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PROTEIN SUPPLEMENT IN THE UTILIZATION OF HIGH PROTEIN BARLEY IN THE DIETS OF GROWING-FINISHING PIGS

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ALAVIUHKOLA, T. & PARTANEN, J. 1975. **Protein supplement in the utilization of high protein barley in the diets of growing-finishing pigs.** Ann. Agric. Fenn. 14: 277–285.
(Agricultural Research Centre, Swine Research Station, SF-05840 Hyvinkää 4, Finland)

In a feeding test on growing-finishing pigs a comparison was made between two varieties of barley: Birgitta (Svalöv, Sweden), which had a crude protein content of 18.7 per cent of dry matter, and Karri (Tammisto, Finland), which had 14.6 per cent. Superior growth and feed efficiency were obtained with Birgitta at all the employed levels of protein feed supplementation (180, 120 and 60 g of fishmeal per pig per day). When the barley protein was supplemented with pure lysin and pure methionin, Birgitta again clearly produced the better growth (650 v. 613 g/day). The respective feed consumption figures were 3.25 and 3.48 feed units per kg of liveweight gain.

Introduction

In Finland barley is the most important energy feed and the most important source of protein for pigs. The crude protein content of barley can be increased by some 1–2 percentage points by means of nitrogen fertilization (EGGUM 1970, SCHILLER and OSLAGE 1970, TALVITIE 1974, THOMKE 1970), while the crude protein content in different varieties of barley varies by as much as 4–5 percentage points. These two factors, together with other factors related to growth, cause the crude protein content of barley to range all the way from 8 to 18 per cent.

A high level of nitrogen fertilization lowers the biological value of barley protein because the relative amount of essential amino acids needed by feeding pigs then declines (EGGUM 1973). According to TALVITIE (1974) a 100 kg N-fertilization increased the content of the most important amino acids in barley by about 10 per cent; but the relative proportion of lysine in the protein declined at the same time by about 7 per cent. The variation in lysine content among different varieties of barley was approximately 20 per cent.

The production of most essential amino acids in barley can be increased only marginally by agricultural techniques. Attempts are being made by means of plant breeding to raise the protein content of barley, and especially to increase the size of the protein fraction containing the greatest amount of amino acids essential to animals. A difficulty

with this is the negative correlation between the protein content of barley and the grain yield (REKUNEN 1970).

The digestibility in pigs of the crude protein of barley is approximately 73—80 per cent (MADSEN 1963, NEHRING et al. 1970), and the digestibility of lysine is lower than that of the other amino acids taken together (EGGUM 1973, POPPE et al. 1970). Lysine, threonine and methionine are minimum factors in barley feeding. Thus lysine and methionine supplements have been found to have a positive effect upon growth and feed efficiency in growing-finishing pigs (BRAUDE and LERMAN 1970, COLE and LUSCOMBE 1969, MADSEN et al. 1969). The protein content of the basic feed has been 10—11 per cent in most studies dealing with supplementation of the crude protein in barley.

A feeding test in which growing-finnishing pigs were fed on barley of exceptionally high crude protein content was carried out at the Swine Research Station of the Agricultural Research Centre in 1972. The overall purpose of the test was to discover whether the amount of supplementary protein can be reduced when high-protein barley is used for feed cereal, and to determine the extent to which protein concentrated feed can be replaced by pure amino acids when the protein content of the feed cereal is high.

Materials and methods

Feeds

Two varieties of barley were used in the experiment: Birgitta (Svalöv, Sweden) and Karri (Tammisto, Finland). Fishmeal was used as protein feed, its quantity being constant for each group per animal per day throughout the duration of the experiment (20—90 kg). The chemical composition of the experimental feeds, as analyzed by the Department of Agricultural Chemistry, is shown in Table 1. The amino acid composition of the protein in the feed (Table 2) was determined at the State Institute for technical Research. The two batches of barley contained a higher than normal amount of protein. The lysine content of the protein was low, especially in Birgitta. Nevertheless, in both varieties it was higher than in the barleys used by EGGUM (1970) and THOMKE

Table 1. Chemical composition of feeds (% in D.M.).

	Barley meal		Fish meal
	Birgitta	Karri	
Ether extract	2.13	1.60	13.88
Crude protein	18.65	14.63	73.21
Crude fibre	4.25	4.11	—
Nitrogen free extr.	73.73	76.80	—
Ash	2.24	2.86	11.17
Pure protein	16.88	13.26	63.88
Calculated energy[1] content FU/100 kg D.M.	111.90	112.00	135.55

[1] 1 FU = 0.7 kg starch equivalent

Table 2. Amino acid content of feeds, g/16 g N.

Amino acid	Birgitta	Karri	Fish meal
Lysine	3.33	4.16	8.04
Methionine	0.98	1.09	2.51
Cystine	2.16	2.32	0.70
Cystathionine	0.16	0.32	0.10
Aspartic acid	5.40	6.12	9.30
Threonine	3.24	3.65	4.53
Serine	3.89	4.03	4.03
Proline	13.04	12.49	4.52
Glutamic acid	28.46	27.42	14.62
Glycine	3.66	4.35	5.75
Alanine	4.31	3.69	6.31
Valine	5.05	5.39	5.55
Isoleucine	3.86	3.87	4.55
Leucine	7.52	7.88	8.32
Tyrosine	3.74	3.66	3.32
Phenylalanine	5.99	5.71	4.02
Ornithine	1.04	0.83	0.08
Histidine	1.94	2.23	2.10
Arginine	4.24	4.89	5.56
Tryptophane	0.83	0.99	0.63
Ammonia	3.20	3.42	1.90

(1970) in studies on the interrelationship between nitrogen content of barley and lysine content of the protein. There was also less of the other essential amino acids in the protein of Birgitta than in that of Karri. The only exceptions were phenylalanine and isoleucine. On account of tis high protein content, however, the Birgitta barley contained an absolutely greater amount (g/kg of dry matter) of all the essential amino acids than did the Karri. The high protein content of Birgitta is thus a typical consequence of an abundant nitrogen fertilization and of other favourable growing conditions.

Feeding

The limited quantity of barley high in crude protein that was available for the experiment meant that the number of animals had to be confined to 8 per group. The pigs, of the Finnish Landrace type, were separated into 10 different groups on the basis of sex, litter and liveweight. Four pigs were added to each of the Karribarley groups but have not been included in the comparison between the sets of results for the two varieties. All the pigs were fed individually by trough feeding and received water freely.

In previous protein-level experiments, barley supplemented with 180 g of fishmeal per pig per day produced as good growth and feed-consumption as did 240 g/day in growing-finishing pigs, and distinctly better results than did 120 g per pig per day (ANON. 1971). Hence, 180 g of fishmeal was chosen as the upper limit for protein supplementary feed, this being the equivalent of 113 g of digestible crude protein. The pigs were reared throughout the liveweight interval of 20—90 kg, high-low standards (PARTANEN 1971) being utilized. The weekly feed unit standard for all groups was, from 20 kg upwards, as follows:

Week	1	2	3	4	5	6	7	8	9	10 etc.
Feed units/day	1.20	1.30	1.45	1.65	1.85	2.05	2.25	2.45	2.60	2.60

Other aspects of the feeding of the experimental animals are detailed in Table 3. The pigs of Groups VII and VIII got pure amino acids (98 % lysine and 99 % d-l-methionine) in daily amounts equivalent to those received by the pigs of Group IV in 120 g of fishmeal. The lysine and methionine rations of Group IX were raised to the levels of Group II, and those of Group X to the levels of Group IV.

Table 4 shows the quantities of lysine, methionine and methionine + cystine received, in grammes per animal per day, at the beginning of the experiment, when the

Table 3. Barley variety and protein feed supplement given to groups I—X.

Group		g/animal/day				
	Barley variety	Fish meal	Lysine	Methionine	Mineral mixt.	Vitam. mixt.
I	Birgitta	180	—	—	+	+
II	Karri	180	—	—	+	+
III	Birgitta	120	—	—	+	+
IV	Karri	120	—	—	+	+
V	Birgitta	60	—	—	+	+
VI	Karri	60	—	—	+	+
VIII	Birgitta	—	5.27	1.33	+	+
VIII	Karri	—	5.52	1.75	+	+
IX	Karri	120	2.69	0.89	+	+
X	Karri	60	2.77	0.91	+	+

Table 4. Calculated lysine, methionine and methionine + cystine allowance (g/animal/day) during the first week and from the ninth week to the end.

Group	Lysine		Methionine		Methionine + cystine	
	21—24 kg	60—90 kg	21—24 kg	60—90 kg	21—24 kg	60—90 kg
I	15.29	22.90	4.68	6.93	9.11	16.30
II	15.10	22.60	4.44	6.39	8.26	14.37
III	12.30	20.20	3.74	6.06	8.06	15.49
IV	12.11	19.80	3.49	5.51	7.17	13.50
V	9.57	17.50	2.88	5.21	7.25	14.70
VI	9.39	17.10	2.62	4.63	6.32	12.64
VII	12.11	19.80	3.49	5.51	7.75	14.89
VIII	12.11	19.80	3.49	5.51	7.05	13.38
IX	15.10	22.60	4.44	6.39	8.12	14.38
X	12.11	19.80	3.49	5.51	7.19	13.52

animals were fed 1.2 feed units per day, and in the ninth week, i.e. at a weight of approximately 60 kg, from which time the pigs were being fed 2.6 feed units per day until the termination of the experiment. Upon termination, the pigs were slaughtered and the carcass quality was evaluated by assessment and measurement techniques applicable in progeny testing. The half carcasses of the pigs were dissected in order to separate the lean meat + bone component of the most valuable parts (back, foreback, shoulder, loin and ham) from the fat + skin component, and these components were then weighed. During the experiment most of the pigs suffered from a diarrhoea infection lasting some 2—3 days. Antibiotics were used in the treatment. No differences among groups could be observed in the diarrhoea cases.

Results and discussion

The weight increase of the pigs of the groups (I—VI) to which a fishmeal supplement was administered is shown in Figure 1, and that of Groups VII—X in Figure 2. Results for the growth, feed consumption and carcass quality of the eight first groups are shown in Table 5. The figures are averages for 8 pigs.

Table 5. Average daily gain, feed conversion efficiency and carcass quality for groups in treatments I—VIII.

Item	Croup, barley variety and protein supplement							
	I B 180 g f.m.	II K 180 g f.m.	III B 120 g f.m.	IV K 120 g f.m.	V B 60 g fm.	VI K 60 g f.m.	VII B lys. + met	VIII K lys. + met.
Daily gain g/d	731	691	701	682	660	636	650	613
» » ratio	100	95	96	93	90	87	89	84
Days in trial	90.9	96.0	95.3	96.9	101.3	103.6	101.9	106.7
Feed: gain FU/kg[1])	2.85	3.05	2.99	3 09	3.21	3.35	3.25	3.48
» » ratio	100	107	105	108	113	118	114	122
Barley meal kg DM/animal	151.5	162.0	166.3	169.9	185.3	190.4	192.6	204.4
Fish meal (air dry) kg/anim.	15.9	17.0	11.0	11.3	5.8	6.0	—	—
Lysine suppl. g/animal/day	—	—	—	—	—	—	5.27	5.52
Methionine » » »	—	—	—	—	—	—	1.33	1.75
Feed consumption FU/day	2.08	2.11	2.10	2.11	2.12	2.13	2.12	2.13
Back fat thickness mm	23.7	26.1	22.9	23.9	23.0	27.3	24.5	24.9
Lean meat in valuable cuts %	77.1	75.9	78.4	77.4	77.1	73.9	75.8	76.2

[1]) 1 FU = 0.7 kg starch equivalent B = Birgitta K = Karri f.m. = fish meal

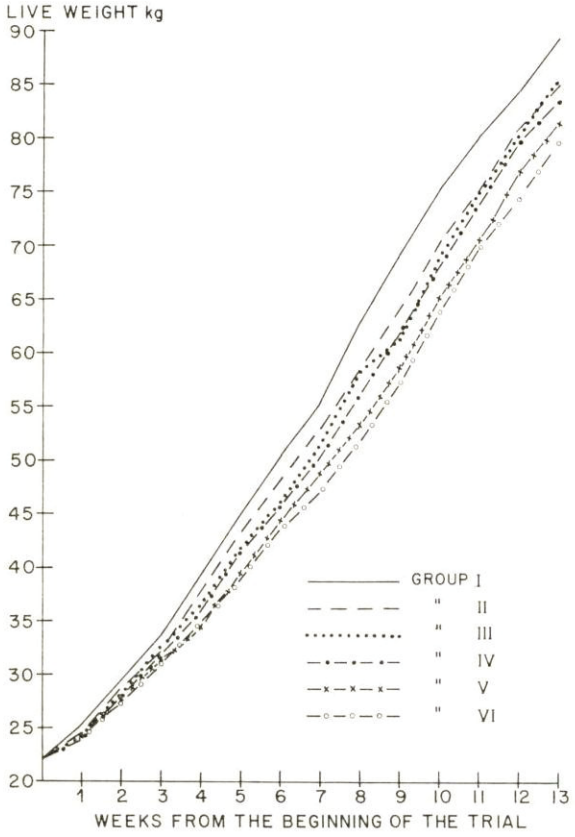

Fig. 1. The weight increase of the pigs in the groups I—VI.

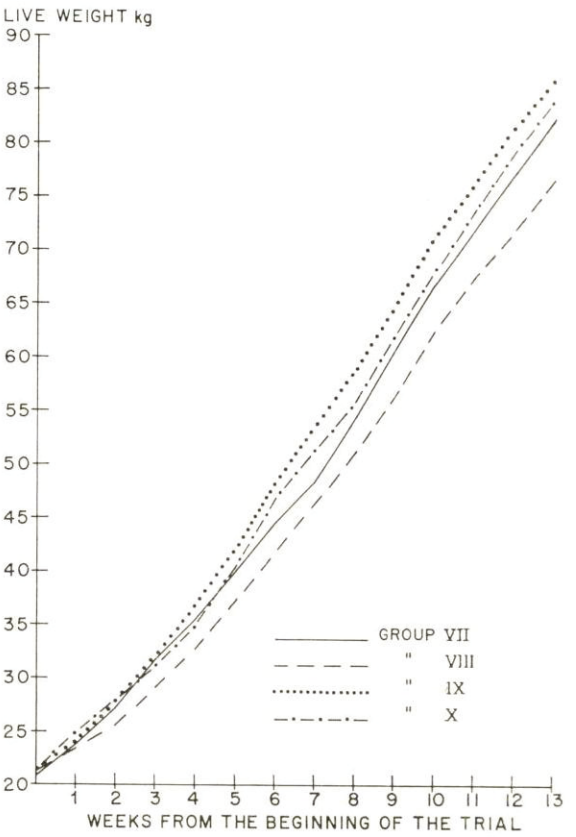

Fig. 2. The weight increase of the pigs in the groups VII—X.

Table 6. Statistically significant differences: comparison between barley varieties and protein levels (8 groups à 8 animals) differences in sex taken into account.

Item	Between varieties	Between protein levels, within varieties	Between sexes, within protein levels and varieties
Feed efficiency FU/kg gain	***	***	NS
Daily gain g/d	**	***	NS
Back fat thickness (corr.) mm	***	*	***
Slight of lean mm	**	NS	***
Lean meat in valuable cuts %	*	NS	**

*** = $P < 0.001$ ** = $P < 0.01$ * = $P < 0.05$

The results of statistical processing by variance analysis and F-test are shown in Table 6.

Table 7 shows the average results for the groups fed on Karri barley, which is lower in protein. In each group the calculations include the basic eight pigs, for which results are given in Table 5, as well as the four pigs subsequently included in the ecperiment.

The significances of the differences among the groups with respect to feed consumption are shown in Table 8. The differences in carcass quality for the various protein levels were not significant.

In the results of Tables 5 and 7 note should be taken of the surprisingly poor growth, feed-consumption and carcass quality for pigs of Group II. Some of the pigs of

Table 7. Supplementing protein of Karri barley: daily gain, feed efficiency and carcass guality.

Item	Group and protein supplement					
	II 180 g f.m.	IV 120 g f.m.	VI 60 g f.m.	VIII lys. + met	IX 120 g f.m. + lys + met	X 60 g f.m. + lys + met
Daily gain g/d	686	674	626	611	693	674
» » ratio	100	98	91	89	101	98
Days in trial	96.9	98.3	104.4	108.0	94.5	98.7
Feed efficiency FU/kg	3.08	3.14	3.40	3.50	3.03	3.14
» » ratio	100	102	110	114	98	102
Barley DM kg/animal	163.8	173.3	191.9	206.1	164.8	180.3
Fish meal » (air dry)	17.2	11.5	6.1	—	11.1	5.8
lysine suppl.g/anim/d	—	—	—	5.52	2.69	2.77
Methionine » »	—	—	—	1.75	0.89	0.91
Feed consumption FU/animal/day	2.11	2.12	2.13	2.14	2.10	2.12
Back fat thickness mm	26.3	24.8	26.7	25.1	25.1	24.9
Lean meat in valuable cuts %	76.1	76.9	74.2	75.8	75.8	76.5

Table 8. Significance of differences in daily gain and feed efficiency between Karri-groups.

Daily gain g/d						Feed efficiency FU/kg					
	II	IV	VI	VIII	IX		II	IV	VI	VIII	IX
IV	NS					IV	NS				
VI	**	**				VI	**	**			
VIII	***	***	NS			VIII	***	***	NS		
IX	NS	NS	***	***		IX	NS	NS	***	***	
X	NS	NS	***	***	NS	X	NS	NS	**	***	NS

this group showed extremely poor growth towards the end of the experiment. The diet probably had no part in this. Since the number of animals in each group was small, the poor progress of one or two animals showed up in the average for the group.

Because of the high crude protein content of the barley rations, the amount of fishmeal, i.e. 120 g per pig per day, sufficed to raise the digestible crude protein level above the generally recommended level. Despite this, the 180 g fishmeal supplement appeared to give better results with both the barley varieties than did the supplement of 120 g per pig day. Admittedly, the differences were not statistically significant. For Groups VI, VII, VIII and X the digestible crude protein content fell below the standard levels. Thus 60 g fishmeal per pig per day was insufficient with both varieties of barley, and the results indicate a distinct deterioration in the animals. In the groups (V and VI) that received a large proportion of their amino acids from barley protein, a shortage of lysine probably occurred, for the digestibility of barley-lysine is relatively low (EGGUM 1973). Thus the pigs of Group X, which were fed like those of Group VI, with the addition of lysine and methionine, show a 7 per cent better growth and an 8 per cent lower feed consumption per kg of growth. However, at the 120 g level of fishmeal supplement, lysine and methionine additions produced no improvements in the results.

The quantity of lysine in the feed remained close to or above the recommended level (POPPE and WIESEMULLER 1968, RERAT

and LOUGNON 1968) in all the groups except V and VI, as did the amounts of other amino acids measured as percentages of the feed. For instance, the amount of threonine fell below the 0.58 per cent given by RERAT (1972) only in the feed of Group VIII.

The growth rates were usually in line with the various protein levels. Barley supplemented with lysine and methionine produced relatively good results. Amino acid supplements alone, however, did not produce results as good as those produced by the respective quantities of lysine and methionine administered in the form of fishmeal. The same result has been obtained by a number of researchers (COLE and LUSCOMBE 1969, RERAT and HENRY 1969). The cause may lie in a lower feed efficiency of pure amino acids, or in a deficiency in other essential amino acids or digestible crude protein in general. The latter case was suggested by the 5 per cent better growth results and 8 per cent better feed efficiency results obtained with the barley richer in protein, for the lysine contents of the barley rations were nearly identical: 6,2 g/kg dry matter in Birgitta, and 6.1 g/kg of dry matter in Karri. In a Danish experiment (MADSEN et al. 1973) superior results were likewise obtained with a barley containing more crude protein and supplemented with pure amino acids than with a barley containing less protein and identically supplemented.

At all the levels of protein employed, Birgitta barley produced a better daily gain and a lower feed consumption per kilo of liveweight growth. The differences in favour of the Birgitta groups were 3—5 per cent for growth and 3—8 per cent for feed consumption. It is thus possible to save on protein supplement by utilizing barley containing more crude protein. In experiments arranged in Sweden and Denmark similar conclusions have been reached (MADSEN et al. 1973, THOMKE and FRÖLICH 1968). The differences in growth between the groups had already appeared between liveweights of 20 kg and 60 kg, after which the different protein levels and varieties no longer gave rise to distinct differences in growth. Consequently, in the final stage of the rearing period, protein feeds can be replaced with pure amino acids without growth suffering, as shown by THIER and BRUNE (1969).

