendix 4. (continued) Sampling 2.5 hours after the beginning of feeding.

	Sucrose			Starch			Cellulose		
	0 %	15 %	30 %	0 %	15 %	30 %	0 %	15 %	30 %
pH									
AIV I	6.45	6.33	6.19	6.67	6.37	6.35	6.70	6.67	6.42
Formic acid	6.51	6.49	6.47	6.39	6.38	6.31	6.61	6.41	6.37
Viher solution	6.68	6.42	6.29	6.54	6.64	6.47	6.82	6.57	6.40
NH_3-N, mg/100 ml									
AIV I	33.9	25.1	15.4	35.0	32.7	20.8	35.0	31.0	27.3
Formic acid	34.1	25.9	15.1	39.4	28.6	23.5	36.9	31.0	27.9
Viher solution	28.8	20.6	14.5	35.3	27.4	16.4	32.8	28.2	20.3
Total VFA, mmoles/100 ml									
AIV I	10.17	10.49	10.39	10.35	10.58	10.99	9.90	10.24	10.73
Formic acid	10.86	11.54	10.47	11.04	10.88	10.64	11.32	11.17	11.57
Viher solution	10.24	11.12	11.59	10.73	10.41	10.07	10.54	10.45	10.77
Acetic acid, molar %									
AIV I	71.2	67.9	58.7	70.8	71.5	69.6	70.3	72.5	71.8
Formic acid	70.2	64.4	62.6	69.0	69.3	71.0	68.4	70.1	69.5
Viher solution	70.0	63.0	56.6	69.5	75.2	74.7	76.2	71.5	72.2
Propionic acid, molar %									
AIV I	19.3	18.1	19.5	19.4	17.2	17.6	19.9	17.5	19.0
Formic acid	18.8	19.1	22.4	19.4	18.2	16.9	19.9	17.9	18.7
Viher solution	19.3	18.9	26.7	19.3	15.3	15.1	15.9	18.0	18.5
Butyric acid, molar %									
AIV I	7.1	12.3	20.5	7.5	8.5	10.2	7.5	8.1	7.6
Formic acid	8.7	14.4	13.2	8.7	9.1	9.7	8.8	9.5	9.7
Viher solution	8.3	15.9	15.5	8.6	6.8	7.3	5.4	8.6	8.1
Isovaleric acid, molar %									
AIV I	1.6	1.0	0.3	1.4	1.9	1.7	1.5	1.4	1.0
Formic acid	1.6	1.3	0.8	2.1	2.3	1.8	1.9	1.8	1.4
Viher solution	1.4	1.2	0.3	1.7	1.9	2.1	1.8	1.2	0.7
Valeric acid, molar %									
AIV I	0.7	0.7	0.9	0.8	0.9	0.9	0.8	0.6	0.6
Formic acid	0.7	0.9	1.0	0.9	1.1	0.8	1.0	0.7	0.7
Viher solution	1.0	1.1	1.0	1.0	0.8	0.8	0.7	0.6	0.5
Ratio acetic: propionic									
AIV I	3.71	3.87	3.06	3.78	4.41	4.17	3.61	4.22	3.87
Formic acid	3.82	3.40	2.92	3.58	3.84	4.28	3.46	3.97	3.77
Viher solution	3.64	3.42	2.27	3.62	4.99	5.03	4.92	4.01	4.13
Ratio acetic: butyric									
AIV I	10.11	5.69	3.11	9.62	8.79	7.04	9.47	9.04	9.56
Formic acid	8.07	5.04	4.95	8.09	14.14	7.61	7.82	7.36	7.36
Viher solution	8.51	4.00	3.93	8.25	11.48	10.56	14.57	8.40	8.91
Ratio propionic: butyric									
AIV I	2.73	1.51	1.03	2.58	2.02	1.77	2.66	2.17	2.53
Formic acid	2.17	1.51	1.81	2.28	3.93	1.79	2.28	1.88	2.01
Viher solution	2.36	1.21	1.98	2.28	2.28	2.09	2.97	2.12	2.30

Appendix 4. (continued) Sampling 5.5 hours after the beginning of feeding.