The carcass quality of the pigs fed on Birgitta barley was, on average, clearly superior to that of the pigs fed on Karri barley ($P < 0.001$). The difference could be seen in the thickness of the backfat and sidefat and in the ralative amounts of lean meat on the most valuable parts of the carcass. The female pigs were meatier than the castrated males ($P < 0.001$): for example, the thickness of the sidefat of the castrated males averaged 24.2 mm and that of the females 19.4 mm. The percentages of lean meat on the most valuable parts of the carcass were 75.2 and 77.7, respectively.

The effects of different protein levels were less noticeable with respect to carcass quality. There was a tendency towards increased fat content with declining protein content of feed, however. No differences were observed in other quality characteristics, such as the colour of the meat or the quality of the fat.

The barley containing the higher amount of protein was clearly the more economical of the two feeds at all levels of protein supplementation. Identical net profits would result if the price per kilogramme of Birgitta barley had been as much as 2—5 Finnish pence (depending on protein level) higher than the price per kilo of Karri. The use of lysine and methionine supplements raised the feeding prices disproportionately, chiefly because of the high price of lysine. On the basis of the experiment it was concluded that it pays to supplement high-protein barley with lysine and methionine when the price of lysine is at most 4—5 times that of fishmeal. The price of methionine has remained relatively low in comparison with

the price of lysine, but when use is made of a cereal containing a lot of protein, supplementation with methionine may be superfluous. It must be pointed out, however, that the experimental data in question were too few for any conclusive price comparisons to be made. The question of whether protein content can be adopted as one of the bases for the pricing of feed cereal requires a great deal of additional consideration.

The protein norms reported in the literature are not fully applicable when barley containing a high level of protein is utilized as the basic ration. Because of the poor digestibility and unfavourable amino acid composition of the protein, the amount of supplementary protein feed cannot be reduced to the extent suggested by the increase in the protein content of the barley.

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SELOSTUS

Valkuaistäydennys runsaasti proteiinia sisältävää ohraa lihasikojen rehuviljana käytettäessä

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Maatalouden tutkimuskeskus

Runsaasti raakavalkuaista sisältävän ohran täydentämistä erilaisilla määrillä kalajauhoa tai puhtaita aminohappoja tutkittiin lihasioilla kahta ohralajiketta käyttäen. Toinen lajikkeista (Birgitta, Svalöv) sisälsi raakavalkuaista 18.7 % kuiva-aineesta. Vertailuohrana käytetyn Karrin (Tammisto) raakavalkuaispitoisuus oli 14.6 %. Käytetyt valkuaislisärehutasot olivat 180, 120 ja 60 g kalajauhoa eläintä kohti päivässä, sekä kummallakin lajikkeella lysiini- ja metioniinilisäysryhmät, joiden eläimet saivat ohran lisäksi lysiiniä ja metioniinia 120 g:n kalajauhotasolle lasketut määrät. Edelleen oli Karri-ohralla kaksi ryhmää, joiden ruokinnat olivat: ohra + 120 g kalajauhoa + lysiini + metioniini laskettuna 120 g:n kalajauhotasolle. Koe-eläimiä oli Birgitta-ryhmissä kahdeksan ja Karri-ryhmissä kahdeksan + neljä. Eläimet ruokittiin yksilöllisesti.

Tuloksista todettiin, että edullisin käytetyistä valkuaislisärehutasoista oli kummallakin lajikkeella 180 g kalajauhoa eläintä kohti päivässä. Erot alemmalle tasolle (120 g) kasvussa ja rehunkulutuksessa eivät kuitenkaan olleet tilastollisesti merkitseviä. Seuraavalla tasolla (60 g) eläimet menestyivät selvästi huonommin, kuten myös pelkästään aminohappolisäyksen saaneet eläimet. Lysiini- ja metioniinilisäys niukalla valkuaislisärehutasolla (60 g/pv) paransi kasvua 7 % ja rehuhyötysuhdetta 8 %. Ylemmällä tasolla (120 g/pv) aminohappolisäysten vaikutus oli vastaavasti 3 % kasvussa ja 4 % rehunkulutuksessa. Runsaammin proteiinia sisältäneellä ohralla saatiin ylivoimaisesti paremmat tulokset kuin valkuaisniukemmalla ohralla. Ero oli selvä kasvussa ($P < 0.01$), rehunkulutuksessa ($P < 0.001$), selkäsilavan paksuudessa ($P < 0.001$) sekä taloudellisessa lopputuloksessa. Valkuaisrehujen korvaaminen lysiinillä ja metioniinilla on täysin mahdollista. Tulokset ovat sitä paremmat, mitä enemmän perusrehu sisältää valkuaista. Kokeen perusteella laskettu hintasuhde lysiinin ja kalajauhon välillä saa kuitenkin olla enintään 5: 1, jotta lysiinin käyttö olisi taloudellisesti perusteltua.

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ENSILAGE OF GRASS WITH ACIDS AND ACID-FORMALDEHYDE ADDITIVES

I Preservation and composition of silages

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Grass heavily fertilized with nitrogen was ensiled in large experimental silos, after treatment with acid additives (formic acid, AIV 1: formic acid plus hydrochloric acid, AIV 2: formic acid plus phosphoric acid) and additives containing formaldehyde and acid (Viher solutions 1–3), applied at rates of 4–5 l/ton (acids) and 5–6 l/ton (Viher solutions). The mean storage period (first day of preparation to last day of feeding) was 295 days.

Good quality silage was obtained with all the additives, quality being most uniform with formic acid and AIV 2. The preservative effect of Viher solution was dual. The bacteriostatic effect of the formaldehyde was in evidence in the first months of storage, when fermentation was weak and the silage pH values were high (ca. 4.5–5.5). Later an acidifying effect, due mainly to lactic-acid fermentation, caused an increase in overall fermentation. The silages prepared with acids showed relatively constant pH values throughout (ca. 4.0–4.4), and more stable fermentation. The soluble nitrogen fraction of total nitrogen was significantly ($P < 0.01–0.001$) lower in the Viher solution than in the acid-treated silages.

Introduction

Silage has been prepared in Finland for about 40 years by the original AIV method (VIRTANEN 1929). Inorganic acids (hydrochloric acid and sulphuric acid) are used to bring the acidity of the cut herbage rapidly down to ca. pH 4 to achieve good quality silage. In the late 1960's less strong silage additives were introduced since it had become usual to add the preservative to the forage at cutting and an increase in the use of silage had raised the requirements for palatability. A solution of pure formic acid, two acid mixtures with formic acid as one of the components (AIV 1 and AIV 2; Central Co-operative Valio), and a mixture of formaldehyde + formic acid ("Viher" solution; Farmos Oy) were put on the market. Thus all these new preservatives contained formic acid.

By that time a large number of experimen-

tal results had already been published on the effectiveness of formic acid as a silage additive. In Norway ensiling results with formic acid were almost as good as with the original AIV solution (BREIREM et al. 1959, SAUE 1968, ULVESLI and SAUE 1965, ULVESLI et al. 1965). Similar results had already been published in Sweden (JARL 1948, JARL and HELLEDAY 1948) and were later obtained in Denmark (NØRGAARD PEDERSEN et al. 1969). The effect of the formic acid was reinforced when forage harvesters were introduced that chopped the herbage and applied the silage additive directly in the field. Thus ensilage with formic acid became common practice in Norway in the late 1960's (SAUE and BREIREM 1969). Little attention was paid to additives containing formaldehyde before the end of the 1960's (KUCHLER and WACHTER 1931, OZIGOV 1962, THOMAS 1965). In Finland, the development of a formaldehyde silage additive had been under way since 1966.

The introduction of the new silage additives coincided in Finland with a considerable increase in the application of nitrogen fertilizer to the leys. This was the result of studies of JÄNTTI (1968) and HUOKUNA (1970), which showed that the optimum application of nitrogen fertilizer to silage leys i Finnish conditions was about 300 kg N/ha, given in three instalments. However, the ensilage of high-protein forage involves much greater risks than that of forage rich in carbohydrates (FOX and BROWN 1969, GORDON et al. 1964, JACOBSON and WISEMAN 1962, TOTH et al. 1956, WILSON and WEBB 1937). It was therefore considered important to investigate the efficiency of the new additives in ensiling grass heavily fertilized with nitrogen. The results presented in this paper were obtained from experiments made at the Agricultural Research Centre in the years 1969—73.

Materials and methods

The percentages by weight (w/w) of the components (100 %) of the silage additives were as follows:

Formic acid, 86 %
AIV 1 solution: formic acid 25 % plus hydrochloric acid 20 % plus corrosion-preventing agent 0.2 %
AIV 2 solution: formic acid 83 % plus orthophosphoric acid 2 %
Viher solution
1, in 1969: formaldehyde 22 % plus formic acid 26 % plus stabilizers 1 %
2, in 1970: formaldehyde 26 % plus formic acid 17 % plus stabilizers 1 %
3, in 1971—72: formaldehyde 20 % plus acetic acid 24 % plus stabilizers 3.5 %

All these solutions were included in comparative experiments at the North Savo Experiment Station, Maaninka, in 1969—71 (experiments 1—3). In addition, AIV 2 and Viher solution 3 were tested on various forage crop species at the Lintupaju Farm of Jokioinen Estates in 1971 (experiment 4) and at the North Savo Experiment Station in 1972 (experiment 5, a and b). The silos at Jokioinen were two identical concrete tower silos, 6×19.6 m^2 = 117.6 m^3 in volume; at the North Savo station they were four identical silos constructed of glassfigre reinforced polyester, 7.5×7.1 m^2 = 53 m^3 each.

The silage leys (aged 1—7 years) consisted of several grass species and were either mixed leys (experiments 1—3) or almost pure stands of one species (experiment 5). In experiment 4 the midsummer (2) and autumn (3) crops contained considerable proportions of red clover (Table 1), which, owing to its deep root system, thrived best in that exceptionally dry summer.

Nitrogen fertilizer was given at the rate of 200—300 kg N/ha, except in the above-mentioned clover-mixed ley, which received

Table 1. Application of nitrogen fertilizer and botanical composition of the silage leys.

Experiments, years	kg N/ha per crop	Botanical composition % of fresh weight								
		timothy	meadow fescue	cocks-foot	Italian ryegrass	meadow-grass	couch-grass	other grasses	red clover	dicot. weeds
Expt. 1 1969	96	58	30			4	1		1	6
Expt. 2 1970	104	60	14	4			18	2		2
Expt. 3 1971	74	57	7	3		1	19	4	2	7
Expt. 4 1971	44	39		12		2	4		33	10
Expt. 5 a 1972	91	81	4			11			1	3
Expt. 5 b 1972	51[1]				93					3

[1]) The ryegrass ley established in 1972 also received 49 t/ha farmyard manure in the previous autumn.

ca. 130 kg N/ha. The average application of nitrogen per crop varied between 44 and 104 kg N/ha (Table 1). Most of the nitrogen was given in the form of calcium ammonium nitrate ("Oulu saltpetre") but part of the mid-summer fertilizer was given as urea. The average rate of application of phosphorus, given mainly in the form of superphosphate, was 35 kg P/ha (31—37 kg/ha) and the average application of potassium was 68 kg K/ha (0—115 kg/ha). An exception from the above pattern of fertilizer application (Table 1) was the farmyard manure used at the establishment of the leys.

Every effort was made to cut the herbage before the grasses reached the stage of heading. In general the early-summer crops were furthest advanced at cutting, especially in 1970 (experiment 2), when growth was extremely rapid owing to favourable weather conditions in early summer and abundant nitrogen fertilizer. Heading of timothy had just begun, meadow fescue was partly and cocksfoot fully headed. The mid- and late-summer cuttings were usually performed at the sward stage. Even then the mid-summer herbage often contained occasional headed stems from plants which had preserved their inflorescence primordia through the first cutting. The mid- and late-summer crops of experiment 4 were exceptional; owing to severe drought, the timothy, 30—40 cm tall at cutting, was in ear and the red clover in bloom. In experiment 5, the timothy (50—60 cm) and ryegrass (30—40 cm) were largely at the sward stage, although some headed stalks were present as well. The meadow-grass *(Poa pratensis)*, which occurred to some extent among the timothy (cf. Table 1), was either headed or just coming into head.

Cutting was performed by driving four (experiments 1—3) or two (experiments 4—5) identical forage harvesters simultaneously through alternate strips of ley. The silage preservatives were added through an applicator at cutting. The manufacturers' instructions regarding the rate of application were followed (4—5 l/t), but in the first year of the experiments a sufficiently uniform distribution of the solution was not achieved, because it was not possible to have all forage loads weighed. In the other years, however, every load was weighed individually and the amount of solution used for each measured. In terms of averages, the application was quite successful (Table 2) but some variation still occurred between the loads. The rate of application was increased from the third experiment on, in order to bring even the lowest amounts applied within the range recommended by the manufacturers. The average application rate then rose to 5—6 l/t (Table 2). Work was always completed by adding ca. four more litres of solution to the surface of the ensiled forage.

In each of the silos, silage was prepared three times (in 1969 twice) during the summer season (Table 1). The average amount

Table 2. Amounts of raw material ensiled and additives used at different cuttings (1—3) and in total.

Experiments, additives	Raw material t/silo				Silage additive l/t			
	1	2	3	Total	1	2	3	Average[2]
Expt. 1[1]	—	24.0	14.6	38.6	—	4.0	4.8	4.3
Expt. 2								
AIV 1	33.8	25.0	8.2	67.0	4.0	3.8	4.0	4.1
AIV 2	33.7	27.1	8.2	69.0	4.1	3.9	4.1	4.2
Formic acid	33.6	25.1	8.5	67.2	4.1	4.2	3.9	4.3
Viher solution 2	33.6	23.4	7.2	64.2	5.0	4.9	4.7	5.1
Expt. 3								
AIV 1	40.2	16.1	6.8	63.0	4.9	4.9	5.3	5.2
AIV 2	41.2	16.0	7.3	64.4	5.0	5.2	5.2	5.3
Formic acid	40.9	15.1	7.0	63.0	5.1	5.3	5.0	5.3
Viher solution 3	40.5	13.7	6.8	61.0	6.0	6.5	6.4	6.4
Expt. 4								
AIV 2	68.1	52.8	9.4	130.3	5.6	4.6	6.8	5.3
Viher solution 3	58.5	52.3	9.8	120.6	4.7	5.3	7.0	5.1
Expt. 5 a (timothy)								
AIV 2	44.8	18.3	8.2	71.3	5.0	5.3	5.4	5.3
Viher solution 3	44.9	17.1	5.7	67.7	5.7	6.5	7.0	6.2
Expt. 5 b (ryegrass)								
AIV 2	39.9	34.6	19.9	94.4	4.8	4.9	5.1	5.0
Viher solution 3	40.1	34.6	18.3	93.0	5.4	6.1	5.5	5.8

[1]) In experiment 1 only some of the forage loads were weighed.
With all the additives (AIV 1, AIV 2, formic acid, Viher solution 1) the aim was to ensile equal amounts of raw material with equal amounts of solution.
[2]) Including the amount of solution spread on the silage surface.

of early-summer herbage ensiled was 148 t (54.2 %, the work taking 3—5 days to complete), the amount of mid-summer silage 93 t (33.9 %, 2—3 days) and that of late-summer silage 33 t (11.9 %, 1—2 days). In mid and late summer, silage was prepared to the full capacity of the towers after the forage had settled. The Viher solution silages took slightly longer to consolidate than the other silages; their amounts therefore remained slightly less (Table 2). Consolidation mostly occurred within the first few days. Weighting was with water in containers or stone blocks at 350 kg/m². A plastic sheet was spread over the forage before weighting. In experiment 2 the sheets were left in position between the layers of forage. Effluent from the upper layers was led through perforated 3/4" plastic pipes, fitted on the silo wall, to drains at the bottom of the silo.

It was not possible in this work to measure the amounts of effluent, but in experiments 1—3 data on the composition and acidity of the effluent were recorded (Table 3). The average dry-matter content of the grass in the different experiments and crops was as follows:

Experiment	First crop	Second crop	Third crop	Average
1	—	21.5 %	20.2 %	21.4 %
2	18.0 %	14.0 »[1])	15.6 »	16.2 »
3	19.2 »	18.5 »	17.0 »	18.8 »
4	22.7 »	21.8 »	24.6 »	22.5 »
5 a	16.3 »	13.8 »	15.4 »	15.5 »
5 b	12.5 »	12.3 »[1])	12.5 »	12.4 »

[1]) Rain

In dry summers (experiments 1 and 4) the dry matter exceeded 20 %. Ryegrass had the lowest dry-matter content (experiment 5 b). The weather at cutting was generally fair and dry and most of the occasional showers were light. The mean

(24-h) temperatures of the cutting days varied from 10.5 to 26.1° C (average 16.8 ° C) in June and July, and from 5.1 to 22.2° C (average 14.2° C) in August and September. The maximum temperatures for the two periods were 12.7—30.8° C (21.5° C) and 10.3—26.8° C (19.2° C), respectively (Anon. 1969, 1970, 1971, 1972). The lowest temperature reading was obtained in autumn 1969, when night temperatures fell below zero and by morning the grass was covered with frost.

At the beginning of feeding, the silage in the towers was 5—6 m thick. Feeding started 24—80 days after the last date of ensiling and continued for 90—165 days. The storage periods (time from the first day of ensiling to the last day of feeding) for the bottom layers in the towers varied between 209 and 330 days, with an average of 295 days. The silages were sampled fortnightly by taking thin cores from the layer of forage (ca. 0.5 m) under consumption at the time. Samples were taken at three sampling points: close to the silo wall, close to the silo centre, and halfway between these. They were mixed together and a representative sample was taken from the bulk sample for analysis.

Volatile fatty acids, lactic acid, ammonia-N, cold water soluble N and sugar were determined on an aqueous extract of fresh silage. Fatty acids were determined by gas-liquid chromatography (HUIDA 1973), lactic acid (BARKER and SUMMERSON 1941) and ammonia-N (MCCULLOUGH 1967) colorimetrically, soluble N by the Kjeldahl method, and sugar by the method of SOMOGYI (1945) as modified by SALO (1965). The sugar was expressed as glucose. Silage pH and nitrate nitrogen were determined electrometrically, the former on samples of silage effluent and the latter on samples dried at 60° C (PAUL and CARLSON 1968). The conventional feed analysis was performed by standard methods

Table 3. Composition and pH of silage effluents.

Experiments, additives	No. of samples	pH	Dry-matter %	Ash %	Crude protein %
Expt. 1					
AIV 1	14	4.3[1])	8.4[ab]	2.2	2.1[c1])
AIV 2	14	4.4[1])	8.5[a]	2.3	1.9[c1])
Formic acid	14	4.4[1])	8.2[ab]	2.2	2.0[c1])
Viher solution 1	14	4.9[1])	7.7[b]	2.3	1.4[d1])
Expt. 2					
AIV 1	22	4.52[c]	5.8[ab]	1.3	2.1[c]
AIV 2	22	4.48[c]	6.1[c]	1.4	2.1[c]
Formic acid	22	4.53[c]	6.1[a]	1.3	2.1[c]
Viher solution 2	22	5.22[d]	5.1[bd]	1.3	1.3[d]
Expt. 3					
AIV 1	12	4.75[a]	8.2[c]	1.5	2.6[c]
AIV 2	12	4.81[ab]	8.1[c]	1.4	2.4[c]
Formic acid	12	4.82[ab]	8.1[c]	1.5	2.4[c]
Viher solution 3	12	5.08[b]	7.1[d]	1.4	1.8[d]
Differences between experiments 2—3					
AIV 1		*	***	—	—
AIV 2		***	***	—	—
Formic acid		***	***	—	—
Viher solution		—	***	—	***

[1]) Determined on 6 samples.
Significance of differences within experiments tested by analysis of variance; the Tukey test (STEEL and TORRIE 1960) used for testing the differences between averages for the different silage additives; a—b: $P < 0.05$, c—d: $P < 0.01$. Differences between experiments 2—3: *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Dry-matter content was determined by drying the samples at 105° C and the values corrected by adding 100 % of the butyric and propionic acids and 80 % of the acetic acid (JARL and HELLEDAY 1948, NORDFELDT 1955).