	Sucrose			Starch			Cellulose		
	0 %	15 %	30 %	0 %	15 %	30 %	0 %	15 %	30 %
pH									
AIV I	6.63	6.58	6.43	6.53	6.35	6.32	6.80	6.76	6.54
Formic acid	6.54	6.66	6.62	6.59	6.39	6.23	6.67	6.56	6.51
Viher solution	6.58	6.60	6.54	6.62	6.61	6.54	6.79	6.49	6.45
NH_3-N, mg/100 ml									
AIV I	25.5	12.8	5.8	25.3	20.2	10.5	24.3	23.5	20.2
Formic acid	26.9	13.6	7.2	29.6	16.0	9.3	21.9	22.6	16.2
Viher solution	17.9	9.2	5.8	24.2	17.8	7.7	26.5	16.2	12.3
Total VFA, mmoles/100 ml									
AIV I	8.60	8.56	8.72	9.17	10.28	10.33	9.04	9.27	9.91
Formic acid	9.85	9.96	9.16	9.78	10.36	10.30	10.07	9.45	9.75
Viher solution	10.02	9.51	9.90	9.75	9.81	9.80	10.06	10.26	10.30
Acetic acid, molar %									
AIV I	75.8	73.4	67.1	74.7	75.9	71.0	73.9	74.4	73.4
Formic acid	73.5	71.1	68.4	73.3	72.6	74.0	72.7	74.1	71.9
Viher solution	72.6	69.3	64.3	73.5	76.2	76.2	77.3	73.7	73.7
Propionic acid, molar %									
AIV I	16.9	15.6	16.1	17.7	15.0	17.2	18.1	16.8	18.6
Formic acid	17.5	17.3	18.7	17.4	15.4	15.0	18.1	16.0	17.1
Viher solution	18.2	16.0	21.0	16.9	15.0	14.2	16.0	17.1	18.0
Butyric acid, molar %									
AIV I	6.2	10.5	15.9	6.7	7.6	10.2	6.8	7.8	7.3
Formic acid	7.7	10.9	11.7	7.7	9.5	9.3	8.1	8.7	9.8
Viher solution	7.8	13.5	13.5	8.0	6.9	7.4	5.3	8.4	7.7
Isovaleric acid, molar %									
AIV I	0.9	0.1	0.01	0.7	1.1	1.2	0.9	0.8	0.5
Formic acid	1.0	0.3	0.5	1.3	1.9	1.3	0.8	1.0	0.8
Viher solution	0.9	0.5	0.01	1.1	1.5	1.7	1.1	0.6	0.3
Valeric acid, molar %									
AIV I	0.2	0.3	0.9	0.2	0.4	0.4	0.4	0.3	0.2
Formic acid	0.5	0.4	0.7	0.3	0.5	0.4	0.4	0.2	0.3
Viher solution	0.5	0.6	1.2	0.5	0.4	0.5	0.3	0.2	0.2
Ratio acetic: propionic									
AIV I	4.51	4.75	4.18	4.26	5.18	4.47	4.19	4.45	3.98
Formic acid	4.29	4.13	3.69	4.25	4.85	5.22	4.05	4.66	4.30
Viher solution	4.01	4.35	3.16	4.36	5.12	5.40	4.88	4.36	4.26
Ratio acetic: butyric									
AIV I	12.35	7.12	4.48	11.28	10.24	7.55	10.89	9.61	10.17
Formic acid	9.67	7.23	6.13	9.60	7.82	8.26	9.49	8.59	7.86
Viher solution	9.41	5.14	4.95	9.30	11.20	10.53	14.89	8.93	9.59
Ratio propionic: butyric									
AIV I	2.76	1.51	1.07	2.66	2.01	1.88	2.65	2.17	2.58
Formic acid	2.29	1.76	1.69	2.27	1.62	1.67	2.36	1.86	1.91
Viher solution	2.36	1.19	1.68	2.13	2.18	1.95	3.06	2.08	2.36

Appendix 5. Distribution of the energy of the VFA mixture among different acids in different carbohydrate diets in Exp. I.