Results

The effluents of the Viher solution silages had significantly higher pH values, but significantly lower dry-matter and crude-protein contents than the effluents of the acid-treated silages, which were very similar to each other (Table 3). The pH's for the effluents of the Viher solution silages were initially rather high (over 5) but decreased gradually almost to the level of the acid-treated silages, which had fairly uniform values around pH 4. The year-to-year variation in effluent dry matter was caused by differences in the moisture content of the cut grass (cf. p. 290 and Table 3).

The silage samples showed pH differences similar to those found for the effluents. The pH's of the silages prepared with acids were almost the same as each other, having an average of 4.2; the values for the Viher solution silages were significantly higher, with an average of pH 4.7 (Tables 4 and 5). Early in the storage period the Viher solution silages had pH values above 5, but these came down during storage as lactic-acid fermentation proceeded (Fig. 1). In experiment 2, the pH values for the AIV 1 and Viher solution silages fluctuated considerably, while those for the AIV 2 and formic acid silages kept fairly constant, though higher by about 0.2 pH units than in experiments 1 and 3 (Fig. 1).

Fermentation was slightly stronger in the AIV 1 silages than in the others. This is evident from their higher contents of lactic and acetic acids and lower sugar contents (Table 4, Fig. 1). In the Viher solution silages acetic acid increased considerably from experiment 3 on, when Viher solution 3, which contains acetic acid, was used instead of solutions 1 and 2 (Tables 4 and 5). Fermentation was very weak in all the silages in the autumn of 1969, when the temperature of the cut grass was low (cf. p. 290) and storage time was short (24 days). In experiment 5 lactic-acid fermentation was comparatively weak but more propionic acid was formed than in the other experiments.

Butyric acid was rare and very low in the silages (Tables 4 and 5, Fig. 1). Most of it was found in the mid-summer silages of experiments 1 and 2. In the silages prepared with Viher solutions 1 and 2 it was somewhat more frequent and occurred in slightly larger amounts than in the other silages. In the analysis of the averages for experiments 1—3 the difference from the AIV silages proved statistically significant (Table 4). No butyric acid occurred in experiment 3.

The ammonia-N fraction of total N was low in all the silages (mean 4.8 %) (Tables 4 and 5). In experiment 2, however, the ammonia-N contents of the AIV 1 and Viher solution 2 silages varied greatly (Fig. 1).

The soluble N fraction of total N was very significantly lower in the Viher solution silages than in the acid-treated silages (Tables 4 and 5, Fig. 1). Soluble nitrogen was highest in the AIV 1 silages (average 55 %). In some experiments the soluble N fraction of the total N in the acid-treated silages rose near the bottom of the silos to over 70 % (Fig. 1).

The composition of the silages was very little affected by the different additives (Tables 4, 5, 6 and 7). Total N (and correspondingly crude protein) was slightly higher in the Viher solution silages than in the others. In some experiments the difference was significant, in others it merely indicated a

Table 4. Quality and composition of the silages (experiments 1—3)

Experiments, silages	No. of samples	Dry-matter %		pH		% of dry-matter										% of total N			
						Sugar		Lactic acid		Acetic acid		Butyric acid		Propionic acid		Total N		NO_3-N		NH_3-N		Soluble N	
		mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Expt. 1																							
AIV 1	14	24.0	2.8	4.0^{e}	0.1	6.6	3.9	4.3	3.5	0.87	0.40	0.01	0.02	—[1]		3.1	0.5	—[1]		3.2	2.2	45.7^{e}	5.8
AIV 2	14	24.6	2.9	4.1^{e}	0.1	7.6	4.7	2.8	2.3	0.92	0.36	0.01	0.02	—		3.0	0.5	—		3.3	1.4	44.2^{e}	6.3
Formic acid	14	24.3	2.9	4.1^{e}	0.1	7.5	4.0	3.0	2.6	0.88	0.53	0.14	0.41	—		3.1	0.4	—		3.1	1.9	39.7^{e}	6.6
Viher solution 1	14	24.4	3.4	4.5^{d}	0.3	7.2	4.4	4.2	3.6	1.04	0.47	0.23	0.41	—		3.1	0.5	—		3.9	2.1	27.6^{d}	5.6
Expt. 2																							
AIV 1	13	21.7	2.7	4.5^{e}	0.3	0.8^{e}	1.0	8.0^{ac}	3.3	2.65^{e}	1.34	0.01	0.02	0.19^{ac}	0.18	3.5	0.6	0.10	0.06	6.5	2.8	60.2^{e}	10.4
AIV 2	13	22.2	2.1	4.4^{e}	0.1	4.6^{cd}	6.3	5.4^{ab}	1.7	1.10^{d}	0.52	0.00	0.01	0.01^{bd}	0.04	3.3	0.3	0.14	0.05	4.1	2.1	54.5^{e}	15.6
Formic acid	13	21.8	2.2	4.3^{e}	0.1	2.6^{cd}	3.3	7.3^{a}	2.2	1.35^{d}	0.36	0.00	0.01	0.00^{bd}	0.00	3.3	0.4	0.14	0.05	4.4	1.8	53.5^{e}	15.3
Viher solution 2	12	21.7	2.3	4.8^{d}	0.4	7.3^{d}	6.2	4.0^{bd}	2.8	1.02^{d}	0.79	0.32	0.74	0.06^{b}	0.10	3.6	0.4	0.12	0.05	4.9	4.3	34.1^{d}	11.6
Expt. 3																							
AIV 1	12	22.4	2.5	4.1^{e}	0.2	1.7^{e}	1.4	9.2^{e}	1.2	1.85^{ae}	0.42	0.00	0.00	0.08	0.08	3.3^{a}	0.3	0.14	0.07	5.1^{a}	0.9	60.3^{e}	7.5
AIV 2	12	23.0	2.6	4.2^{cd}	0.2	5.5^{cd}	2.4	5.2^{ed}	1.5	1.40^{cd}	0.26	0.00	0.00	0.11	0.08	3.3^{ab}	0.4	0.12	0.07	4.3^{ab}	0.8	56.5^{e}	6.8
Formic acid	12	23.2	2.5	4.2^{cd}	0.2	7.3^{d}	4.3	3.5^{e}	1.4	1.16^{d}	0.36	0.00	0.00	0.10	0 11	3.3^{a}	0.3	0.11	0.05	3.9^{b}	1.3	54.9^{e}	6.7
Viher solution 3	12	23.1	3.2	4.4^{d}	0.3	5.3^{cd}	6.3	6.6^{d}	2.5	2.45^{be}	0.77	0.00	0.00	0.09	0.06	3.6^{b}	0.3	0.12	0.09	3.8^{b}	0.9	41.1^{d}	9.6
On average																							
AIV 1	39	22.8	2.8	4.2^{e}	0.3	3.2^{ac}	3.6	7.0^{e}	3.6	1.76^{e}	1.11	0.01^{a}	0.02	0.14^{a}	0.15	3.3	0.5	0.12	0.07	4.9	2.5	55.0^{ac}	10.6
AIV 2	39	23.3	2.7	4.2^{e}	0.2	6.0^{b}	4.9	4.4^{d}	2.2	1.13^{d}	0.44	0.01^{a}	0.02	0.06^{b}	0.08	3.2	0.4	0.13	0.06	3.9	1.6	51.4^{cd}	11.6
Formic acid	39	23.1	2.7	4.2^{e}	4.4	5.8^{b}	0.2	4.6^{d}	2.9	1.12^{d}	0.46	0.05^{ab}	0.25	0.05^{b}	0.09	3.2	0.4	0.13	0.05	3.8	1.7	49.0^{bd}	12.3
Viher solutions	38	23.1	3.2	4.6^{d}	0.4	6.6^{bd}	5.5	4.9^{d}	3.2	1.48^{cd}	0.94	0.19^{b}	0.49	0.07^{ab}	0.09	3.4	0.5	0.12	0.07	4.2	2.7	33.9^{e}	10.5
Differences between experiments 1—3																							
AIV 1		—		***		***		***		***		—		—		—		—		**		***	
AIV 2		—		***		—		**		*		—		**		—		—		—		*	
Formic acid		—		***		**		***		*		—		**		—		—		—		***	
Viher solutions		—		*		—		—		***		—		—		**		—		—		**	

[1]) Not determined

Significance of differences between silages tested by analysis of variance both within experiments and on the basis of the averages for the three experiments. Differences between additives tested by the Tukey test: a—b: $P < 0.05$, c—e: $P < 0.01$. Experiments combined by pooling.

Differences between experiments *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Table 5. Quality and composition of the silages (experiments 4—5).

Experiments, silages	No. of samples	Dry-matter %	pH	% of dry-matter							% of total N	
				Sugar	Lactic acid	Acetic acid	Butyric acid	Propionic acid	Total N	NO_3-N	NH_3-N	Soluble N
		mean s.d.	mean s.d.	mean s.d.	mean s.d.	mean s.d.	mean s.d.	mean s.d.	mean s.d.	mean s.d.	mean s.d.	mean s.d.
Expt. 4												
AIV 2	7	27.2 1.6	4.2 0.2	7.1[a] 3.9	6.4[c] 2.9	0.96[e] 0.20	0.00 0.00	0.07 0.10	3.1 0.3	0.04 0.01	2.8[a] 1.3	39.4[a] 1.6
Viher solution 3	7	27.1 3.6	4.3 0.2	2.4[b] 2.3	11.0[d] 2.6	2.76[f] 0.73	0.02 0.05	0.06 0.07	3.2 0.3	0.04 0.02	4.8[b] 1.6	35.5[b] 3.7
Expt. 5 a (timothy)												
AIV 2	13	21.5 2.4	4.2[e] 0.1	5.2 2.3	2.1 1.4	0.93[e] 0.53	0.01 0.02	0.13 0.22	3.0 0.5	0.18 0.10	3.7 1.5	52.4[e] 10.5
Viher solution 3	14	21.1 2.7	4.8[f] 0.3	5.3 4.1	2.9 2.4	1.98[f] 0.84	0.01 0.03	0.16 0.23	3.2 0.4	0.16 0.11	3.5 1.7	27.7[f] 8.1
Expt. 5 b (ryegrass)												
AIV 2	14	20.0 2.4	4.3[e] 0.2	6.8[a] 4.2	2.3 1.4	0.96 0.66	0.00 0.01	0.26 0.37	3.2 0.4	0.13 0.04	3.1 1.4	44.9[e] 4.7
Viher solution 3	14	20.0 2.2	5.1[f] 0.3	10.0[b] 3.7	1.5 1.2	1.45 0.77	0.01 0.03	0.37 0.52	3.5 0.4	0.12 0.05	2.7 1.7	25.3[f] 6.8
On average												
AIV 2	34	22.0 3.5	4.2[e] 0.1	6.3 3.5	3.1 2.4	0.95[e] 0.53	0.00 0.01	0.17 0.28	3.1[a] 0.5	0.13 0.08	3.3 1.4	46.7[e] 8.6
Viher solution 3	35	21.9 3.8	4.8[f] 0.4	6.6 4.7	4.0 4.1	1.92[f] 0.91	0.01 0.03	0.23 0.37	3.3[b] 0.4	0.12 0.08	3.5 1.8	28.3[f] 7.7
Differences between experiments 4—5 a—5 b												
AIV 2		***	—	—	***	—	—	—	—	***	—	**
Viher solution 3		***	***	***	***	**	—	—	—	**	*	*

Significance of differences between silages tested by analysis of variance both within experiments and on the basis of the averages for the three experiments.
Differences between additives tested by F test. a—b: $P < 0.05$, c—d: $P < 0.01$, e—f $P < 0.001$. Experiments combined by pooling.
Differences between experiments *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

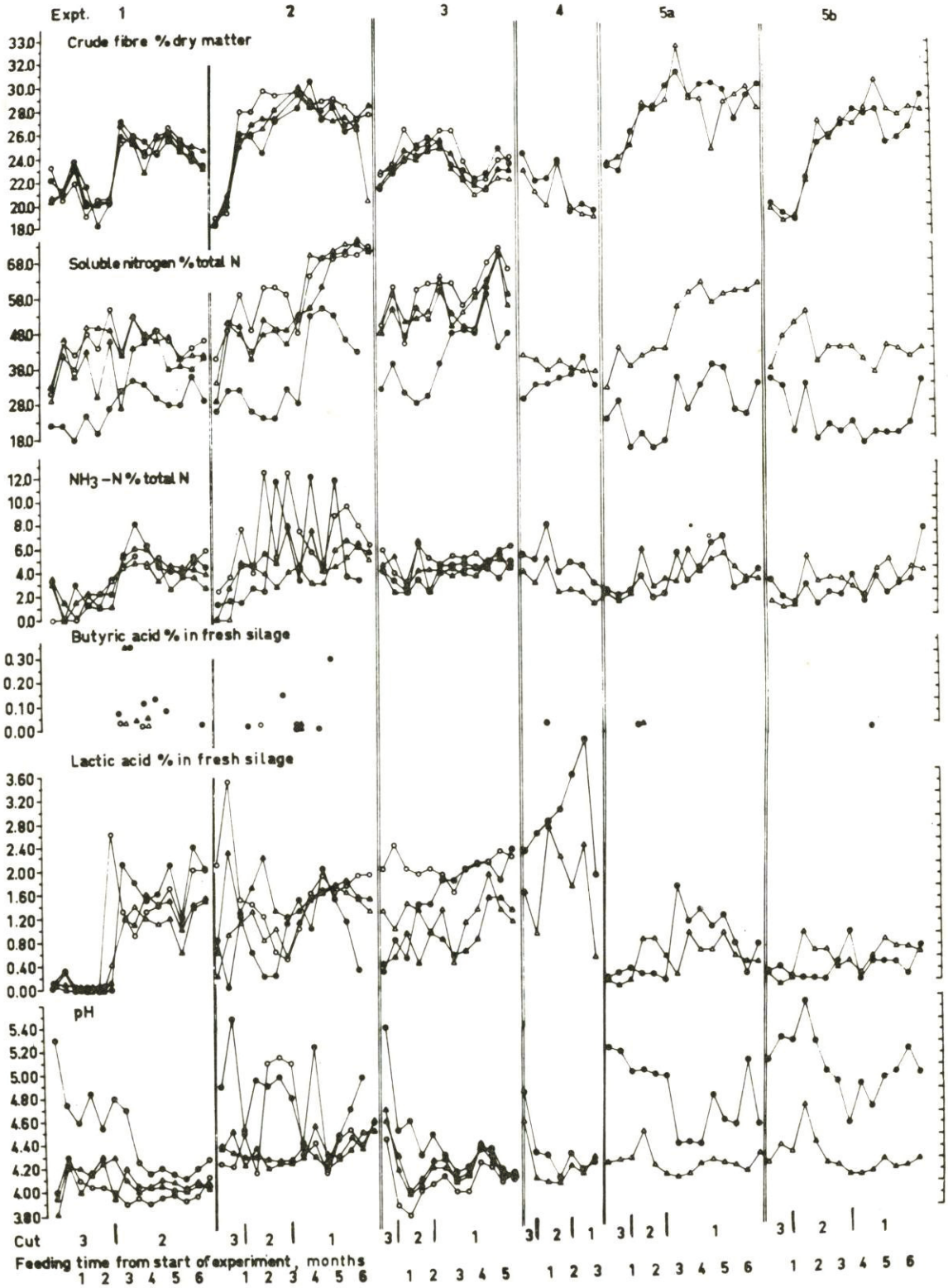

Fig. 1:- Quality and composition of the silages (AIV1 o, AIV2 Δ, formic acid Δ, Viherliuos e) during storage.

Table 6. Chemical composition of the silages in experiments 1—3.

Experiments, silages	% of dry-matter											
	ash		organic matter		crude protein		crude fat		crude fibre		N-free extract	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Expt. 1												
AIV 1	10.6	1.9	89.4	1.9	18.6	3.4	5.5	0.6	24.7	2.4	40.6	2.5
AIV 2	11.7	2.7	88.3	2.7	17.3	3.1	5.3	0.4	24.6	2.3	41.1	3.2
Formic acid	10.4	2.8	89.6	2.8	18.6	2.4	5.4	0.7	25.0	2.7	40.7	2.5
Viher solution 1	12.1	3.3	87.9	3.3	18.1	2.6	5.0	1.3	24.8	2.5	40.0	3.1
Expt. 2												
AIV 1	8.0	1.0	92.0	1.0	20.7	3.4	6.9^{c}	1.0	28.7	3.7	35.8	4.0
AIV 2	7.9	0.9	92.1	0.9	20.4	2.5	6.3^{ab}	0.7	27.4	3.5	38.1	3.4
Formic acid	7.8	1.0	92.2	1.0	20.2	3.1	6.6^{a}	0.8	28.0	3.4	37.4	3.1
Viher solution 2	7.7	0.7	92.3	0.7	21.6	2.6	5.6^{bd}	0.4	27.5	3.5	37.6	3.2
Expt. 3												
AIV 1	8.6	1.7	91.4	1.7	19.5^{ab}	1.5	6.3	0.8	25.9	1.8	39.6	2.7
AIV 2	7.8	1.3	92.2	1.3	19.6^{ab}	1.6	6.1	0.6	24.7	1.6	41.9	2.5
Formic acid	7.7	1.5	92.3	1.5	19.4^{a}	1.7	5.9	0.7	24.9	1.5	42.0	1.9
Viher solution 3	8.0	1.6	92.0	1.6	21.3^{b}	1.8	5.6	0.6	25.3	1.4	39.9	2.4
On average												
AIV 1	9.1	1.9	90.9	1.9	19.6	3.0	6.2	1.0	26.4	3.2	38.7	3.7
AIV 2	9.2	2.6	90.8	2.6	19.0	2.8	5.9	0.7	25.5	2.8	40.4	3.4
Formic acid	8.7	2.3	91.3	2.3	19.4	2.5	6.0	0.9	26.0	3.0	40.0	3.2
Viher solutions	9.4	3.0	90.6	3.0	20.2	2.9	5.4	0.9	25.8	2.8	39.2	3.0
Differences between experiments 1—3												
AIV 1	***		***		—		***		**		***	
AIV 2	***		***		**		***		*		**	
Formic acid	**		**		—		***		**		***	
Viher solutions	***		***		**		—		*		—	

Statistical analysis and pooling of the data as in Table 4 a—b: $P < 0.05$; c—d: $P < 0.01$
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

tendency. Some differences, ascribable to the intensity of fermentation, were found between the crude fat contents of the silages, as some of the volatile fatty acids dissolved in ether during the crude fat determination.

The differences between the experiments were highly significant in respect of most components of the silages (Tables 4, 5, 6 and 7). In experiments 1—3 the differences were mainly caused by differences in growth stage at cutting, in experiments 4—5 by differences in growth stage as well as in botanical composition of the forage. Dry matter was highest (about 27 %) in silages containing clover (experiment 4, cf. p. 288) and lowest in ryegrass silage (about 20 %) (experiment 5 b). Fibre content was highest in experiments 2 and 5 and lowest in experiment 4 (silage with clover) (Tables 6 and 7, Fig. 1). Because of the heavy application of nitrogen fertilizer, nitrate nitrogen was comparatively high (average 0.13 % of dry matter) in silages consisting of grass species only; it was low (average 0.04 %) in silages containing clover. There were no large differences in average total N between the silages of the various experiments, even though the amounts of fertilizer N given to the leys varied considerably. The differences between the experiments in fermentation products were much smaller than the differences in silage composition (Tables 4, 5, 6 and 7).

Since there were some notable differen-

Table 7. Chemical composition of the silages in experiments 4—5.