Diets		Sampling time	Energy of VFA mixture kcal/100 ml	Distribution of energy among different acids (%)				Average caloric value of mixture kcal/mole
				Acetic acid	Propionic acid	Butyric acid	Valeric acid (1	
0 %	carbohydrate		1.84^{cd}	55.7	24.4	15.5	4.4^{ab}	271^{ab}
15 %	sucrose		1.76^{cd}	53.0	26.1	16.6	4.3^{ab}	277^{ab}
30 %	"	Before	1.71^{d}	53.3	26.6	16.4	3.6^{ab}	275^{ab}
15 %	starch	feeding	1.98^{bc}	52.5	25.2	16.1	6.2^{a}	279^{ab}
30 %	"		1.86^{cd}	50.9	24.7	18.5	5.8^{a}	282^{a}
15 %	cellulose		2.13^{ab}	56.2	24.4	16.6	2.9^{b}	270^{ab}
30 %	"		2.31^{a}	56.4	26.5	15.4	1.7^{b}	268^{b}
0 %	carbohydrate		3.56	38.6^{bcd}	24.1	24.1^{ab}	13.2^{a}	317^{abc}
15 %	sucrose		3.37	35.7^{cd}	28.4	26.1^{ab}	9.8^{ab}	321^{ab}
30 %	"	2.5 hr	3.28	33.3^{d}	25.4	32.9^{a}	8.5^{b}	331^{a}
15 %	starch	after	3.39	40.7^{abc}	26.0	21.4^{ab}	11.9^{ab}	309^{bc}
30 %	"		3.26	39.7^{abc}	24.4	24.7^{ab}	11.2^{ab}	313^{abc}
15 %	cellulose		3.57	40.9^{ab}	26.9	21.1^{b}	11.0^{ab}	308^{bc}
30 %	"		3.31	44.0^{a}	27.1	19.4^{b}	9.5^{ab}	299^{c}
0 %	carbohydrate		2.52	47.5^{ab}	24.9	20.2^{ab}	7.4^{ab}	291^{bc}
15 %	sucrose		2.49	44.3^{bc}	27.2	22.3^{ab}	6.2^{ab}	297^{ab}
30 %	"	5.5 hr	2.53	41.5^{c}	24.3	27.6^{a}	6.7^{ab}	307^{a}
15 %	starch	after	2.52	47.4^{ab}	24.9	20.2^{ab}	7.6^{a}	291^{bc}
30 %	"		2.64	46.4^{abc}	22.8	23.2^{ab}	7.6^{a}	295^{ab}
15 %	cellulose		2.72	49.2^{ab}	26.0	18.5^{ab}	6.2^{ab}	286^{bc}
30 %	"		2.67	50.9^{a}	27.4	17.3^{b}	4.5^{b}	280^{c}
0 %	carbohydrate		2.64	47.3^{ab}	24.5	19.9^{ab}	8.4	293^{ab}
15 %	sucrose		2.54	44.3^{ab}	27.2	21.7^{ab}	6.8	298^{ab}
30 %	"	Average	2.51	42.7^{b}	25.4	25.6^{a}	6.3	304^{a}
15 %	starch		2.63	46.9^{ab}	25.3	19.2^{b}	8.6	293^{ab}
30 %	"		2.59	45.6^{ab}	24.0	22.2^{ab}	8.2	297^{ab}
15 %	cellulose		2.81	48.8^{ab}	25.8	18.7^{b}	6.7	288^{ab}
30 %	"		2.76	50.4^{a}	27.0	17.3^{b}	5.2	282^{b}

1) isovaleric acid is included.
Meaning of index letters in a vertical column same as in Table 12.

Appendix 6. Distribution of the energy of the VFA mixture among different carbohydrate diets in Exp. II.

Diets	Sampling time	Energy of VFA mixture kcal/100 ml	Distribution of energy among different acids (%)				Average caloric value of mixture kcal/mole
			Acetic acid	Propionic acid	Butyric acid	Valeric acid (1	
0 % carbohydrate		2.22^{bc}	59.9^{a}	22.4^{b}	12.6^{c}	5.0^{ab}	264^{c}
15 % sucrose		2.17^{bc}	57.2^{b}	21.9^{b}	15.4^{b}	5.6^{ab}	270^{ab}
30 % "	Before	2.05^{c}	56.0^{b}	22.6^{ab}	17.9^{a}	3.5^{bc}	272^{ab}
15 % starch	feeding	2.31^{ab}	58.2^{ab}	21.9^{b}	15.1^{b}	4.9^{abc}	268^{abc}
30 % "		2.24^{bc}	56.4^{b}	20.9^{b}	16.4^{ab}	6.4^{a}	273^{a}
15 % cellulose		2.37^{ab}	59.3^{ab}	21.4^{b}	16.4^{ab}	2.9^{bc}	265^{bc}
30 % "		2.51^{a}	57.4^{ab}	24.1^{a}	15.9^{ab}	2.4^{c}	267^{abc}
0 % carbohydrate		2.92^{b}	53.7^{a}	25.3^{ab}	14.8^{b}	6.2^{ab}	276^{b}
15 % sucrose		3.24^{a}	46.6^{b}	23.4^{b}	25.2^{a}	4.8^{c}	293^{a}
30 % "	2.5 hr	3.29^{a}	41.1^{c}	27.7^{a}	28.1^{a}	3.2^{d}	304^{a}
15 % starch	after	2.92^{b}	55.0^{a}	22.3^{b}	15.4^{b}	7.2^{a}	276^{b}
30 % "		2.93^{b}	54.3^{a}	21.9^{b}	17.1^{b}	6.6^{ab}	277^{b}
15 % cellulose		2.92^{b}	54.4^{a}	23.7^{ab}	16.6^{b}	5.2^{bc}	275^{b}
30 % "		3.02^{ab}	54.7^{a}	25.1^{ab}	16.2^{b}	4.0^{cd}	273^{b}
0 % carbohydrate		2.55	58.5^{a}	24.0^{a}	14.0^{b}	3.4^{b}	266^{c}
15 % sucrose		2.57	54.3^{b}	21.8^{abc}	22.1^{a}	1.9^{c}	275^{b}
30 % "	5.5 hr	2.66	48.7^{c}	23.9^{ab}	24.9^{a}	2.6^{bc}	287^{a}
15 % starch	after	2.72	58.7^{a}	20.7^{c}	15.7^{b}	4.9^{a}	269^{c}
30 % "		2.75	57.2^{ab}	20.9^{bc}	17.2^{b}	4.7^{a}	271^{bc}
15 % cellulose		2.58	58.2^{a}	22.9^{abc}	16.2^{b}	2.6^{bc}	267^{c}
30 % "		2.67	57.2^{ab}	24.6^{a}	16.2^{b}	2.0^{c}	267^{c}
0 % carbohydrate		2.56	57.4^{a}	23.9^{abc}	13.8^{c}	4.9^{ab}	269^{c}
15 % sucrose		2.66	52.6^{b}	22.3^{cd}	20.9^{a}	4.1^{bc}	280^{b}
30 % "	Average	2.66	48.6^{c}	24.8^{a}	23.6^{a}	3.1^{c}	287^{a}
15 % starch		2.65	57.3^{a}	21.6^{d}	15.4^{bc}	5.7^{a}	270^{c}
30 % "		2.64	55.9^{ab}	21.3^{d}	16.9^{b}	5.9^{a}	274^{bc}
15 % cellulose		2.63	57.3^{a}	22.7^{bcd}	16.5^{b}	3.6^{c}	269^{c}
30 % "		2.73	56.4^{a}	24.6^{ab}	16.1^{b}	2.8^{c}	269^{c}