Experiments, silages	% of dry-matter											
	ash		organic matter		crude protein		crude fat		crude fibre		N-free extract	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Expt. 4												
AIV 2	11.0	3.0	89.0	3.0	19.1	1.9	4.8	0.7	22.7	2.0	42.5[a]	2.0
Viher solution 3	11.6	2.5	88.4	2.5	19.6	1.0	5.1	0.9	23.3	2.2	40.4[b]	1.4
Expt. 5 a (timothy)												
AIV 2	7.1	1.2	93.0	1.2	18.6	3.4	6.0[c]	0.4	30.2	3.0	38.1	2.4
Viher solution 3	7.1	1.0	92.9	1.0	19.9	2.6	5.4[d]	0.6	30.5	2.7	37.0	1.4
Expt. 5 b (ryegrass)												
AIV 2	9.7	0.7	90.3	0.7	20.2	2.7	7.7[e]	0.7	28.0	4.1	34.5	3.3
Viher solution 3	10.1	0.7	89.9	0.7	21.3	2.1	6.8[f]	0.6	27.3	3.7	34.6	2.9
On average												
AIV 2	8.9	2.2	91.1	2.2	19.4	2.9	6.4	1.3	27.8	4.3	37.5	4.1
Viher solution 3	9.2	2.3	90.8	2.3	20.4	2.2	5.9	1.0	27.8	4.0	36.7	3.0
Differences between experiments 4—5 a—5 b												
AIV 2	***		***		—		***		***		***	
Viher solution 3	***		***		—		***		***		***	

Statistical analysis and pooling of the data as in Table 5.
a—b: $P < 0.05$; c—d: $P < 0.01$; e—f: $P < 0.001$.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

ces between the acid-treated and Viher solution silages, interrelationships between fermentation products and silage constituents affecting fermentation were studied by means of two correlation matrices, and the homogeneities of the correlations were tested by the chisquare method (SNEDECOR and COCHRAN 1971 p. 186). The results show (Table 8) that while the correlations of most of the characteristics differed relatively little between the acid-treated and the Viher solution silages, those of the pH values and with the other characteristics did differ highly significantly, even to the degree of being of opposite signs. The pH values of the acid-treated silages were in significant positive correlation with volatile fatty acids, ammonia-N and soluble N, whereas the corresponding correlations for the Viher solution silages were negative and significant only in some cases. It can be concluded from the highly significant negative correlation between pH and lactic acid in the Viher solution silages that the acidity of these silages was mainly due to the formation of lactic acid. In the acid-treated silages, lactic acid influenced the pH value less than in the Viher solution silages, so the added acid preservatives must have played an important role.

Increasing fibre content increased the amount of undesirable fermentation products, i.e. butyric acid, other volatile fatty acids, and NH_3-N (Table 8, Fig. 1). Increasing total N content had a similar effect. The correlations of NO_3-N with the abovementioned fermentation products were negative.

Since complex interrelationships existed between the different characteristics, stepwise regression analysis (NENONEN 1971) was applied to determine which of the various forage constituents and fermentation products best explain secondary fermentation. Twelve parameters representing forage composition and quality were chosen as independent variables (cf. Tables 4 and 6). The variation

Table 8. Correlations between characteristics indicating quality and composition of the silages.
A = silages prepared with acids (AIV 1, AIV 2, formic acid) (104 silages).
V = silages prepared with Viher solution (55 silages).

Characteristics	Type of silage	pH		Butyric acid		Volatile fatty acids	Lactic acid		NH_3-N	Soluble N	NO_3-N		Total N	Sugar	Crude fibre
		r	r-diff.	r	r-diff.	r	r	r-diff.	r	r	r	r-diff.	r	r	r
pH	A	1.00													
	V	1.00													
Butyric acid	A	+0.13		1.00											
	V	+0.04		1.00											
Volatile fatty acids	A	+0.39		+0.31		1.00									
	V	−0.23	***	+0.62	*	1.00									
Lactic acid	A	−0.12		−0.06		+0.37	1.00								
	V	−0.75	***	+0.15		+0.52	1.00								
NH_3-N	A	+0.40		+0.22		+0.70	+0.49		1.00						
	V	−0.20	***	+0.58	*	+0.62	+0.36		1.00						
Soluble N	A	+0.31		−0.06		+0.44	+0.46		+0.67	1.00					
	V	−0.37	***	+0.33	*	+0.40	+0.51		+0.55	1.00					
NO_3-N	A	−0.14		−0.10		−0.39	−0.00		−0.08	−0.14	1.00				
	V	+0.35	**	−0.13		−0.46	−0.43	**	−0.24	−0.29	1.00				
Total N	A	+0.27		−0.01		+0.24	+0.22		+0.32	+0.61	−0.25		1.00		
	V	−0.41	***	−0.06		+0.00	+0.29		+0.24	+0.75	−0.18		1.00		
Sugar	A	+0.04		−0.08		−0.57	−0.69		−0.65	−0.45	−0.10		−0.16	1.00	
	V	+0.59	***	−0.30		−0.66	−0.71		−0.47	−0.33	+0.29	*	−0.08	1.00	
Crude fibre	A	−0.12		+0.24		+0.30	−0.02		+0.26	−0.06	+0.09		−0.45	−0.33	1.00
	V	−0.28		+0.21		+0.47	+0.19		+0.36	−0.07	−0.29	*	−0.17	−0.48	1.00

Significance of the correlations for acid-treated silages (A): $P < 0.05$ $r > 20$, $P < 0.01$ $r > 0.26$, $P < 0.001$ $r > 0.33$.
Significance of the correlations for Viher solution silages (V): $P < 0.05$ $r > 28$, $P < 0.01$ $r > 0.37$, $P < 0.001$ $r > 0.46$.
Homogeneity of the correlations for A and V silages as tested by χ^2 test: *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

in butyric acid was significantly accounted for by crude fibre content alone (R^2 % 5.8) in the acid-treated silages and by NH_3-N content (R^2 % 33.2) in the Viher solution silages. The variation in NH_3-N was significantly accounted for by the following variables:

Acid-treated silages

Step	Independent variable	t-value	R^2 %
1	pH	+6.67***	15.6
2	Crude fibre	+3.72***	4.8
3	Sugar	−3.67***	4.7
4	Total N	+3.09**	3.3
5	Lactic acid	+2.78**	2.7
	Total		66.8

Viher solution silages

Step	Independent variable	t-value	R^2 %
1	Sugar	−3.81***	22.5

The results show that in the acid-treated silages rising pH and increasing contents of crude fibre and total N speeded up the degradation of protein nitrogen to ammonia. An increasing rate of lactic-acid fermentation had the same effect. In the Viher solution silages sugar content was the only independent variable significantly accounting for the variation in NH_3-N. Forage dry-matter content did not have a significant effect on fermentation products in these studies.

Discussion

The five experiments presented here show very clearly that silage of good quality can be obtained with all the additives used. Some typical differences were noted, however, between the silages prepared with acids and those prepared with the Viher solutions containing formaldehyde and acids.

The preservative effect of Viher solution appears to be dual. The bacteriostatic effect of formaldehyde was strong early in the storage period i.e. in the first 2—3 months after the opening of the silos. Later the acidifying effect of principally lactic acid became evident (Table 8, Fig. 1). As a result, pH values decreased and overall fermentation increased. The dual nature of the preservation was clearly seen in experiments 1, 3 and 4, less clearly in experiments 2 and 5. Detrimental fermentation products occurred in greater amounts in experiment 2 than in the other experiments. There may be several reasons for this. The herbage in experiment 2 was relatively high in fibre content and the weather at the mid-summer cutting was rainy (cf. p. 289). Also, the acid to formaldehyde ratio was lower in this experiment (0.65: 1) than in the others (about 1.2: 1). After the application rate of Viher solution was raised to an average of 6 l/t from experiment 3 on and its formic acid component was replaced by acetic acid, harmful secondary fermentations were hardly observed any more (Fig. 1).

Pedersen et al. (1973), using a 2: 1 formalin + acid mixture for silage preparation, found that the number of coliform bacteria increased considerably towards the end of the storage period. They concluded that secondary fermentation was caused by degradation of formaldehyde during ensilage. Honig and Rohr (1973) in their studies of secondary fermentation came to the conclusion that if formaldehyde was used alone, the greater part of it was broken down during ensilage, whereas it persisted fairly well in a mixture of formalin and acid (the Farmos solutions). It appears essential that acid be added to the formaldehyde, for in addition to the problems of

secondary fermentation (BARRY and FENNESY 1972) the correct rate of application of pure formaldehyde has proved difficult to determine (BROWN and VALENTINE 1972, WILKINS et al. 1973 a, b).

The interactions between the pH values and the fermentation products in the Viher solution silages were quite contrary to those in the acid-treated silages (Table 8). In a Viher solution silage a high pH was generally an indication of very weak overall fermentation, whereas in the acid-treated silages it indicated secondary fermentation. However, an increase in the pH of a Viher solution silage towards the end of the storage period, was also found to be a sign of secondary fermentation. Because of the great differences between the different types of silage in this respect, it is inadvisable to judge the quality of Viher solution silages on the basis of pH alone, as is done in the case of silages prepared with acids.

Very clear differences were found between the Viher solution and acid-treated silages in their content of soluble nitrogen (Tables 4 and 5, Fig. 1). The amount of soluble N compounds was especially low in the Viher solution silages in the early part of the storage period, when the influence of the formaldehyde was strongest. The protein-preserving effect of formaldehyde has been noted in many studies (HUILAJA et al. 1971, KORHONEN et al. 1973, POUTIAINEN and HUIDA 1970, SYRJÄLÄ 1972), although it has not been apparent in some other investigations (POUTIAINEN et al. 1972, WALDO et al. 1973 a). The lower solubility of crude protein in the Viher solution silages was also evident from the lower nitrogen content of the effluent (Table 3) and the resultant somewhat higher total N of the silage (Tables 6 and 7). The contents of ammonia-N varied more in the Viher solution silages than in the AIV 2 and formic acid silages. On the average, however, NH_3-N was low in all the silages. Similar contents of NH_3-N have been found in many other experiments (BURSTEDT et al. 1971, HUILAJA et al. 1971, POUTIAINEN and HUIDA 1970, POUTIAINEN et al. 1972, SAUE et al. 1972, SYRJÄLÄ 1972, WALDO et al. 1973 a). Butyric acid was present in slightly greater amounts in the Viher solution silages than in the others, although on the whole its content was very low in our experiments, especially in the silage prepared with Viher solution 3 (Tables 4 and 5, Fig. 1). This result agrees with those of many other investigators (BURSTEDT et al. 1971, HONIG and ROHR 1973, HUILAJA et al. 1971, POUTIAINEN et al. 1972, SAUE et al. 1972). In some studies butyric acid has not occurred at all (KORHONEN et al. 1973, POUTIAINEN and HUIDA 1970, SYRJÄLÄ 1972, WILKINS et al. 1973 a).

The formic acid and AIV 2 solutions proved almost equally effective as silage additives (Tables 4 and 5, Fig. 1), as might be expected from their very similar compositions (p. 287). The small addition of orthophosphoric acid did not essentially affect the preservative qualities of the solution, although there were indications that it had a beneficial effect (Table 4, Fig. 1). According to VIRTANEN (1933) the effectiveness of phosphoric acid as a silage preservative is of the same order as that of organic acids. BERGNER and LANGE (1969) obtained relatively good results when they prepared silage with phosphoric acid alone, provided the rate of application was sufficiently high (about 3 g P/kg forage).

In our present investigation the AIV 2 and formic acid silages were uniformly high in quality. The use of formic acid in silage preparation has been the object of growing interest in many countries in recent years (BREIREM 1969, CASTLE 1972). To test its efficiency, formic acid has been added to both fresh and prewilted grass with generally good results (CASTLE and WATSON 1970, 1973, DERBYSHIRE and GORDON 1970, FOX et al. 1971, HENDERSON and MCDONALD 1971, HENDERSON et al. 1972, TAYLOR and

PHILLIPS 1970, WALDO et al. 1973 c, WILSON and WILKINS 1973). The uniform and high quality of formic acid silages has been noted in many recent experiments in which formic acid, as a control treatment, has been compared with formaldehyde additives (BURSTEDT et al. 1971, HONIG and ROHR 1973, PEDERSEN et al. 1973, POUTIAINEN and HUIDA 1970, POUTIAINEN et al. 1972, SAUE et al. 1972, WALDO et al. 1973 b, WILKINS et al. 1973 a). In these studies formic acid (85—86 %) has been used at rates of 0.22—0.88 % of the amount of forage. Good results have been achieved with as little as 0.23 % (CASTLE 1972, WILSON and WILKINS 1973). In the present study a rate of 0.4 % was sufficient to produce successful results with the AIV 2 and formic acid solutions (experiments 1 and 2) (Tables 4 and 5, Fig. 1).

Fermentation was somewhat more intense in the AIV 1 silages than in the other silages prepared with acids (Tables 4 and 5, Fig. 1). Contents of lactic acid, acetic acid and propionic acid were higher and sugar content was lower in AIV 1 than in the other silages prepared with acids. There was very little butyric acid in the AIV 1 silages. Similar results have been obtained in earlier experiments at this department (KORHONEN et al. 1973, POUTIAINEN and HUIDA 1970, SYRJÄLÄ 1972). The pH and NH_3-N values of the AIV 1 silage in experiment 2 varied considerably. Factors considered to contribute to the variation were the uneven distribution of the silage additive, the rainy weather, the plastic sheets spread between the layers of forage and the relatively high crude fibre content of the raw material (ETTALA et al. 1972). As the other acid additives gave silage of uniform quality under the same conditions, the preservation efficiency of the AIV 1 solution would appear to be somewhat weaker. This may be ascribable to the lower concentration of this additive, although the dissociation constant of the hydrochloric acid is high. 14 N AIV 1 solution (7 N HCOOH + 7 N HCl) provided 0.06—0.07 g equivalents of acid per kg of grass, whereas 22 N formic acid and AIV 2 solutions gave 0.09—0.11 g equivalents. NØRGAARD PEDERSEN et al. (1969) recommended 0.07 g equivalents per kg for both the original AIV solution and formic acid. With the Viher solution the forage received 0.02—0.03 g equivalents of acid.

In this study the contents of total N and NO_3-N in the experimental silages were negatively correlated (Table 8). This was possibly caused by the fact that NO_3-N decreased during storage as a result of nitrate reduction, while the total N remained unchanged. According to WIERINGA (1966) the nitrite phase in the course of nitrate reduction is an important factor preventing formation of butyric acid, providing that the NO_3 content of the grass is in the range of 0.6—1.0 % of the dry matter. In our study the NO_3-N content of the silages varied between 0.02 and 0.38 % of the dry matter, which corresponds to 0.09—1.68 % NO_3, so the NO_3 content of the grass may well have been in the range proposed by Wieringa. HEIKONEN et al. (1973) also found that if silage was high in nitrates, butyric acid was scarce. The negative correlations between nitrate nitrogen and fermentation products found in the present study (Table 8) could possibly also be due to the fact that in our autumn silages, which were used right at the start of the indoor feeding period, both nitrate reduction and fermentation processes were weak in comparison with the summer silages. There was no difference between the silage additives in this respect.

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SELOSTUS

Hapot sekä hapon ja formaldehydin seokset ruohon säilönnässä. I Säilöntätulokset

ELSI ETTALA, ONNI POHJANHEIMO, LEA HUIDA ja MARTTI LAMPILA

Maatalouden tutkimuskeskus

Hapoilla (muurahaishappo, AIV 1: muurahaishappo + suolahappo, AIV 2: muurahaishappo + fosforihappo) sekä formaldehydiä ja happoa sisältävillä säilöntäaineilla (Viherliuokset 1—3) on säilötty runsaasti typpilannoitettua ruohoa suuriin koesiiloihin. Happoja on käytetty 4—5 l/tn, Viherliuoksia 5—6 l/tn. Kokonaissäilöntäaika (ensimmäisestä valmistuspäivästä viimeiseen syöttöpäivään) on ollut keskimäärin 295 pv.

Kaikilla säilöntäaineilla on saatu hyvänlaatuista säilörehua. Laatu on ollut tasaisinta muurahaishappo- ja AIV 2 -rehuissa. Viherliuoksen säilyttämistapa on ollut kaksijakoinen. Formaldehydin bakterisidinen vaikutus on ilmennyt voimakkaana säilytysajan ensimmäisinä kuukausina, jolloin käyminen on ollut vähäistä ja rehun pH korkea (n. 4.5—5.5). Myöhemmin on tullut mukaan pääasiassa maitohappokäymisen aiheuttama happovaikutus ja sen seurauksena muunkin käymisen voimistuminen. Happosäilörehuissa pH-arvot ovat koko ajan olleet samaa tasoa (n. 4.0—4.4) ja käyminen vähemmän muuttuvaa. Liukenevan typen osuus kokonaistypestä on Viherliuosrehuissa ollut merkitsevästi ($P < 0.01—0.001$) alempi kuin happosäilörehuissa.

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ENSILAGE OF GRASS WITH ACIDS AND ACID-FORMALDEHYDE ADDITIVES

II Intake and nutritional value of silages

ELSI ETTALA, ONNI POHJANHEIMO and MARTTI LAMPILA

ETTALA, E., POHJANHEIMO, O. & LAMPILA, M. **Ensilage of grass with acids and acid-formaldehyde additives. II Intake and nutritional value of silages.** Ann. Agric. Fenn. 14: 304–318.
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When silages prepared with acid additives (formic acid, AIV 1: formic acid plus hydrochloric acid, AIV 2: formic acid plus phosphoric acid) and additives containing formaldehyde and acid (Viher solutions 1–3) were fed to cows in three experiments, the daily intakes were, respectively, 2.02, 1.90, 2.10 and 1.97 kg DM per 100 kg liveweight, the corresponding daily 4 % milk yields being 13.4, 12.6, 13.9 and 13.4 kg per animal. In two further experiments, the daily intakes of AIV 2 and Viher solution silages were 2.18 and 2.15 kg DM per 100 kg liveweight and the 4 % milk yields were 15.7 and 15.7 kg per animal. The AIV 1 silage had a somewhat, though not significantly, smaller intake than the others, and this caused a statistically significant difference in 4 % milk production between the animals on AIV 1 and AIV 2 silage ($P < 0.05$). A significant difference in the lactose content of the milk was found between the animals receiving AIV 2 and Viher solution silage in one experiment ($P < 0.05$).

The digestibility of the crude protein of the Viher solution silage was slightly lower than in the other silages in four out of five experiments, but the difference was statistically significant in only one ($P > 0.01$). No significant differences were found in the nitrogen balance. The digestibility and nitrogen balance experiments were performed with sheep.

Introduction

The main object of the research on silage conducted in Finland in recent years has been to satisfy protein requirement in cattle feeding without protein concentrates. Thus, besides preservation efficiency, attention has also been paid to palatability, digestibility, energy concentration, and protein contents. In the first part of this study (ETTALA et al. 1975), good quality silage was obtained with the silage additives investigated (AIV 1, AIV 2, formic acid and Viher solutions). The nutritive characteristics of these silages are presented in this paper. Feeding experiments (5) were perform-

ed with dairy cows and digestibility and nitrogen balance experiments (5) were conducted with sheep. The experiments are designated by the same symbols (1—5 b) as the corresponding experiments in part I of this study.

Materials and methods

Experimental animals and feeding

Ayrshire cows (96 in all) weighing 400—500 kg were used. They received silage ad libitum in individually weighed portions. Each animal was also offered 2 kg hay a day, a kilogram being given at each feeding time. Barley was given as the only concentrate, at the rate of 1/3, 2/3 or 3/3 of the energy required for milk production exceeding 10 kg (4 %), except in the case of one group in experiment 4, which did not receive any supplemental concentrate. The barley ration was determined on the basis of the milk production of the preceding 5 days. The energy requirement was taken as 0.4 f.u./kg 4 % milk (1 feed unit = 0.7 kg starch equivalent).

The mineral supplementation of the rations was adjusted to meet the mineral requirements of the cows according to the mineral contents of the feeds of previous experiments. In experiment 1, the cows were given sodium carbonate to satisfy their sodium requirement; in the other experiments they received a mineral mixture containing sodium as chloride or phosphate. In most of the experiments the mineral mixtures contained the necessary vitamin D supplement, but in some vitamin D preparations were given separately.

In the feeding experiments there was a preliminary period of 20 days, during which the cows all received the same feeding, consisting predominantly of silage. This was followed by a transition to the experimental diet. The experimental period ranged from 80 to 160 days. A Latin square design (4 × 4) was used in the first experiment, the rations being used for 30 days. Since the aim was to examine the long-term effect of the feeds, the other trials were conducted as factorial experiments (experiments 3, 4 and 5) or as a group feeding experiment (experiment 2). In the factorial experiments the silage additive was used as one of the factors and the level of the concentrate (experiments 3 and 4) or the botanical composition of the silage (experiment 5) as the other.

The cows were divided into groups, which were as uniform as possible in respect of the milk production and silage intake during the preliminary period, and the liveweight and time elapsed since calving. The average time elapsed between calving and the grouping of the cows ranged from 70 to 104 days (Table 4). The experimental period was divided into 5-day stretches, which were used as the temporal unit throughout the experiments.

The milk yields of the cows were weighed individually at each milking time. The milk was analysed for fat at 5-day intervals and for protein and lactose at 10-day intervals, the determinations being made on combined samples for 2 days. The cows were weighed at the beginning of the preliminary period, the transitional period and the experimental period, and also at 30-day intervals during the experimental period and at its end. Weighing was performed on two successive days before the afternoon feed.