1) isovaleric acid is included.
Meaning of index letters in a vertical column same as in Table 12.

Appendix 7. pH, NH_3-N and VFA in the rumen fluid of sheep on different carbohydrate diets in Exp. I and Exp. II.

	Sampling time	Carbohydrate	Sucrose		Starch		Cellulose	
		0 %	15 %	30 %	15 %	30 %	15 %	30 %
pH		6.78	6.76	6.80	6.71	6.75	6.59	6.51
NH_3-N, mg/100 ml		21.9	13.8	8.3	17.5	13.3	15.8	12.3
Total VFA, mmoles/100 ml	Before	8.12	7.32	6.97	7.97	7.49	8.49	9.08
Acetic acid, molar %	feeding	74.9	71.9	71.5	72.5	71.3	73.6	72.8
Propionic acid "		16.5	17.6	18.0	17.3	17.1	16.5	18.3
Butyric acid "		6.7	8.4	9.0	8.1	9.1	8.6	8.1
Isovaleric acid "		1.6	1.6	1.0	1.6	2.0	0.9	0.6
Valeric acid "		0.3	0.4	0.4	0.6	0.5	0.3	0.2
pH		6.57	6.37	6.27	6.40	6.25	6.44	6.34
NH_3-N, mg/100 ml		38.4	30.1	21.1	36.1	25.1	38.2	31.3
Total VFA, mmoles/100 ml	2.5 hr	10.69	10.81	10.43	10.77	10.49	10.98	11.05
Acetic acid, molar %	after	68.4	60.5	56.3	66.7	66.3	66.6	67.8
Propionic acid "		19.3	21.1	22.5	19.1	18.3	19.6	20.1
Butyric acid "		9.1	15.2	18.5	10.1	11.6	10.5	9.5
Isovaleric acid "		2.1	1.8	1.0	2.6	2.3	2.1	1.5
Valeric acid "		1.1	1.4	1.6	1.4	1.4	1.3	1.1
pH		6.62	6.58	6.49	6.44	6.27	6.49	6.42
NH_3-N, mg/100 ml		26.2	16.3	9.2	20.0	10.8	23.8	17.7
Total VFA, mmoles/100 ml	5.5 hr	9.43	8.88	8.83	9.50	9.63	9.58	9.76
Acetic acid, molar %	after	72.7	67.7	64.3	71.2	70.4	71.2	71.2
Propionic acid "		17.8	18.7	19.0	16.9	16.7	17.9	19.1
Butyric acid "		7.8	12.1	14.8	9.4	10.6	9.2	8.5
Isovaleric acid "		1.1	0.7	0.4	1.7	1.6	1.1	0.7
Valeric acid "		0.5	0.8	1.5	0.7	0.9	0.6	0.5
pH		6.66	6.57	6.52	6.51	6.42	6.51	6.43
NH_3-N, mg/100 ml		28.8	20.1	12.9	24.6	16.4	26.0	20.4
Total VFA, mmoles/100 ml	Average	9.41	9.00	8.74	9.42	9.20	9.69	9.97
Acetic acid, molar %		72.0	66.7	64.0	70.1	69.3	70.4	70.6
Propionic acid "		17.9	19.1	19.9	17.8	17.4	18.0	19.1
Butyric acid "		7.9	11.9	14.1	9.2	10.4	9.4	8.7
Isovaleric acid "		1.6	1.4	0.8	2.0	2.0	1.4	1.0
Valeric acid "		0.6	0.9	1.2	0.9	0.9	0.7	0.6

SELOSTUS

Rehuannokseen lisätyn sokerin, tärkkelyksen ja selluloosan vaikutuksesta nurmisäilörehujen hyväksikäyttöön märehtijöillä

LIISA SYRJÄLÄ

Maatalouden tutkimuskeskus, Kotieläinhoidon tutkimuslaitos Tikkurila

Säilönnän aikana rehussa tapahtuu käymistä, joka kohdistuu lähinnä sen hiilihydraatteihin ja typellisiin yhdisteisiin. Seurauksena on mm., että tuoreen ruohon sokerit ja muut helppoliukoiset hiilihydraatit häviävät säilöntämenetelmästä riippuen joko kokonaan tai lähes kokonaan ja typellisten aineiden hajoamisaste ja liukoisuus kasvavat. Koska märehtijäin pötsissä hajoitusta ja syntetisointia suorittavat mikrobit vaativat tehokasta toimintaansa varten energian lähteeksi helppoliukoisia hiilihydraatteja, on tullut yhä ajankohtaisemmaksi ottaa säiliörehuruokinnan suunnittelussa huomioon, että märehtijät saavat tällöin tarpeellisen määrän näitä hiilihydraatteja. Helppoliukoisten hiilihydraattien vaikutusta säilörehun hyväksikäyttöön ei kuitenkaan ole vielä tutkittu. Tästä johtuen tämän tutkimuksen tarkoituksena on ollut selvittää erilaisten sokeri-, tärkkelys- ja selluloosalisäysten vaikutusta eri säilöntäaineilla valmistettujen nurmisäilörehujen hyväksikäyttöön märehtijöillä. Tällöin on erityistä huomiota kiinnitetty säilörehun typellisten aineiden hyväksikäyttöön.

Tutkimus on suoritettu vuosina 1970—1972 Maatalouden tutkimuskeskuksen Kotieläinhoidon tutkimuslaitoksessa Tikkurilassa. Se käsittää kaksi koetta, jotka järjestettiin latinalaisten neliöiden mukaan. Kokeessa I käytettiin 7 × 7 neliötä (kuva 1, neliöissä olevat kirjaimet ovat koeeläinten nimien lyhennyksiä) ja kokeessa II 9 kpl 3 × 3 neliötä, jotka oli edelleen järjestetty sekä säilörehujen että hiilihydraattien mukaan 3 × 3 neliöksi (kuva 2). Jokainen koejakso käsitti 14 vuorokauden valmistuskauden ja 7 vuorokauden varsinaisen koekauden. Koe-eläiminä käytettiin täysikasvuisia suomalaisia pässejä, joille tehtiin pötsifistelit.

Tutkimus sisälsi keruumenetelmään perustuvia sulavuus- ja typpitasekokeita, pötsin sisältöön kohdistuvia analyysejä ja määrityksiä sekä veritutkimuksia. Myöskin seurattiin veden kulutusta sekä kokeen II valmistuskaudella säilörehujen vapaaehtoista syöntiä. Näytteet pötsistä otettiin jokaisen koekauden kolmena viimeisenä päivänä kolme kertaa:

1) ennen aamuruokintaa, klo 8.[5
2) 2.5 tuntia ruokinnan aloittamisesta, klo 11.00
3) 5.5 tuntia ruokinnan aloittamisesta, klo 14.00

Jokaisesta näytteestä mitattiin pH sekä määritettiin ammoniakki ja haihtuvat rasvahapot (etikka-, propioni-, voi-, isovaleriaana- ja valeriaanahappo). Verinäytteistä, jotka otettiin koe-eläinten kaulalaskimosta kokeessa II kaksi kertaa kunkin koejakson aikana, määritettiin hematokriitti, hemoglobiini, glukoosi, urea ja ammoniakki sekä kivennäis- ja hivenaineet (Ca, Mg, K, Na, P, Zn, Mn, Cu, Fe).