Digestibility and nitrogen balance trials were performed with the silages of experiments 3, 4 and 5. The silages used in the digestibility experiments were preserved frozen in plastic sacks. Two successive digestibility experiments, conducted as Latin

squares (2 × 2, with two replicates), were performed with the silage of experiment 4, so that digestibility and nitrogen balance values could be obtained separately for the two silages — the first consisting predominantly of timothy grass cut in early summer at an early stage of growth, the second consisting of clover cut at the flowering stage in late summer (cf. part I, p. 288). The other digestibility experiments were conducted as 4 × 4 Latin squares. The digestibility experiments lasted 21 days, comprising a 7—10 day preliminary period and a 7—10 day collection period. The sheep were offered silage only, either ad libitum or, during the collection period, at the rate of 1 kg dry matter per animal per day (experiment 5). Water and minerals were offered ad libitum.

Digestibility experiments could not be performed with all the silages, and values obtained in earlier studies for the same kind of silages were taken in some cases. The values for the silage of experiment I were obtained from POUTIAINEN and HUIDA (1970), and those for experiment 2 from POUTIAINEN and RINNE (1971). The values for the digestibility of the hay and the barley were taken from the feed table published for the Nordic countries (NJF, Fodermiddeltabel 1969).

Sampling

In the feeding experiment with the cows, samples representing two weeks' feeding were taken from the towers (part I, p. 287). Hay and barley samples were collected daily and composite samples representing one month's feeding were taken for analysis. Silage samples for the digestibility experiments were taken for each experimental period when the silage was thawed out. When necessary, samples were also taken from the feed residues. Faeces and urine were weighed daily and pooled, the samples made up for analysis representing each sheep and each experimental period. A complete feed analysis was made on the feed and the dried faeces (cf. part I, p. 290) and total nitrogen was determined on the urine and the fresh faeces.

The fat content of the milk was determined with a Milko-Tester II apparatus or by the method of Gerber. Its protein content was either measured with a Pro-Milk apparatus (experiment 1) or determined together with lactose contents with an Infra Red Milk Analyser (experiments 2—5).

Statistical methods

The statistical analysis was performed with an IBM 1130 computer. The significance of the differences between the treatments was determined with the least-squares analysis of variance (HARVEY 1966). To eliminate the effect of differences between the animals, the following parameters were taken as linear regression variables: weight, milk production, milk composition and voluntary intake of silage in the preliminary period, and time elapsed since calving. The regression variables were changed, depending on the object of the analysis. In experiment 1, which was designed as a Latin square, corresponding regression variables were obtained from the results of the first 10 days of the experiment and the results of the following 20 days were used for the calculations and analyses. The differences between the feeds were examined with the analysis of variance, and Tukey's test (STEEL and TORRIE 1960) was applied to the differences between the means.

Results

The chemical composition of the silages prepared with the different additives was very similar (Table 1), as was already evident in part I from the samples taken throughout the silage towers (Tables 6 and 7, p. 295, 296). The only notable differences were found in experiments 2, 3 and 5 b, where the crude fat content of the Viher solution silages was significantly smaller than in the other silages. In contrast, the composition of the silages differed considerably between the years.

Table 1. Mean chemical composition and feed value of diets in experiments 1–5.

Experiments and feeds	No. of samples	DM %	% DM						f.u.		fresh	
			ash	crude protein	crude fat	crude fibre	N-free extract	DCP	DCP g	DM kg	DCP %	kg/f.u.
Silages												
Expt. 1												
AIV 1	9	23.3	10.9	18.8	5.6	23.9	40.9	15.2	188	1.23	3.5	5.3
AIV 2	9	24.1	11.3	17.5	5.3	24.2	41.7	14.2	175	1.23	3.4	5.2
Formic acid	9	23.7	9.8	19.2	5.5	24.4	41.1	15.3	188	1.23	3.6	5.2
Viher solution 1	9	23.8	11.8	18.5	5.3	24.4	40.0	14.0	179	1.28	3.3	5.4
Expt. 2												
AIV 1	11	21.5	7.9	20.3	6.9^{ac}	29.4	35.5	15.3	201	1.32	3.3	6.2
AIV 2	11	22.0	7.8	19.9	6.4^{ab}	28.5	37.4	15.0	197	1.32	3.3	6.0
Formic acid	11	21.8	7.6	19.8	6.7^{a}	28.5	37.3	15.0	196	1.31	3.2	6.1
Viher solution 2	11	21.8	7.6	21.4	5.7^{bd}	28.2	37.1	16.2	212	1.31	3.5	6.1
Expt. 3												
AIV 1	11	22.7	8.4	19.5	6.5^{a}	26.1	39.5	15.0	189	1.26	3.4	5.6
AIV 2	11	23.4	7.6	19.6	6.1^{ab}	24.7	42.0	14.7	187	1.28	3.4	5.5
Formic acid	11	23.6	7.4	19.3	6.1^{ab}	25.1	42.1	14.3	182	1.27	3.4	5.5
Viher solution 3	11	23.5	7.7	21.2	5.7^{b}	25.5	39.9	15.7	200	1.27	3.7	5.5
Expt. 4												
AIV 2	6	27.5	11.2	19.3	4.9	22.3	42.2	11.9	186	1.56	3.3	5.7
VIher solution 3	6	27.8	11.9	19.7	5.2	22.8	40.3	11.4	169	1.50	3.2	5.5
Expt. 5 a (timothy)												
AIV 2	12	21.5	7.1	18.2	5.9	30.5	38.4	12.6	164	1.31^{e}	2.7	6.1
Viher solution 3	12	21.2	7.0	19.7	5.5	30.7	37.1	13.2	179	1.35^{f}	2.8	6.5
Expt. 5 b (ryegrass)												
AIV 2	12	19.9	9.6	20.0	7.7^{e}	28.2	34.5	15.0	186	1.24^{e}	3.0	6.3
Viher solution 3	12	20.0	10.0	21.2	6.7^{f}	27.2	24.9	14.2	188	1.33^{f}	2.8	6.7
Hay												
Expt. 1	4	82.7	6.2	10.4	2.1	32.7	48.7	6.7	103	1.53	5.6	1.9
Expt. 2	5	82.7	6.4	13.9	2.9	30.0	46.8	9.7	136	1.40	8.0	1.7
Expt. 3	5	80.4	6.3	14.1	2.5	30.6	46.6	8.0	140	1.75	6.4	2.2
Expt. 4	8	81.0	6.4	9.0	2.3	30.3	52.0	6.4	95	1.49	5.2	1.8
Expt. 5	5	77.9	6.4	13.5	2.5	33.7	43.8	7.7	142	1.84	6.0	2.4
Barley												
Expt. 1	4	85.3	2.7	11.2	1.8	5.1	79.2	8.2	72	0.87	7.0	1.0
Expt. 2	5	86.2	2.6	10.9	2.2	4.5	79.8	8.0	69	0.87	6.9	1.0
Expt. 3[1])	5	78.5	2.6	13.3	1.7	4.1	78.4	9.7	83	0.85	7.6	1.1
Expt. 4	5	87.7	2.7	13.1	2.1	4.5	77.5	9.6	84	0.87	8.4	1.0
Expt. 5[1])	5	81.4	2.7	14.5	1.9	4.6	76.3	10.6	91	0.86	8.6	1.1

[1]) Barley preserved with propionic acid.
Significance of differences within experiments tested by analysis of variance and differences between averages by the Tukey test.

The fibre content showed the greatest variation, being highest in the silages of experiment 5 a (30.5 and 30.7 % of DM) and lowest in those of experiment 4 (22.3 and 22.8 % of DM).

The differences in digestibility between the silages were seldom found to be statistically significant (Table 2). In experiment 3 the crude fat content of the Viher solution silage was digested significantly better than that of the other silages, and in experiment 5 b most of its components were digested significantly less well than those of the AIV 2 silage. In experiments 4 a, 4 b ja 5 a, the digestibility of the crude protein of the AIV 2 silages was somewhat, but not significantly, better than that of the Viher solution silage. No significant differences were found between the silages in the nitrogen balance or the biological value of the protein. The differences in digestibility between the different experiments were remarkably great. The silages of experiment 3 were digested best; those of experiment 4 b, consisting predominantly of clover, were digested least well.

Since the silages prepared with different additives differed very little in composition and digestibility, their feed values were very much the same (Table 1), the only exception being found in experiment 5, where the feed value of the Viher solution silage was significantly greater than that of the AIV 2 silage. The feed values of the silages did, however, differ considerably between the experiments, being highest in experiment 1 (0.81—0.78 f.u./kg DM), and lowest in experiment 4 (0.67—0.64 f.u./kg DM). The feed values of the hay ranged from 0.71 to 0.54 and those of the barley from 1.18 to 1.15 f.u./kg DM.

The voluntary intake of the silages prepared with the different additives was very similar. In experiment 4 there was a significant difference between the intakes by the rams of the AIV 2 and the Viher

Table 2. Acceptability, digestibility and nitrogen balance of silages prepared with different additives in experiments with sheep (Experiments 3, 4 and 5).

Experiments and feeds	Digestibility %						N-balance g/day	Biological value of prot.	Intake/day	
	DM	organic matter	crude protein	crude fat	N-free extract	crude fibre			kg	DM kg
Experiment 3										
AIV 1	75.4	76.6	76.8	71.0^{a}	78.1	75.6	3.83	34.0	5.5	1.37
AIV 2	73.5	75.0	74.7	68.0^{c}	76.3	74.8	4.35	33.7	5.4	1.35
Formic acid	73.6	75.1	74.3	67.3^{c}	76.3	75.9	4.08	33.3	5.6	1.42
Viher solution 3	74.7	75.8	74.3	76.4^{bd}	74.5	79.0	5.84	37.6	4.8	1.20
Experiment 4 a										
AIV 2	60.8	64.3	64.5	73.5	61.9	63.1	2.89	29.6	3.8	1.10^{a}
Viher solution 3	66.2	70.9	60.2	81.7	75.0	69.0	3.48	47.6	3.5	0.96^{b}
Experiment 4 b										
AIV 2	58.0	64.5	57.9	74.3	73.9	50.8	1.72	45.7	3.4^{c}	0.92
Viher solution 3	60.1	63.7	55.1	73.9	68.8	60.8	1.68	45.6	3.6^{d}	0.88
Experiment 5 a										
AIV 2	70.1	73.3	69.4	75.7	70.4	78.0	2.16	52.1	5.4	1.12
Viher solution 3	68.8	70.7	66.8	75.9	69.1	73.3	2.09	45.4	5.3	1.14
Experiment 5 b										
AIV 2	75.2^{c}	78.9^{c}	74.9^{c}	72.6	77.7^{a}	84.4	2.85	39.8	5.0	1.02
Viher solution 3	70.7^{d}	74.7^{d}	67.5^{d}	67.6	72.4^{b}	83.8	1.68	39.0	6.1	1.18

Significance of differences tested as in Table 1.
a—b: $P < 0.05$, c—d: $P < 0.01$

solution silages, but conflicting results were obtained for the spring and autumn silages (Table 2). There were no significant differences between the intakes of silage by the cows (Table 3). In experiments 2 and 3 the cows ate less AIV 1 silage than the other silages (Table 3 and Fig. 1), but the difference was not statistically significant. In experiments 1—3, the unweighted means of the intakes, expressed as kilograms of dry matter per cow per day, were AIV 1: 8.4, AIV 2: 9.2, formic acid: 9.0 and Viher solution: 9.1. The corresponding values calculated as kilograms of dry matter per 100 kg liveweight per day were 1.90, 2.10, 2.02 and 1.97. In experiments 1—5 the mean intakes of the AIV 2 and Viher solution silages were, respectively, 9.7 and 9.5 kg DM per cow per day (2.13 and 2.04 kg DM/100 kg liveweight per day).

The effect of the quality of the silages on the intake by the cows was examined separately for the acid-treated silages and the Viher solution silages, and also for all the silages together, the experiments being combined by pooling. The investigation of the acid-treated silages comprised 123 samples, representing the intake of two weeks, with 64 cows. The investigation of the Viher solution silages was made with 61 samples and 48 cows. The correlations between the intake and the quality of the silages were as follows:

Table 3. Mean daily feed intake of cows.

Experiments and feeding groups	Cows kg	Silage kg		Silage kg DM		Silage kg DM/100 kg livewt.		Barley kg		Hay kg		Total kg DM	
		mean	s.d.	mean	s.d.	mean	s.d.	maen	s.d.	mean	s.d.	mean	s.d.
Experiment 1													
AIV 1	457	42.6	8.1	9.8	1.5	2.15	0.2	0.8	0.7	1.7	0.3	11.9	2.1
AIV 2	456	42.9	8.7	10.1	1.5	2.23	0.3	0.8	0.9	1.7	0.3	12.1	2.4
Formic acid	458	41.8	10.0	9.7	1.8	2.14	0.3	0.7	0.6	1.7	0.4	11.7	2.3
Viher solution 1	459	42.1	10.6	9.9	1.9	2.16	0.4	0.7	1.0	1.8	0.2	11.9	2.6
Experiment 2													
AIV 1	456	37.9	2.3	7.8	0.5	1.74	0.2	0.4^{a}	0.3	2.0	0.0	9.9	0.7
AIV 2	447	39.6	2.5	8.5	0.5	1.92	0.2	0.9^{b}	0.2	1.9	0.2	10.9	0.8
Formic acid	442	39.1	4.3	8.3	0.9	1.89	0.2	0.6^{ab}	0.4	1.9	0.1	10.4	1.2
Viher solution 2	461	40.6	1.8	8.6	0.4	1.88	0.2	0.7^{ab}	0.3	1.9	0.1	10.8	0.6
Experiment 3													
AIV 1	429	33.8	9.1	7.6	2.1	1.80	0.7	1.4	0.8	1.3^{ab}	0.3	9.6	2.6
AIV 2	429	39.5	2.4	9.1	0.5	2.15	0.4	2.0	0.7	0.9^{a}	0.1	11.3	1.1
Formic acid	445	38.9	4.9	9.1	1.1	2.04	0.2	2.0	1.1	1.2^{ab}	0.3	11.6	0.5
Viher solution 3	464	38.0	6.1	8.7	1.4	1.88	0.1	1.9	1.1	1.5^{b}	0.3	11.5	1.5
Experiment 4													
AIV 2	482	43.7	4.7	12.1	1.3	2.51	0.2	1.4	1.3	2.0	0.0	14.9	1.4
Viher solution 3	489	43.7	3.4	12.1	1.0	2.50	0.2	1.2	1.1	2.0	0.0	14.8	1.0
Experiment 5 a + b													
AIV 2	460	41.8	4.6	8.5	1.1	1.85	0.3	2.6	1.6	1.0	0.3	11.3	1.5
Viher solution 3	462	41.3	5.3	8.3	1.0	1.80	0.2	2.8	1.4	1.2	0.2	11.5	1.7

Differences between silages tested within experiments. Statistical significance of differences tested by least-squares analysis of variance (cf. p. 306) and differences of averages tested by the Tukey test. a—b: $P < 0.05$, c—d: $P < 0.01$.

Table 4. Mean milk yields of cows.

Experiments and feeding groups	No. of cows	Time since calving, days[1]	Trial period, days	kg milk/cow/day				composition of milk						Change in live-weight, kg
				mean	s.d.	4 %		fat %		protein %		lactose %		
						mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	
Experiment 1														
AIV 1	4×4	94	120	13.2	3.0	14.0	3.2	4.49	0.5	3.78	0.4	[2]		+ 3
AIV 2	»	95	120	13.0	4.4	13.6	4.2	4.49	0.5	3.75	0.4	[2]		± 0
Formic acid	»	83	120	13.0	3.0	13.8	3.0	4.50	0.4	3.79	0.4	[2]		− 5
Viher solution 1	»	94	120	13.0	4.9	13.3	4.6	4.34	0.5	3.81	0.4	[2]		− 5
Experiment 2														
AIV 1	4	104	150	10.1	1.9	10.6^{a}	2.0	4.46	0.3	3.53	0.3	4.64^{ab}	0.2	−20
AIV 2	4	94	150	12.5	1.2	13.1^{b}	0.8	4.44	0.4	3.59	0.4	4.71^{a}	0.2	−17
Formic acid	4	97	150	10.7	1.4	11.7^{ab}	1.6	4.73	0.2	3.70	0.4	4.62^{ab}	0.1	− 6
Viher solution 2	4	104	150	11.7	1.3	12.1^{ab}	1.3	4.28	0.4	3.56	0.1	4.61^{b}	0.3	+ 7
Experiment 3														
AIV 1	4	89	150	12.5	2.6	13.2	3.0	4.43	0.2	3.43	0.4	4.66	0.2	−22
AIV 2	4	76	150	13.8	1.8	15.0	2.0	4.68	0.5	3.68	0.1	4.79	0.2	+22
Formic acid	4	90	150	13.4	1.5	14.6	1.7	4.73	0.1	3.86	0.4	4.70	0.3	+33
Viher solution 3	4	81	150	14.5	4.3	14.9	3.5	4.36	0.5	3.58	0.4	4.81	0.3	+13
Experiment 4														
AIV 2	16	74	80	15.7	3.5	15.9	3.3	4.10	0.3	3.17	0.4	4.86	0.2	+ 8
Viher solution 3	16	73	80	15.5	2.2	15.4	2.3	3.90	0.3	3.14	0.2	4.84	0.3	+ 5
Experiment 5 a + b														
AIV 2	8	74	160	14.5	3.4	15.4	3.7	4.46	0.4	3.51	0.3	4.58	0.1	−13
Viher solution 3	8	70	160	15.7	3.2	16.0	3.1	4.18	0.3	3.47	0.3	4.73	0.2	− 7

[1]) Time elapsed between calving and grouping of cows.
[2]) Not determined
Statistical analysis performed as in Table 3, a−b: $P < 0.05$.

	Intake by cows as kg DM/day per 100 kg liveweight		
	Acid silages	Viher solution silages	All silages
Sugar	+0.27**	+0.27*	+0.27***
Acetic acid	−0.21*	−0.21	−0.16
NH_3-N	−0.20*	−0.20	−0.19*
Butyric acid	−0.08	−0.21	−0.12
Lactic acid	−0.14	−0.09	−0.12
pH	+0.06	+0.14	+0.09
Soluble N	−0.09	+0.07	−0.05
Crude fibre	−0.23*	−0.35**	−0.26***
Total N	+0.09	+0.18	+0.12
Dry matter	−0.10	+0.07	−0.03

The correlations reveal that intake decreased with increasing intensity of fermentation. The content of sugar was positively correlated and the fermentation products were negatively correlated with the intake by the cows. The correlations were very similar for the acid-treated silages and the Viher solution silages. The very small content of butyric acid in the acid silages (cf. part I, Fig. 1) is evident from the low correlation coefficient. The influence of lactic acid and pH on intake was not significant. Intake decreased significantly as the fibre content increased. In contrast, the total nitrogen, soluble nitrogen and dry matter contents exerted little influence on intake.