Kokeissa käytetty sokeri oli puhdasta sakkaroosia, tärkkelys perunan tärkkelystä (perunajauhoa) ja selluloosa puusta saatua sulfiittiselluloosaa. Hiilihydraattilisäyksillä korvattiin 15 % ja 30 % päivittäisen rehuannoksen kuiva-aineesta, joka kokeessa I oli keskimäärin 947 g ja kokeessa II 928 g. Hiilihydraattilisäykset olivat tällöin 15 % tasoilla keskimäärin 2—3 g ja 30 % tasoilla 5 g elopainokiloa kohti. Näiden hiilihydraattien vaikutusta verrattiin paitsi keskenään myöskin ruokintaan, joka sisälsi ainoastaan säilörehua.

Kokeessa I käytetty säilörehun raaka-aine oli nurminatavaltaista (86 %) nurmea, joka korjattiin ennen tähkimistä. Kokeessa II se sisälsi timoteita (42 %), puna-apilaa (23 %) sekä nurminataa (18 %) ja se korjattiin ennen timotein tähkimistä. Säilöntäaineena oli kokeessa I ainoastaan AIV II, kun taas kokeessa II käytettiin AIV I:tä, muurahaishappoa ja Viherliuosta. Kokeen I rehu säilöttiin puurakenteiseen torniin ja kokeessa II kolmeen muoviseen tyhjöaumaan (pohjan pinta-ala 2 × 4 m²), n. 4000 kg kuhunkin.

Kaikki tutkimuksessa käytetyt säilörehut olivat laadultaan moitteettomia. Kokeen II säilörehuissa pH oli melko korkea, AIV I rehussa keskimäärin 4.55, muurahaishapporehussa 4.41 ja Viherliuosrehussa 4.83. Voihaposta ei kuitenkaan löytynyt muuta kuin jälkiä joissakin näytteissä. Ammoniakkitypen prosenttinen osuus kokonaistypestä oli kaikissa rehuissa alhainen ja pysyi koko kokeen ajan lukujen 3.1—8.3 välillä. Vertailun kohteina olevat AIV I-, muurahaishappo- ja Viherliuossäilörehut eivät kemialliselta koostumukseltaan suuresti poikenneet toisistaan. Raakaproteiinifraktio oli kuitenkin Viherliuosrehussa vähiten liukoisessa muodossa. Kokonaissäilöntätappiot jäivät muurahaishapolla säilötyssä rehussa vähäisemmiksi kuin AIV I:llä ja Viherliuoksella säilötyissä rehuissa.

Tutkittujen säilörehujen eri komponenttien keskinäiset sulavuudet olivat yleensä sekä sokeri- että tärkkelyslisäyksen sisältävissä dieeteissä jonkin verran alhaisempia verrattuna pelkkään säilörehudieettiin. Näiden hiilihydraattilisäysten sulavuuskertoimia alentava vaikutus oli keskenään samanlainen ja lisääntyi annostustason mukana, kun taas eri selluloosalisäyksillä ei havaittu olevan sanottavaa vaikutusta säilörehun sulavuuteen. Kuvasta 3 näh-

dään säilörehun orgaanisen aineen, kuvasta 4 raakakuidun ja kuvasta 5 raakaproteiinin sulavuus (digestibility) sokeri- (sucrose), tärkkelys- (starch) ja selluloosa- (cellulose) lisäysten (supplements) 0 %, 15 % ja 30 % tasoilla (levels).

Pötsissä tapahtuvassa rehun hajoamisessa, jota pötsinesteen haihtuvien rasvahappojen konsentraatio kuvaa, esiintyi eroja eri hiilihydraattidieeteillä, joskaan erot eivät aina olleet merkitseviä. Sokerilisäykset yleensä alensivat näiden rasvahappojen kokonaismäärää, tärkkelyslisäyksillä ei juuri ollut mitään vaikutusta, kun taas selluloosalisäykset suurensivat sitä. Kuvasta 9 nähdään pötsinesteen haihtuvien rasvahappojen (VFA) keskimääräiset konsentraatiot (etikkahappo = acetic acid, propionihappo = propionic acid, voihappo = butyric acid, isovaleriaanahappo = isovaleric acid, valeriaanahappo = valeric acid). Etikka- ja isovaleriaanahapon suhteellinen mooliosuus haihtuvien rasvahappojen kokonaismäärästä laski ja propioni-, voi- ja valeriaanahapon osuus nousi sokeridieeteillä verrattaessa pelkkään säilörehudieettiin. Tärkkelys- ja selluloosalisäysten vaikutus ei ollut niin selvä, joskin selluloosalisäyksillä etikkahapon osuus joissakin tapauksissa nousi.

Pötsinesteen pH pysyi kaikilla dieeteillä ja kaikkina näytteenottoaikoina lukujen 6.1—6.9 välillä ja vastasi täten yleensä normaaliruokinnalla saatuja arvoja.

Säilörehun typellisten aineiden hyväksikäytön tutkimisessa käytettiin seuraavia kriteerioita:

— raakaproteiinin sulavuus
— typpitase
— valkuaisen biologinen arvo
— pötsinesteen ammoniakkikonsentraatio
— veren urea- ja ammoniakkikonsentraatiot

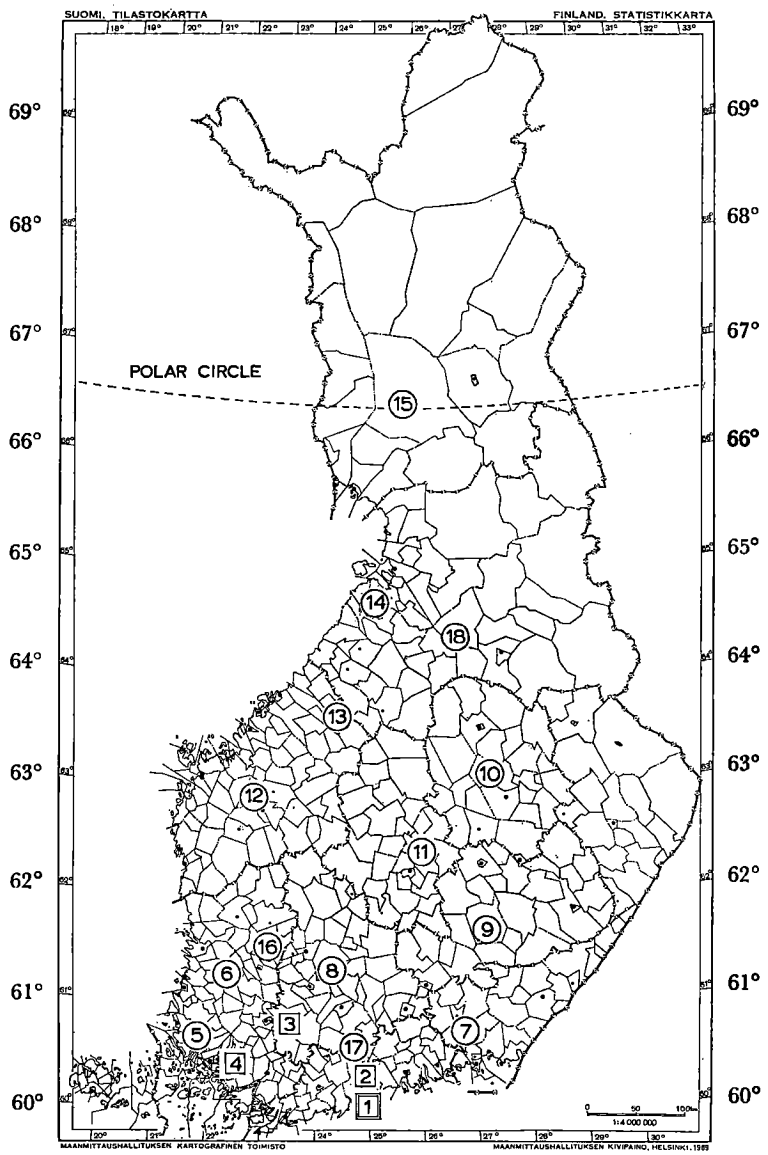
Näyttää siltä, että sokerilisäyksillä oli edullisempi vaikutus säilörehujen typellisten aineiden hyväksikäyttöön kuin vastaavilla tärkkelys- ja selluloosalisäyksillä. Tätä osoittaa sokeridieeteillä saatu muita korkeampi, joskaan ei aina tilastollisesti merkitsevästi korkeampi typpitase (kuva 6) ja valkuaisen biologinen arvo sekä tilastollisesti selvästi alhaisempi pötsinesteen NH_3-N konsentraatio (kuva 8).

Sokeri-, tärkkelys- ja selluloosalisäysten erilaisen vaikutuksen säilörehun sulavuuteen sekä typellisten aineiden hyväksikäyttöön on selitetty johtuvan lähinnä näiden hiilihydraattien erilaisesta hajoamisnopeudesta pötsissä. Sokeri hajoaa nopeimmin, seuraavaksi nopeammin tärkkelys ja hitaimmin selluloosa.