The correlations may give a somewhat misleading picture of the factors controlling intake, since, as the experimental period progressed, the intake of silage was influenced by both increasing fermentation (cf. part I, Fig. 1) and decreasing milk production. Stepwise regression analysis (NENONEN 1971) was undertaken in order to explain the fluctuation in the intake of silage. The dependent variable was the 4 % milk production and the independent variables were the parameters reflecting the fermentation of the silage (7 first properties in the

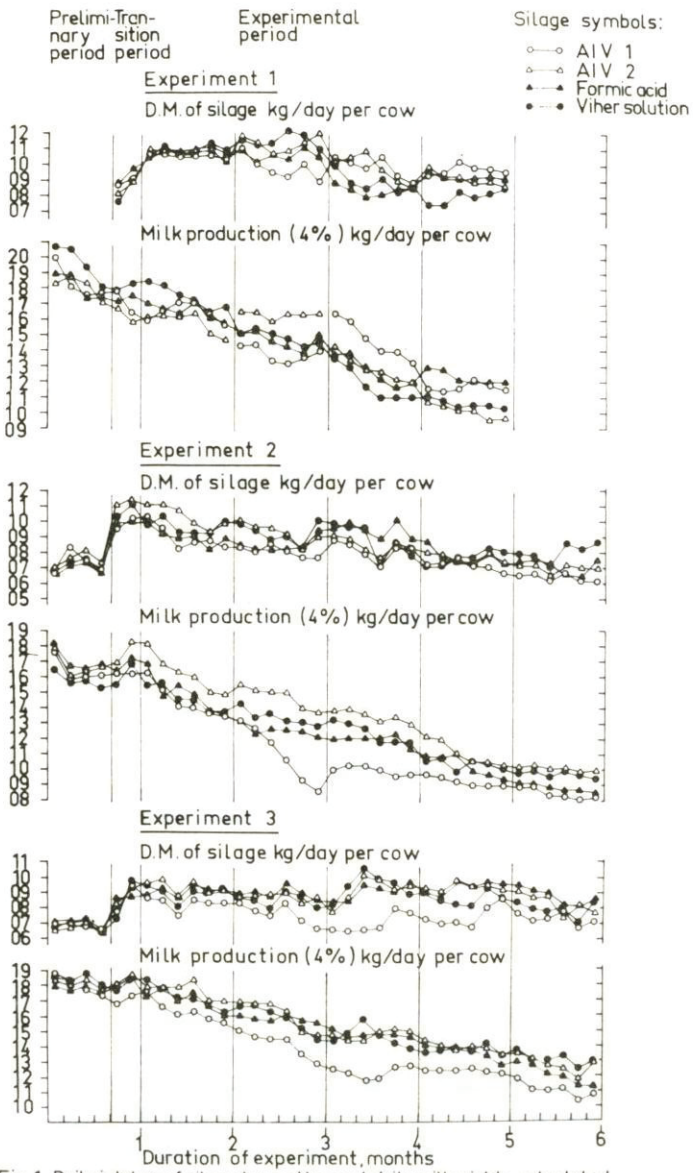

Fig. 1. Daily intakes of silage dry matter and daily milk yields calculated as 5-day averages for feeding groups in experiments 1 - 3

preceding tabulation). According to the results of the analysis, the milk production explained 7.1 % of the variation in intake, and the sugar content accounted for 3.1 %, the percentage explained by the two variables together (R^2 %) being 14.2. The fermentation products are so strongly correlated with the sugar content (cf. part I, Table 8) that they did not contribute any statistically significant explanation of the variation in intake. Thus, the most palatable silage was that which was only slightly fermented.

The daily intake of silage by the cows was 7.6—12.1 kg DM per animal, or 1.74—2.51 kg DM per 100 kg liveweight (Table 3). Differences were found between the experiments, which were ascribable to the composition of the silages, the milk production

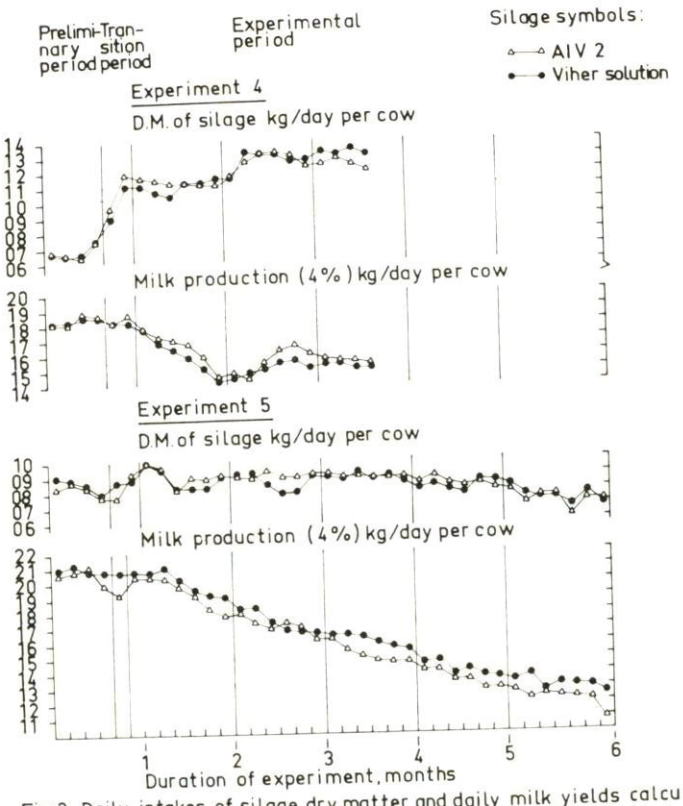

Fig. 2. Daily intakes of silage dry matter and daily milk yields calculated as 5-day averages for feeding groups in experiments 4–5.

of the cows, the concentrate supply and possibly also to other factors. The influence of composition on intake was seen particularly clearly in experiment 4, where intake increased when the feed was changed from autumn silage containing red clover to silage prepared from forage cut at an earlier growth stage and containing mainly timothy grass (Fig. 2).

A decrease in the intake of silage was rapidly reflected in the milk production, as the animals received only small amounts of other feeds (Figs. 1 and 2). The smaller intake of AIV 1 silage in experiments 2 and 3 caused a statistically significant difference between the AIV 1 and AIV 2 silages in the 4 % milk production in experiment 2 (Table 4) and in the combined milk production in experiments 2—3. The decrease in intake also led to a decrease in the liveweights of the animals offered AIV 1 silage (Table 4). The decrease in the milk production was generally uniform and in accordance with the normal production curve (Figs. 1 and 2). Exceptions were the divergent values for the AIV 1 group in experiments 2 and 3, and also the rise in production resulting from an increase in the intake of silage in experiment 4.

The composition of the milk was normal in all the experiments and the only significant difference between the silage groups was that in the lactose contents of the milk produced in the AIV 2 and the Viher solution groups in experiment 2 (Table 4). The liveweights of the cows in the different feeding groups did not differ significantly from each other.

Estimates of the energy and protein received and required

Table 5. Estimated daily energy and protein supplies and requirements of the cows.

Experiments and feeding groups	Silage				Barley		Hay		Supply		Requirement		Supply – requirement			
	f.u.		DCP g			DCP		DCP		DCP		DCP	f.u.		DCP g	
	mean	s.d.	mean	s.d.	f.u.	g	f.u.	g	f.u.	g	f.u.	g	mean	s.d.	mean	s.d.
Experiment 1																
AIV 1	8.0	1.3	1523	314	0.7	54	0.9	96	9.6	1673	9.3	1158	+0.3	1.0	+515	237
AIV 2	8.2	1.2	1523	435	0.8	57	0.9	89	9.8	1668	9.2	1136	+0.7	0.9	+533	315
Formic acid	7.9	1.5	1533	364	0.6	48	0.9	93	9.4	1674	9.2	1146	+0.2	1.0	+528	284
Viher solution 1	7.7	1.5	1423	389	0.7	50	1.0	96	9.3	1569	9.1	1122	+0.2	0.9	+447	285
Experiment 2																
AIV 1	5.9	0.4	1226	73	0.4[a]	32[a]	1.2	160	7.5	1419	8.0	960	−0.4	0.5	+459	90
AIV 2	6.5	0.4	1304	81	0.9[b]	66[b]	1.1	153	8.5	1523	8.9	1107	−0.4	0.4	+416	76
Formic acid	6.3	0.7	1276	139	0.6[ab]	43[ab]	1.1	150	8.0	1470	8.3	1020	−0.3	0.6	+449	135
Viher solution 2	6.5	0.3	1408	65	0.7[ab]	48[ab]	1.1	155	8.3	1611	8.6	1050	−0.3	0.3	+561	65
Experiment 3																
AIV 1	6.0	1.7	1132	318	1.3	108	0.6	81	7.9	1320	8.9	1110	−1.1	1.3	+210	211
AIV 2	7.1	0.4	1324	76	1.8	154	0.4	58	9.3	1536	9.6	1217	−0.3	0.3	+319	33
Formic acid	7.1	0.9	1286	155	1.9	157	0.5	74	9.5	1517	9.5	1198	−0.0	0.3	+319	148
Viher solution 3	6.9	1.1	1375	221	1.8	149	0.7	98	9.4	1622	9.7	1219	−0.4	0.8	+403	242
Experiment 4																
AIV 2	7.8[a]	0.8	1473[c]	153	1.4	115	1.1	99[a]	10.2	1687[c]	10.2	1278	+0.0[a]	1.1	+409[a]	223
Viher solution 3	8.2[b]	0.6	1397[d]	111	1.2	102	1.1	100[b]	10.5	1600[d]	10.0	1249	+0.5[b]	0.8	+351[b]	144
Experiment 5 a + b																
AIV 2	6.6	0.8	1171	137	2.5	228	0.4	58	9.5	1457	9.9	1244	−0.4	0.7	+214	170
Viher solution 3	6.2	0.8	1145	153	2.7	248	0.5	71	9.4	1463	10.1	1282	−0.8	0.7	+181	133

Statistical analysis performed as in Table 3. a–b: $P < 0.05$, c–d: $P < 0.01$

by the cows are shown in Table 5. The maintenance requirements of the cows for energy and protein were calculated according to the norms of POIJÄRVI (1925, 1947) (3, 8 f.u. and 320 g DCP per 500 kg liveweight) and the production requirements were calculated as 0.40 f.u. and 60 g digestible crude protein (DCP) per kilogram 4 % milk. A statistically significant difference in the nutrient supply between the silage groups was found only in experiment 4, where, presumably owing to differences in digestibility, the cows received less energy and more digestible crude protein from the AIV 2 silage than from the Viher solution silage.

According to the calculations, the mean energy received diverged from the maintenance requirement by +0.7 to − 1.1 f.u. per cow per day. The energy requirement was satisfied in the experiments where the silage had a low fibre content (experiments 1 and 4). The supply of protein was greater than the mean requirement in all the experiments (surplus 181—561 g per cow per day). The protein surplus was smallest in experiment 5, where the silage had the highest content of fibre and the barley ration was largest (Tables 1, 3 and 5). In that experiment the silage supplied 69 % of the energy received and 80 % of the protein. The corresponding values for the barley supplement were 26 % and 16 %. The greatest contribution was made by the silage in experiment 1, where it accounted for 84 % of the energy received and 91 % of the protein, and the barley contributed only 6 % and 3 %, respectively.

Discussion

The AIV 1, AIV 2, formic acid and Viher solution silages proved to be very uniform in palatability and nutritional value. This result accords with the uniform preservation observed in part I (ETTALA et al. 1975). The Ayrshire cows, weighing ca. 400—500 kg, consumed rather large amounts of silage, 7.6—12.1 kg DM per cow per day (1.74—2.51 kg DM/100 kg liveweight per day) (Table 3). One of the factors responsible was the small amounts of other feed offered to the animals (Table 3), but the abundant intake of silage is also evidence of its palatability, since cows react very readily to variations in the quality of the feed. There were no significant differences in voluntary intake between the different silage additives. Differences did occur between the different experiments, which could be attributed to variation in the bulkiness of the silages, in the milk yield of the cows and in the supply of concentrates, among other factors.

The most palatable silage was that which was only slightly fermented and had a high sugar content (p. 310). The fact that the intake of AIV 1 silage was somewhat smaller than that of the other silages in experiments 2 and 3 (Table 3, Fig. 1) can probably be explained by the more vigorous fermentation of the silage (cf. part I, Table 4). PIKE (1972) reported lower voluntary intake of silage prepared with an additive similar to AIV 1 (hydrochloric acid + acetic acid) than of silage prepared with formic acid. The AIV 1 silage was as palatable as the other silages in experiment 1 (Table 3), where the low temperature of the forage (cf. part I, p. 290) had limited fermentation. Some variation in the acceptability of AIV 1 silage has also been reported from experiments with beef cattle and rams (KORHONEN et al. 1973, KOSSILA and LAMPILA 1974, SYRJÄLÄ 1972).

The negative correlation of lactic acid with voluntary intake was not statistically significant when the different experiments were examined separately (p. 310), but became significant when experiments 1—3 were considered together. The effect of lactic

acid on intake has also varied in other studies. GORDON et al. (1964) and WILKINS et al. (1971) reported that lactic acid is positively correlated with intake; JACKSON and FORBES (1970) found a curvilinear relationship, and HARRIS et al. (1966) and MCLEOD et al. (1970) observed a negative correlation. The influence of pH was not significant (p. 310). In some studies a rise in pH increased the voluntary intake (BROWN and RADCLIFFE 1972, HARRIS et al. 1966, MCLEOD et al. 1970, WILKINS et al. 1971); in others it decreased it (GORDON et al. 1964). Acetic acid and ammonia were negatively correlated with intake (p. 310), which agrees with the results of earlier studies (BROWN and RADCLIFFE 1972, JACKSON and FORBES 1970, GORDON et al. 1964, WILKINS et al. 1971). So little butyric acid was found in the analyses of the silages that its influence on intake was merely occasional. Propionic acid was not determined in experiment 1, so that it could not be included as a variable in the regression analyses.

The level of the intake of the silages prepared with formic acid in this study was similar to that reported in many other studies with dairy cows (CASTLE and WATSON 1969, 1973, DERBYSHIRE and GORDON 1969, 1970, FISHER et al. 1971). Silages prepared with formic acid have been found to be more palatable than silages prepared from fresh herbage without any additives (CASTLE and WATSON 1970, FOX et al. 1971, WALDO et al. 1968, 1971) or from prewilted herbage (CASTLE and WATSON 1973, DERBYSHIRE and GORDON 1969, 1970). On the other hand, in some experiments silage prepared from prewilted forage has proved to be more palatable than silage prepared with formic acid (FISHER et al. 1971, WALDO et al. 1970). The superior palatability was probably mainly due to successful prewilting (WALDO et al. 1973 c).

The acceptability of the silages prepared with Viher solution remained constant, although a change occurred during the study from only slightly fermented silage prepared with formaldehyde to silage with a large content of lactic acid (cf. Figs. 1 and 2 and part I, Fig. 1, p. 294). In experiments with growing cattle (7 experiments), silages prepared with Viher solution were on average somewhat more palatable than acid-treated silages, although some variation was apparent (KOSSILA and LAMPILA 1974). In experiments with sheep, Viher solution silages (Norway, Casco) proved equal in palatability to acid-treated silages (SAUE et al. 1972, SYRJÄLÄ 1972) or slightly more palatable (BAEVRE 1974). Silages prepared with mixtures of formaldehyde + acid have most often proved more palatable than silages prepared without additives (HONIG and ROHR 1973, WALDO et al. 1973 a) or with formic acid or formaldehyde alone (VALENTINE and BROWN 1973, WILKINS et al. 1974). The study of WILKINS et al. (1974) indicates that acceptability depends on the ratio of the formaldehyde to the acid.

The voluntary intake of silages prepared with formaldehyde alone has been found to depend on the rate of application of the additive (BROWN and VALENTINE 1972, WILKINS et al. 1974). In the experiments of BARRY et al. (1973) and three of the six experiments performed by WILKINS et al. (1974), silages prepared with formaldehyde proved more palatable than those prepared without additives. Large amounts of formaldehyde have decreased intake considerably (BROWN and VALENTINE 1972, WILKINS et al. 1974). Silage prepared with paraformaldehyde has been found equal in palatability to silage treated with formic acid (WALDO et al. 1973 b, WALDO and KEYS 1974).

The interest attracted by formaldehyde as a silage additive is due not only to its capacity to inhibit fermentation, but also to the protection it affords against the degradation of protein during storage and in the rumen. In some experiments the protection of protein by formaldehyde has

been evident from the superior retention of nitrogen (POUTIAINEN and HUIDA 1970, WALDO et al. 1973 a, WILKINS et al. 1974); in some it has been revealed by a decrease in the ammonia concentration in the rumen (BAEVRE 1974, BARRY and FENNESSY 1973, SAUE et al. 1972, WILKINS et al. 1974). Both BARRY and FENNESSY (1973) and HONIG and ROHR (1973) observed that formaldehyde raised the ratio of acetic acid to propionic acid in the rumen. Protein digestibility was somewhat decreased by the formaldehyde in this (Table 2) as in many other studies (BAEVRE 1974, BARRY and FENNESSY 1973, BROWN and VALENTINE 1972, POUTIAINEN and HUIDA 1970, SAUE et al. 1972, SYRJÄLÄ 1972, WALDO et al. 1973 a, VALENTINE and BROWN 1973, WILKINS et al. 1974). The influence of formaldehyde in the rumen was more clearly apparent in animals fed on dried forage (BARRY 1971, HEMSLEY et al. 1970) or casein (BARRY 1972, FERGUSON et al. 1967, MCRAE 1970) treated with formaldehyde than in animals offered silage.

The protein-protective effect exerted by formaldehyde during storage was evident in this study (cf. part I, Tables 4 and 5, Fig. 1). However, the nitrogen balance of the experimental animals on Viher solution silage was no better than that of the animals receiving other silages (Table 2). This was presumably mainly due to the fact that the nitrogen received from the silages was considerably in excess of the rather low requirements of the fully grown rams. Another possible explanation is that the effect of the formaldehyde on the protein of the silage decreased with the increase in lactic acid fermentation, as is indicated by the course of the content of soluble nitrogen during storage (cf. part I, Fig. 1). This tendency may decrease the significance of the protective effect of formaldehyde in practice, because considerable secondary fermentation may take place during storage. On the other hand, this will diminish the danger of the possibly deleterious effect of the formaldehyde (BECK and GROSS 1973).

The influence of the various silages on the milk production was particularly clearly evident in this study, because the amounts of other feed offered were so small (Tables 3, 4 and 5, Figs. 1 and 2). When the intake of silage decreased, both the energy (Table 5) and the liveweight (Table 4) diminished. Silage treated with formic acid has generally given better production than the other silages used in comparative studies (CASTLE and WATSON 1970, 1973, DERBYSHIRE and GORDON 1970, FISHER et al. 1971, FOX et al. 1971, WALDO et al. 1968, 1970, 1971, 1973 a). Silages prepared with additives containing formaldehyde have also given better growth, more wool, etc. in many comparative studies, partly owing to greater intake and partly to superior utilization of protein (BAEVRE 1974, BARRY et al. 1973, BURSTEDT et al. 1971, KOSSILA and LAMPILA 1974, WALDO et al. 1973 a and b, VALENTINE and BROWN 1973).

The results of the present study emphasize the advantages of cutting forage for ensiling at an early stage of growth. An increase in the crude fibre content diminished preservation efficiency (part I, Table 8, Fig. 1) and decreased the voluntary intake (p. 310) and the energy received (Table 5). The high protein content, good digestibility and high voluntary intake of silage prepared at an earlier growth stage results in a considerable excess of protein at the average level of production (Table 5). With such silage it is also possible to offer larger rations of grain concentrates and to achieve a balance of energy and protein even at high production levels (ETTALA and LAMPILA 1974).

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SELOSTUS

Hapot sekä hapon ja formaldehydin seokset ruohon säilönnässä. II Säilörehujen ruokinnallinen laatu

ELSI ETTALA, ONNI POHJANHEIMO ja MARTTI LAMPILA
Maatalouden tutkimuskeskus

Lehmät ovat syöneet AIV 1-, AIV 2-, muurahaishappo- ja Viherliuos-säilörehuja 1.90, 2.10, 2.02 ja 1.97 kg ka/100 elop.kg/pv 4-%:sten maitotuotosten ollessa 12.6, 13.9, 13.4 ja 13.4 kg/lehmä/pv (3 koetta) sekä AIV 2- ja Viherliuossäilörehua 2.18 ja 2.15 kg ka/100 elop.kg/pv 4-%:sten maitotuotosten ollessa 15.7 ja 15.7 kg/lehmä/pv (2 koetta). AIV 1-rehun syöntimäärä on ollut jonkin verran (ei merkitsevästi) pienempi kuin muiden rehujen ja se on aiheuttanut tilastollisesti merkitsevän eron ($P < 0.05$) AIV 1 ja AIV 2 ryhmien 4-%:siin maitotuotoksiin. Maidon koostumuksessa on todettu merkitsevä ero ($P < 0.05$) AIV 2- ja Viherliuosrehua syöneiden lehmien maitosokeripitoisuudessa yhdessä kokeessa.

Neljässä kokeessa viidestä on Viherliuosrehujen raakavalkuaisen sulavuus ollut jonkin verran alhaisempi kuin muiden rehujen, mutta ero on ollut tilastollisesti merkitsevä ($P < 0.01$) vain yhdessä. Typpitaseessa ei ole ilmennyt merkitseviä eroja. Sulavuus- ja typpitasekokeet on tehty lampailla.