Verrattaessa eri säilörehuja toisiinsa ilman hiilihydraattilisäyksiä ei AIV I:llä, muurahaishapolla ja Viherliuoksella säilöttyjen rehujen syöntimäärissä eikä eri komponenttien sulavuudessa ollut tilastollisesti merkitseviä eroja muussa kuin raakavalkuaisen sulavuudessa. Valmistuskaudella mitattu vapaaehtoinen syöntimäärä, g kuiva-ainetta/eläin/pv, oli eri säilörehuilla seuraava: AIV I rehulla 1 058, muurahaishapporehulla 1 113 ja Viherliuosrehulla 1 048. Viherliuosrehussa raakavalkuaisen sulavuus oli alhaisempi kuin AIV I- ja muurahaishapporehussa, prosenttilukujen ollessa vastaavassa järjestyksessä 68.9, 71.7 ja 72.5. Orgaanisen aineen sulavuusprosentit olivat 73.1, 74.2 ja 75.1 sekä raakakuidun 74.8, 76.2 ja 76.8. Myöskin typpitase jäi Viherliuosrehulla jonkin verran alhaisemmaksi kuin AIV I- tai muurahaishapporehulla ruokittaessa, sillä vastaavat luvut olivat 1.78, 2.78 ja 2.63 g/eläin/pv. Pötsinesteen keskimääräinen ammoniakkipitoisuus oli Viherliuosrehudieetillä 26.3, AIV I -rehudieetillä 26.9 ja muurahaishapporehudieetillä 29.4 mg/100 ml pötsinestettä. Pötsinesteen haihtuvien rasvahappojen kokonaismäärät olivat myös eri säilörehudieeteillä erilaiset. Suurin se oli muurahaishapporehudieetillä, keskimäärin 9.94 mmoolia/100 ml pötsinestettä, sitten Viherliuos- ja AIV I-rehudieeteillä, 9.62 ja 9.03 mmoolia/100 ml. Eri rasvahappojen suhteelliset osuudet poikkesivat sen sijaan vain vähän toisistaan eri säilörehudieeteillä. Typellisten aineiden hyväksikäyttöä kuvaavissa luvuissa esiintyvien erojen on selitetty johtuvan lähinnä Viherliuoksen sisältämästä formaliinista, jolla on valkuaista kovettava vaikutus.

Verianalyysien antamat tulokset pysyivät yleensä normaaliarvojen rajoissa. Koska eläinten terveydentilakin oli kokeiden aikana hyvä, voidaan sanoa, että käytetyt säilörehu- ja hiilihydraattidieetit eivät aiheuttaneet eläimille epänormaalia ravitsemustilaa.

Edellä esitetyssä tutkimuksessa on siis todettu, että sokeri-, tärkkelys- ja selluloosalisäyksillä on toisistaan poikkeava vaikutus säilörehun hyväksikäyttöön. Sen sijaan ei ainakaan tässä tutkimuksessa havaittu eroja eri säilöntäaineilla säilöttyjen nurmirehujen hyväksikäytössä. Niin ikään on todettu, että eri hiilihydraattilisäykset vaikuttavat lähes samalla tavalla eri säilöntäaineilla valmistettuja rehuja käytettäessä.



DEPARTMENTS, EXPERIMENT STATIONS AND BUREAUX OF THE AGRICULTURAL RESEARCH CENTRE IN FINLAND

1. Administrative Bureau, Bureau for Local Experiments (HELSINKI) — 2. Departments of Soil Science, Agricultural Chemistry and Physics, Plant Husbandry, Plant Pathology, Pest Investigation, Animal Husbandry and Animal Breeding; Isotope Laboratory, Pesticide Regulation (TIKKURILA) — 3. Dept. of Plant Breeding (JOKIOINEN) — 4. Dept. of Horticulture (PIIKKIÖ) — 5. Southwest Finland Agr. Exp. Sta. (HIETAMÄKI) — 6. Satakunta Agr. Exp. Sta. (PEIPOHJA) — 7. Karelia Agr. Exp. Sta. (ANJALA) — 8. Häme Agr. Exp. Sta. (PÄLKÄNE) — 9. South Savo Agr. Exp. Sta. (Karila, MIKKELI) — 10. North Savo Agr. Exp. Sta. (MAANINKA) — 11. Central Finland Agr. Exp. Sta. (VATIA) — 12. South Ostrobothnia Agr. Exp. Sta. (PELMA) — 13. Central Ostrobothnia Agr. Exp. Sta. (LAITALA) — 14. North Ostrobothnia Agr. Exp. Sta. (RUUKKI) — 15. Arctic Circle Agr. Exp. Sta. (ROVANIEMI) — 16. Pasture Exp. Sta. (MOUHIJÄRVI) — 17. Pig Husbandry Exp. Sta. (HYVINKÄÄ) — 18. Frost Research Sta. (PELSONSUO)

Suomalaisen Kirjallisuuden Kirjapaino Oy Helsinki 1972

ISBN 951-729-000-4