ANNALES AGRICULTURAE FENNIAE, VOL. 14: 319–324 (1975)
Seria HORTICULTURA N. 27 – Sarja PUUTARHAVILJELY n:o 27

THE EFFECT OF POST-HARVEST DEFOLIATION ON THE CROPPING OF STRAWBERRIES

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SÄKÖ, J. 1975. **The effect of post-harvest defoliation on the cropping of strawberries.** Ann. Agric. Fenn. 14: 319–324.
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Post-harvest defoliation of strawberries did not increase yield the subsequent year; on the contrary, it caused a reduction. The timing of defoliation – immediately after harvesting, and one and two weeks following harvesting – was not found to have any distinct effect upon yield. The harvesting period was shortened slightly as a result of defoliation. Incidence of greymould disease decreased. Defoliation also reduced autumn flowering. However, saleable yield was substantially smaller in the defoliated stands than the in the stands, which had been left undisturbed.

Introduction

In strawberries the development of flower initiation for the following season begins in late summer and continues into late autumn, sometimes as late as Nowember, depending upon weather conditions during the autumn. The determining factors in this event are temperature and amount of daylight. Each variety of strawberry has its own requirements respecting these factors (BAUER and KOCH 1964).

In some cases post-harvest defoliation has produced an increase in yield the following year. Experiments performed in England, showed that both burning and cutting the old foliage produced an increase in the yield compared with the usual procedure of clearing away the straw protecting the crop and cutting back the runners (WILSON 1953, WILSON and ROGERS 1954). Studies in Scotland revealed that defoliation after harvest increased flower initiation and, subsequently, yield. The most favourable result was achieved when defoliation was performed as soon as possible after harvest. Different varieties of strawberry reacted to defoliation in various ways. It usually caused an increased yield in the Talisman variety, and occasionally increased the yield in the Redgauntlet variety. However, in Cambridge Favourite there was a decrease in the formation of buds and in yield. When the plants were defoliated chemically instead of by cutting, yield decreased in all the varieties (GUTTRIDGE et al. 1961, MASON and GUTTRIDGE 1964, GUTTRIDGE and MASON 1965, MASON and STEVENS 1965).

The fact that defoliation increases flowering is held to be due to the changes it causes in the substances that regulate growth and those that regulate flowering. The

amount of daylight affects flowering by regulating formation in the leaves of the hormone that promotes growth and inhibits flowering. The induction of flower initiation is inhibited by a great deal of daylight, when there is no inhibiting concentration. According to theory, the ratios of substances regulating flowering can be altered by eliminating old foliage. Old foliage contains a hormone that promotes vegetative growth and inhibits flowering.

In a study performed in Poland, which included five varieties, it was found that post-harvest defoliation may benefit vigorously growing varieties such as Senga Sengana and Ydun. Defoliation did not produce an increase in yield, but the average weight of the berries increased compared with that of a stand which had not been defoliated. Defoliation also caused a decrease in the number of runners (SOBCZYKIEWICZ et al. 1969).

The following is a description of the effect of post-harvest defoliation performed in Finland, especially on Senga Sengana but also on other strawberry varieties, in 1961—63 and 1967—71. In addition to the observations on varieties, records were kept of what effect the time at which defoliation was performed had upon the following year's yield.

Layout of trials, and results

In an experiment established in spring 1961, when rows were set up one meter apart with 33 cm between the plants, the effect of defoliation and of the time of defoliation were investigated in Senga Sengana and Ydun. The plants were first defoliated as early as the year of planting and at a fairly early stage (29 July and 5 August, 1961). Approximately 70—80 per cent of the strawberry leaves were removed. At that stage the foliage was not yet very luxuriant. In the following year, i.e. the first year of harvest, defoliation was not found to have had any effect upon yield. The control plants, which had not been defoliated, produced the biggest yields in both varieties, but the differences were not significant. Defoliation was repeated in 1962 (24 August and 1 September). This time the effect of defoliation was quite distinct. The yields from defoliated stands of Senga Sengana

Table 1. The effect of post-harvest defoliation on yields of the strawberry varieties Senga Sengana and Ydun.

Spring 1961 planting. Soil: finne sand
Treatments: 1. Defoliation immediately upon harvesting
2. Defoliation 7 days later

Variety and treatment	Saleable yield kg/100 m²	Saleable yield % tot. yield	Total yield kg/100 m²		Yield in first 2 weeks %	Small berries under 15 mm %	Mouldy berries %	Mean weight of berries g
	1963	1963	1962	1963				
Senga Sengana								
Control	130	73	237	178	45	14	13	10.9
Defoliation 1	95	77	221	124	57	13	10	11.3
Defoliation 2	91	77	230	118	56	13	10	10.9
LSD 0.05			44	18				
Ydun								
Control	146	75	275	194	60	11	14	9.9
Defoliation 1	106	79	247	134	70	11	10	9.0
Defoliation 2	108	78	267	138	75	14	8	8.9
LSD 0.05			40	27				

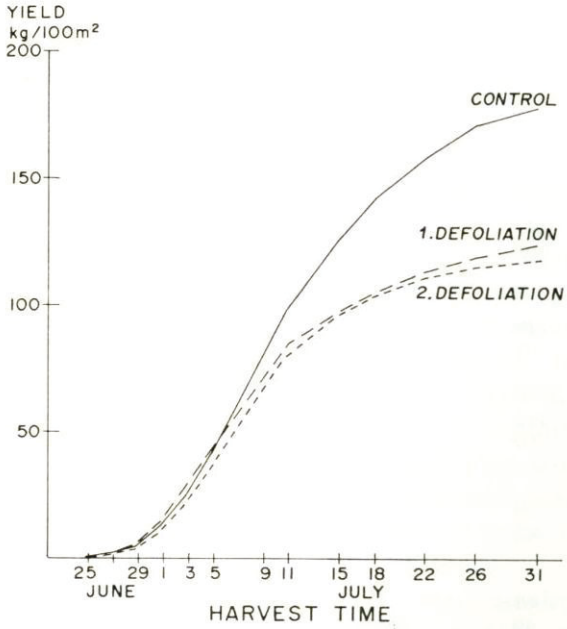

Fig. 1. Cumulative yields of Senga Sengana strawberry in 1963. Defoliation 24. 8. and 1. 9. 1962

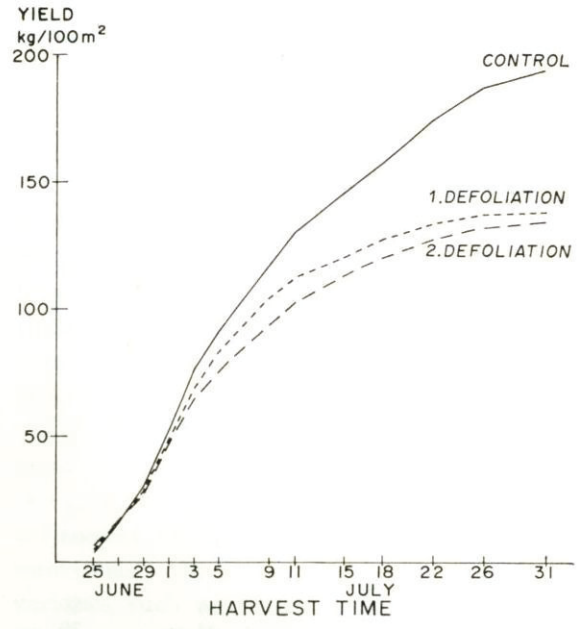

Fig. 2. Cumulative yields of Ydun strawberry in 1963. Defoliation 24. 8. and 1. 9. 1962

and Ydun were 30—34 per cent and 29—31 per cent smaller, respectively, than those obtained from the untreated stands of the corresponding varieties (Table 1). During the first two weeks of the harvest season the crop obtained from the defoliated plots was percentually but not quantitatively bigger than that from the control plots. Defoliation hastened the development of the crop and thus shortened the harvest season (Figs. 1 and 2). Timing of defoliation — the 7-day difference — had no effect upon the yields. Defoliation did not increase the average weight of the berries which, on the contrary, decreased on most plots bearing the two varieties. However, it can be seen that late flowering during the autumn, September—October, which is especially common in the Ydun variety, decreased by 31 per cent when defoliation was peformed

Table 2. The effect of post-harvest defoliation on the yield of Senga Sengana strawberry in 3rd and 4th year stands. The experiment was conducted at the South Savo Experiment Station in 1969—71.

Treatment	Saleable yield 1970—71		Total yield kg/100 m²		Yield in first 2 weeks %	Mouldy berries %	Mean weight of berries g
	kg/100 m²	Ratio	1970	1971			
A 1 Control	82	100	94	147	71	15	7.3
A 2 Defoliated immediately after harvest	60	73	63	124	68	14	6.6
B 1 Control	79	100	82	145	74	10	7.1
B 2 Def. 7 days after harvest	52	66	54	97	75	9	6.6
C 1 Control	78	100	89	135	73	11	7.1
C 2 Def. 14 days after harvest	49	63	53	90	71	9	6.4
A 1, B 1, C 1 Control	79	100	88	142	73	12	7.2
A 2, B 2, C 2 Defoliated	54	68	57	104	72	11	6.5

Table 3. The effect of post-harvest defoliation on the cropping of strawberry. Defoliation 13. 8. 1969 and 3. 8. 1970 immediately after harvesting.

Variety and treatment	Saleable yield		Total yield kg/100 m²		Mouldy berries	Mean weight of berries
	kg/100 m² 1970	% tot. yield 1971	1970	1971	%	g
Redgauntlet						
Control	134	92	165	54	5	12.2
defoliated	135	95	151	60	2	10.2
Senga Sengana						
control	97	84	123	109	14	9.3
defoliated	73	89	93	71	9	10.8
Lihama						
control	90	91	112	86	1	7.2
defoliated	53	92	60	55	2	7.4
Zefyr						
control	72	96	66	85	1	10.5
defoliated	60	95	62	64	1	9.7
Abundance Wannberg						
control	47	80	61	57	4	5.0
defoliated	41	79	49	55	6	4.7
Pocahontas						
control	51	93	59	50	3	7.7
defoliated	29	90	32	32	3	7.1
Guardsman						
control	43	80	54	54	8	7.7
defoliated	41	84	48	49	6	7.4

immediately upon harvesting and by 20 per cent when it was performed 7 days thereafter. As a result of defoliation, less grey mould occured on the berries compared with those of the control group.

An investigation of the effects of defoliation and time of defoliation upon 3—4 year-old stands of Senga Sengana was also made at the South Savo Experiment Station, Mikkeli, in 1969—71. Defoliation was performed at three points: immediately upon harvesting, 7 days and 14 days thereafter. The effect of defoliation was a decrease in yield in both years (Table 2). Slightly less grey mould occured in the defoliated stands, and the average weight of the berries was slightly less than it was in the control group.

In an experiment performed at Piikkiö in 1969—71 the effect of defoliation was investigated in seven varieties of strawberry, i.e. Abundance Wannberg, Guardsman, Lihama, Pocahontas, Redgauntlet, Senga Sengana and Zefyr. Defoliation performed immediately after harvesting caused a decrease in yield during the subsequent year in most of the varieties (Table 3). In some of the varieties, such as Lihama and Pocahontas, the yield decreased very sharply, by 36—46 per cent, as a result of defoliation. Stands of these varieties bear relatively little foliage and regrowth is fairly slow. In the second year of harvesting only Redgauntlet produced a higher yield, as much as 10 per cent higher, on the defoliated stand than on the control stand. Of the varieties mentioned, Senga Sengana was the most susceptible to grey mould. In defoliated stands of Senga Sengana there was less grey mould than there was in the untouched ones. In this experiment, too, in most of the varieties the average weight of the berries was greater in the control stands than in the defoliated stands.

Discussion

The above results show that under Finnish conditions post-harvest defoliation of strawberry plants is not beneficial in the varieties investigated since it leads to a reduction in yield the subsequent year. The fact that this finding disagrees with those of Scottish and Polish experiments is probably due to the differences in varieties and growing conditions, particularly the differences in temperature and the amount of daylight. These factors determine the growth rhythm of the strawberry plant, and probably also cause variation in yield of a variety under different growing conditions, and even at a single location during different years.

A benefit of defoliation is that usually less grey mould occurs on the berries of defoliated stands. This is evidently because the subsequent year foliage will be sparser on stands that have been defoliated and will consequently be more exposed to the air and dry more rapidly than a stand which has retained its foliage. Partial removal of old foliage evidently decreases contamination. It can also be regarded as an advantage that defoliation shorters the harvesting season by almost a week . The practical significance of this advantage is, however, questionable. Defoliation did not produce an increase in the average weight of the berries as it had in the Polish experiment (SOBCZYKIEWICZ et al. 1969), on the contrary, the average weight of the berries was in most cases lower after defoliation. A disadvantage is that defoliation causes a considerable reduction in yield the subsequent year, in the present study about 30 per cent.

Post-harvest defoliation of strawberry plants may, however, be warranted in some cases, for instance when vegetative growth is very great and flower initiation poor. This sometimes occurs in vigorously growing varieties such as Senga Sengana, especially when a great deal of fertilizer has been applied to the soil and when too much nitrogen is available to the plants. Growth may then be inhibited and crop formation promoted by means of defoliation. However, in poorly growing stands defoliation is no help. Defoliation performed too low down on the plant will damage the growing points and seriously debilitate the plant.

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SELOSTUS

Mansikan lehdistön niiton vaikutus seuraavan vuoden satoon

JAAKKO SÄKÖ

Maatalouden tutkimuskeskus

Sadonkorjuun jälkeen suoritettu mansikan lehdistön niitto on Skotlannissa suoritetuissa tutkimuksissa tuottanut seuraavana vuonna sadonlisäystä eräissä mansikkalajikkeissa. Puolalaisissa tutkimuksissa, joissa oli mukana mm. Senga Sengana- ja Ydun-lajikkeet, niitto ei lisännyt satoa, mutta sen seurauksena marjojen keskipaino suureni.

Suomessa tutkittiin Puutarhantutkimuslaitoksella Piikkiössä v. 1961—63 ja 1969—71 sekä Etelä-Savon koeasemalla Mikkelissä v. 1969—71 sadonkorjuun jälkeen suoritetun mansikan lehtien niiton vaikutusta satoon. Kokeissa selvitettiin myös eri niittoaikojen vaikutusta sekä eri lajikkeiden suhtautumista niittoon.

Tulokset (taul. 1—3, kuvat 1 ja 2) osoittavat, että sadonkorjuun jälkeen suoritettu mansikan lehdistön niitto ei ole edullinen toimenpide maamme oloissa, koska se johtaa sadon alentumiseen seuraavana vuonna. Näissä tutkimuksissa niiton seurauksena oli melko suuri (n. 30 %) sadon alentuminen.

Niiton etuna voidaan pitää sitä, että niitetyssä kasvustossa on seuraavana vuonna yleensä vähemmän harmaahomeen turmelemia marjoja kuin niittämättä jätetyssä. Tämä johtuu ilmeisesti siitä, että niitettyjen kasvustojen seuraavan vuoden lehdistö jää harvemmaksi ja on siten ilmavampi ja kuivuu nopeammin kuin niittämätön kasvusto. Vanhan lehdistön osittainen poistaminen vähentää ilmeisesti myös saastuntaa.

Niitto joudutti sadon kehittymistä ja lyhensi poimintakautta vajaalla viikolla (kuvat 1 ja 2). Niitetyillä ruuduilla esiintyi vähemmän syyskukintaa, mikä on yleistä erityisesti Ydun-lajikkeessa. Syyskukinta väheni heti sadonkorjuun jälkeen suoritetun niiton vaikutuksesta 31 % ja seitsemän päivää myöhemmin suoritetun niiton vaikutuksesta 20 %. Mainittujen etujen merkitys oli kuitenkin varsin pieni verrattuna siihen suureen sadonalennukseen, jonka niitto aiheutti. Eri niittoajoilla ei ollut selvää vaikutusta. Niitto ei suurentanut marjojen keskipainoa.

Tulosten poikkeaminen skotlantilaisten ja puolalaisten tutkimusten tuloksista johtunee eri lajikkeista ja erilaisista kasvuoloista, erityisesti lämpöolojen sekä päivän pituuden eroavuuksista. Nämä tekijät määräävät mansikan kasvurytmin ja niistä johtuu myös lajikkeen sadon vaihtelevuus eri kasvuoloissa sekä samallakin kasvupaikalla eri vuosina.

Joissakin tapauksissa saattaa sadonkorjuun jälkeinen mansikan lehdistön niitto kuitenkin olla aiheellista. Näin on silloin, kun mansikan vegetatiivinen kasvu on hyvin voimakasta, jolloin kukka-aiheiden muodostuminen jää heikoksi. Tätä tavataan toisinaan voimakaskasvuisissa lajikkeissa, kuten Senga Sengana'ssa, ja varsinkin silloin kun maan kasviravinteiden ja erityisesti typen määrä on suuri. Lehdistön niitolla voidaan tällöin hillitä kasvua ja auttaa kasvin sadonmuodostusta. Sen sijaan heikosti kasvavissa kasvustoissa ei niitosta ole apua. Liian matalalta niittäminen vioittaa kasvupisteitä ja heikentää pahoin kasvia.

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METHODS OF PROPAGATING THE COWBERRY

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Lehmushovi, A. 1975. **Methods of propagating the cowberry.** Ann. Agric. Fenn. 14: 325–333.
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The research on the propagation of the cowberry *(Vaccinium vitis-idaea* L.) begun at the Institute of Horticulture, Piikkiö, in 1971 has now been in progress for three growing seasons and has already yielded a considerable amount of information. The cowberry can be propagated from wild plantlets, from cuttings and pieces of rhizome, and from seed.

The easiest and most natural method is to take plants from the forest. Disadvantages often encountered are the heterogeneity of the material, difficulty in obtaining and transporting it, and comparatively poor establishment of the plants.

The best times for propagation from cuttings and pieces of rhizome have proved to be spring and autumn. On average, 85 % of the cuttings rooted on milled peat in an automatically regulated mist propagation chamber. The best results for the pieces of rhizome ranged from 60 to 80 %.

In the growing season of 1973, on average germination figure of 50 % was achieved under favourable conditions and on the best substrates.

Both the good results obtained in germination experiments and other observations made in the course of the research performed to date suggest that the most important method of propagating the cowberry may be by seed. The potential for propagation by cuttings is greatly reduced by the poor capacity for vegetative spreading observed in plants derived from cuttings in 1973. Nevertheless, it is essential to develop a satisfactory method of vegetative propagation in order to preserve desirable properties found in certain wild strains.

Introduction

Cultivation of the cowberry on a commercial scale could scarcely be successful in Finland before satisfactory methods of propagation have been developed and plant material is readily available. Research on the cultivation of the cowberry *(Vaccinium vitis-idaea* L.) was commenced in 1971 at the Institute of Horticulture in Piikkiö, and propagation experiments began in the same year. Cowberry plants may be taken from the wild, or raised from cuttings, pieces of rhizome or seed (LEHMUSHOVI and HIIRSALMI 1972). In Sweden, research on the cultivation of the cowberry was begun about 10 years ago and is increasing greatly in scope. More attention is now being paid to its propagation

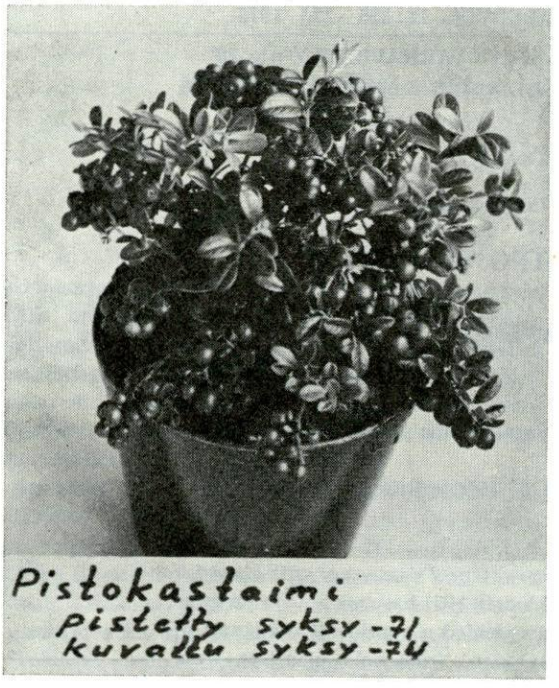

Fig. 1. 3-year-old cowberry plant raised from cutting (rooted autumn 1971, photographed autumn 1974).
Kuva 1. 3-vuotias pistokastaimi.

by both seed and vegetative means (TEÄR 1972).

Material and methods

Transplantation from the wild

The easiest and most natural way of propagating the cowberry is by taking plants from the forest. The greater part of the field plantings made at the Institute of Horticulture were set up using plants taken from the wild. The method of transplantation most often used in the present trials is as follows:

Clumps of cowberry, usually ca. 0.5—1.0 m^2 in size and chosen with a view to achieving maximum homogeneity, are taken from natural habitats and cut with a spade into slices ca. 10 cm thick. These are placed in narrow furrows about 15 cm in depth in the experimental field, and the surrounding soil is made firm. The chief advantages of this method are that it saves time, and that part of the root system is left intact since the clump is not torn into pieces, as was done earlier. This ensures that most of the shoots will become established, especially if care is taken to provide sufficient moisture after transplantation.

Propagation from cuttings and pieces of rhizome

Limited pilot studies performed in the 1960s showed that the cowberry can be propagated from cuttings and pieces of rhizome. Good results can be achieved if the most suitable time for propagation and optimal rooting techniques can be determined. The best period for propagation was studied by performing rooting experiments with cuttings and pieces of rhizome at monthly intervals throughout the growing seasons of 1971 and 1972 (Fig. 7). Attention was also paid to the effect on rooting of different substrates, pretreatments, and heat and moisture conditions.

In the experiments performed to determine the optimal rooting period, the substrate used was a mixture of milled peat and sand (2: 1). Wooden boxes with cuttings and pieces of rhizome were kept in an automatically regulated mist propagation chamber for at least 1.5 months. Each box contained 25 cuttings or pieces of rhizome and there were four replicas. The experimental series was begun in spring, on 15. IV., as soon as the snow had melted, and the last lot of experiments were set up on 15. X., since the ground is generally frozen after this date.

Propagation from seed

Germination experiments were performed with seed originating from field trial plantings. The air-dried seed was kept in plastic bags in a refrigerator (ca. 5—6° C). There

were altogether 12 treatments. Sowing was performed throughout a period of one year from 1. XI. 1971 onwards. The germination substrate used was a mixture of mineral soil and milled peat (2:1). The seeds were sown in 5'' plastic pots and covered with a thin layer of sand. There were 10 replicas in each of which 100 seeds were sown (Fig. 2).

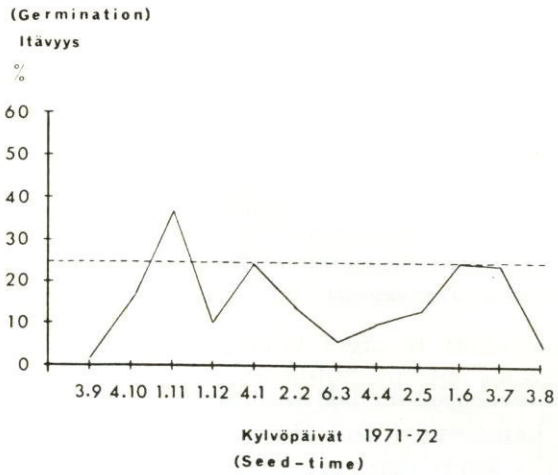

Fig. 2. Germination of cowberry seed in 1971—1972.

Kuva 2. Puolukan siementen idätysaikakoe 1971—1972.

No very definite conclusions could be drawn from the results of the stratification experiments[1]) made in 1971—1972 and 1972—1973, but it was evident that cold treatment promotes the germination of the seeds. Stratification was performed as follows. Batches of seed were placed in small nylon bags and buried in sand in pots. The pots were moistened at regular intervals and stored at a temperature ranging from 0 to 2° C. Different germination substrates were used in an attempt to discover which gave the most vigorous germination. The substrates used were mineral soil, sand, milled peat and heath soil; in 1973 a mixture of milled peat and sand (2: 1) was substituted for the heath soil. No lime or fertilizer was applied. There were 10 replicas in 1971 and five in 1973, each comprising 100 seeds (Figs. 3 and 4).

[1]) Stratification = the arousal of seeds from dormancy by various treatments, e.g. exposure to low and high temperatures with accompanying moisture treatment. The duration of treatment varies, most often depending on the plant species, but is generally 1—6 months. Most seeds are practically unable to germinate without such treatments, which simulate the conditions to which they are exposed during winter in nature. Stratification promotes uniform and simultaneous germination. It also often considerably reduces the period of afterripening, so that germination is accelerated.

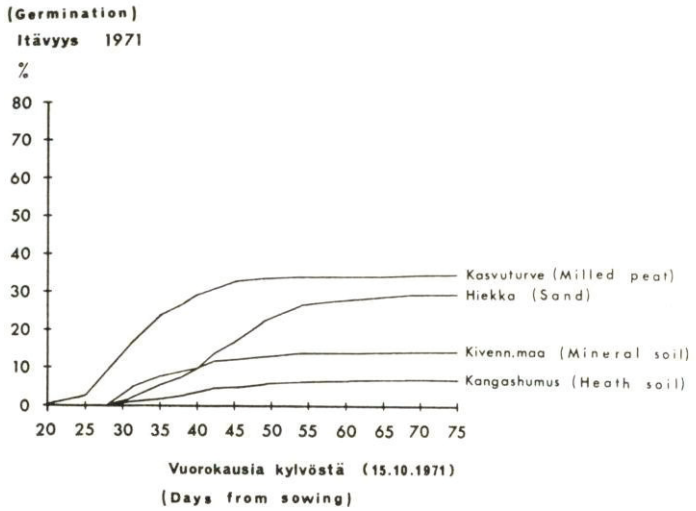

Fig. 3. Germination of the cowberry on different substrates in 1971.

Kuva 3. Puolukan idätyskoe erilaisilla idätysalustoilla 1971.

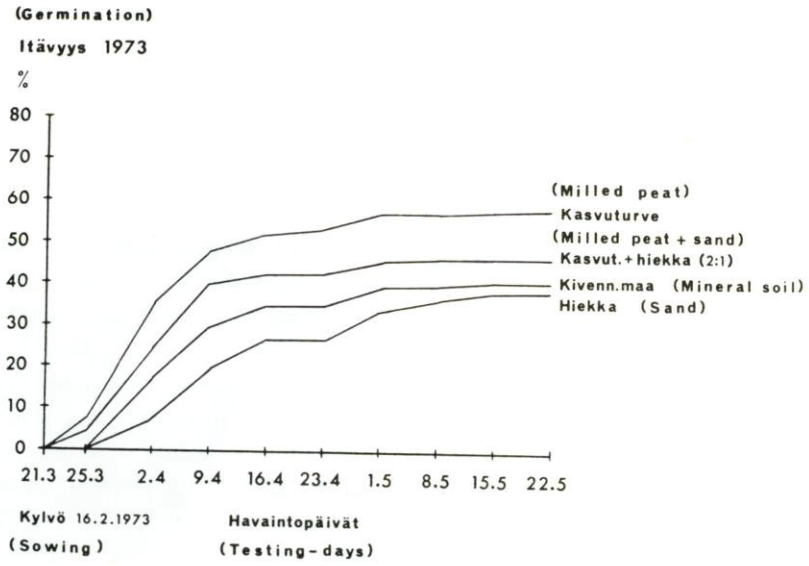

Fig. 4. Germination of the cowberry on different substrates in 1973.
Kuva 4. Puolukan idätyskoe erilaisilla idätysalustoilla 1973.

Results

Experimental planting with wild cowberries

The success of wild cowberries and the growth of their shoots in experimental field plantings could be followed in an experiment commenced in 1968 with different substrates (Lehmushovi and Hiirsalmi 1973). When the plants were set, their average cover was 5—10 % and their average height 6.8—10.0 cm. In autumn 1972, after five growing seasons the cowberries had reached a maximum cover of 100 % on milled peat, the average cover for the 36 milled peat plots having risen to 95.3 % by 1973 (Fig. 5). The maximum cover on a mixed substrate (mineral soil + milled peat, 1: 1) was almost 90 %, the average being 86 %. In contrast, the increase in cover on mineral soil was very poor, cover averaging 11.7 % and only reaching 30 % on certain plots. The height of the shoots decreased at first on all the substrates, but showed a clear increase after 1971, especially in the milled peat and mixed plots (Fig. 6).

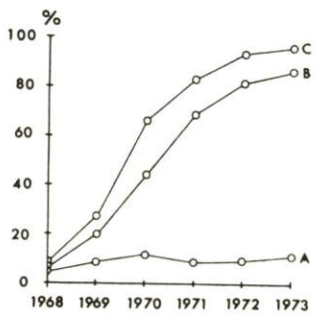

Fig. 5. Cowberry cover (%) in the years 1968—1973 on mineral soil (A), mixture of mineral soil and milled peat (B) and milled peat (C).
Kuva 5. Kivennäismaan (A) kivennäismaan ja kasvuturpeen seoksen (B) sekä kasvuturpeen (C) vaikutus puolukan versojen peittävyyteen (%) vuosina 1968—1973.

Rooting experiments with cuttings and pieces of rhizome

The optimal period for the rooting of cuttings and pieces of rhizome proved to be in the spring, between mid April and mid June.

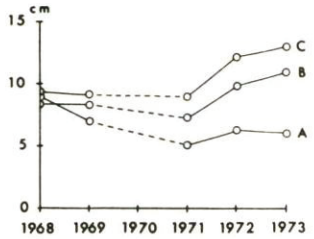

Fig. 6. Cowberry shoot height (cm) in the years 1968—1973 on mineral soil (A), mixture of mineral soil and milled peat (B) and milled peat (C). Shoot height not measured in 1970.

Kuva 6. Kivennäismaan (A), kivennäismaan ja kasvuturpeen seoksen (B) sekä kasvuturpeen (C) vaikutus puolukan versojen korkeuteen (cm) vuosina 1968—1973. Versokorkeutta ei ole mitattu vuonna 1970.

Warm spells generally begin at that time, and technical difficulties will be encountered in maintaining suitable conditions for rooting. Throughout the summer, rooting was notably poorer than in the spring, but

Table 1. Rooting of cowberry cuttings and pieces of rhizome in different months of the growing seasons of 1971 and 1972.

Taulukko 1. Pistokkaiden ja maarönsyn palasten parhaan lisäysajankohdan määrittäminen kasvukausina 1971 ja 1972.

Time of propagation *Lisäysaika*	Rooting *Juurtuminen* 1971 %	Rooting *Juurtuminen* 1972 %	Mean *Keskiarvo* %	Number *Lukumäärä* kpl
Cuttings				
15/4	83	96	89.5	200
15/5	81	91	86.0	200
15/6	72	64	63.0	200
15/7	82	34	58.0	200
15/8	50	62	56.0	200
15/9	35	49	42.0	200
15/10	84	43	63.5	200
Pieces of rhizome				
15/4	79	85	82.0	200
15/5	94	66	80.0	200
15/6	60	58	59.0	200
15/7	65	20*	42.5	200
15/8	52	26*	39.0	200
15/9	57	6*	31.5	200
15/10	77	42	59.5	200

* = possible technical source of error.

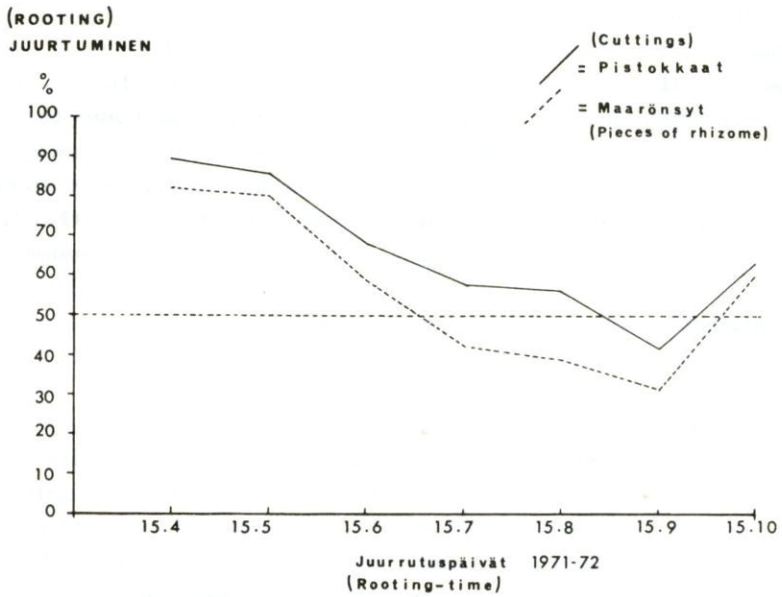

Fig. 7. Rooting of cowberry cuttings and pieces of rhizome at different times in 1971—1972.

Kuva 7. Puolukan pistokkaiden ja maarönsyn palasten parhaan juurtumisajankohdan määrittäminen 1971—1972.

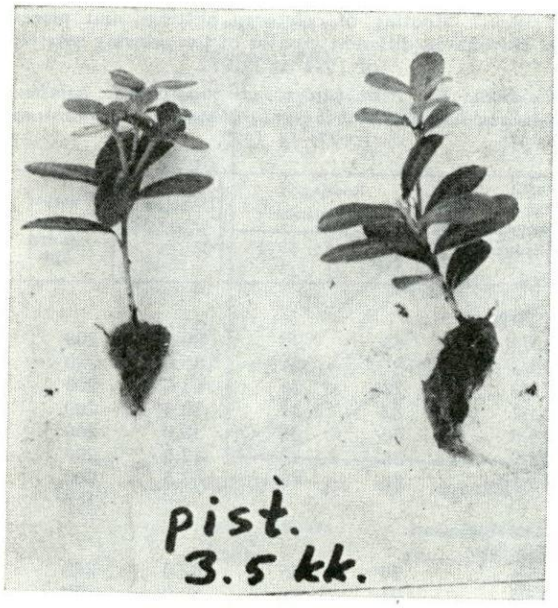

Fig. 8. Plantlets raised from cuttings. (3.5 months)
Kuva 8. Pistokastaimia (3.5 kk).

the spring rooting rates were reached again in the autumn (Table 1, Fig. 7). Milled peat was also found to be the most favourable substrate for rooting cuttings (Fig. 8). In 1972, the average rooting percentage for 300 cuttings on milled peat in a mist propagation chamber was 85. The addition of a 33 % sand fraction decreased the rooting percentage to 65, and a corresponding addition of humus reduced it to 55 %. The results of the experiments performed so far suggest that the substrate controls the development by the cowberry of substances inhibiting rooting and germination.

Of the pretreatments employed, hormone treatment gave the best results in the first experimental year: the average rooting percentage was 80, as opposed to 65 in the controls. In 1972, the controls achieved a rooting percentage of 100, so that the result could not be improved by pretreatment. The results from two years show that treatment with 6 000 ppm IBA hormone solution was best, giving 90 % rooting; weaker hormone solution (3 000 ppm IBA) gave 86 % and the controls averaged 83 %. The experiment comprised four replicas and there were altogether 200 cuttings per treatment. Keeping the cuttings in water for one or two days before planting clearly decreased their rooting capacity.

The most favourable heat and moisture conditions for rooting the cuttings were clearly provided by the automatically regulated mist propagation chamber, where rooting averaged 78 %. In a growth chamber and a plastic chamber, rooting averaged 63 %. Heating the cuttings from below has not promoted rooting noticeably in the studies performed so far.

The results obtained with pieces of rhizome corresponded exactly to those recorded with the cuttings, but this method of propagation is very laborious and in many respects more difficult than propagation by cuttings.

The so-called shoot fragment propagation method is an extremely interesting adaptation of the cutting propagation method, although the results obtained so far have been rather poor. Shoots of the cowberry are crushed into fragments, which are scattered as evenly as possible on the surface of the rooting substrate and covered with a thin layer of, for example, milled peat. The aim is to obtain at least one sturdy plantlet per paper pot. Planting out could then be performed mechanically. In this way it would be possible to substitute a completely mechanized procedure for the time-consuming method of manual handling. So far, the best result achieved has been ca. 50 rooted plantlets per 280 pots.

Germination experiments

On the whole, propagation of the cowberry by seed proved comparatively successful. The germination percentage was rather low at first, values of 25—40 % being common. It was not until 1973 that a level of 50—60 % was reached in certain experiments. However, in view of the fact that cowberry seedlings are somewhat rare in nature, these

results should perhaps be considered rather good. In nature, reproduction is almost exclusively vegetative.

Germination was clearly highest in the experiments performed in November, reaching 55 % in the best replica. After this it declined and did not rise to the level of 25 % until late in the spring (Fig. 2). In the stratification experiments, the best germination percentages were obtained after two and four months of stratification. The seeds were found to keep fairly well stored in plastic bags in the refrigerator. In one experiment, seeds stored in this way for six months and then stratified for half a month in damp sand achieved 72 % germination, which is the highest value so far obtained for the cowberry.

In 1971, acid milled peat was found to be the best germination substrate, and also gave the most rapid germination. In the experiment in which seed was sown on 16. II. 1973, milled peat again proved to be best, germination averaging 58.4 %. Even on mineral soil the average was as high as 40.6 % (Fig. 4).

Discussion

After only three growing seasons, a considerable amount of data is already available from the propagation experiments commenced in 1971 at the Institute of Horticulture in Piikkiö. The cowberry may be propagated from plants taken from the wild, cuttings, pieces of rhizome and seed. The most favourable results have been obtained with seed and cuttings.

The greatest drawback in using wild plantlets is the rather poor rate of establishment. A large proportion of the shoots die, especially during the summer following setting. In addition, the wild material is often heterogeneous, and the task of procuring and transporting it rather awkward and laborious, especially it large plantings are to be established.

Propagation by cuttings gave good results in an automatically regulated mist propagation chamber. The effect on rooting of various pretreatments was comparatively small, at most somewhere in the order of 10 percent so that they are probably not worthwhile in practical propagation.

After the research conducted in 1972, it appeared that attention should be concentrated on propagation by cuttings. This method gave good results and the plantlets were found to bear abundant fruit in the growing season following rooting. Öster (1974) also reports that cuttings rooted well in Sweden. Rhizomes proved rather difficult to procure and use for propagation. Their abundance and rooting are highly dependent on the vigour of vegetative reproduction in the particular cowberry stand. If it is poor, it will be difficult to obtain sufficient pieces of strong rhizome with well-developed buds for rooting. However, a surprising new observation was made in 1973 which may necessitate a complete reassessment of the suitability of propagation by cuttings. It became evident that plantlets derived from cuttings have a poor capacity for vegetative spreading. The plants generally grow comparatively well, form woody branches and bear abundant fruit in the summer following rooting, but they fail to become polycormic and do not develop new, horizontal underground stems from which new offshoots may develop. This raises the question whether the plants can be set so that they grow really close together. This would scarcely be possible in practical cultivation, since very large numbers of plantlets would be required. For instance, almost a million plants might be needed per hectare. Öster (1974) also reports that the rate of horizontal spreading is too low in plants derived from cuttings for this method to be used in practical cultivation.

According to the latest results, propagation by seed may be the most important method for the cowberry. This conclusion is supported

by the good results obtained in germination tests (HALL and BEIL 1970, LEHMUSHOVI 1974). On average, 50 % germination has already been achieved on the best germination substrates and under favourable conditions. In some replicas, germination even exceeded 70 %. The seedlings also have a good capacity for vegetative spreading and form abundant offshoots. (Fig. 9). The only more serious disadvantage observed so far is that it takes rather many growing seasons before they begin to have a good fruit yield. On average, it is only after the fourth growing season that they yield a proper crop.

Fig. 9. Plantlets raised from seed. (8 months old).
Kuva 9. Siementaimia (8 kk ikäisiä).

Nevertheless, it is essential to develop a satisfactory method of vegetative propagation in order to preserve desirable qualities found in certain strains growing in the wild, e.g. for cross-breeding. It is not yet possible to know how certain properties are inherited by progeny derived from seed, but observations made with other cultivated berry plants suggest that such properties will be widely scattered. In this case, optimal material will not be obtained by propagation from seed, e. g. the fruit yield may be much poorer than in the natural strain from which the seed was obtained.

So far, research on propagation has been possible only on a small experimental scale, and it would be desirable to continue it without delay on the scale required for practical cultivation. Only then will it be possible to reach a definite decision regarding the respective merits and disadvantages of propagation by cuttings and by seed.

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SELOSTUS

Puolukan lisäämismenetelmistä

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Puutarhantutkimuslaitoksessa Piikkiössä v. 1971 aloitetut puolukan *(Vaccinium vitis-idaea* L.) lisäämistutkimukset ovat jo kolmen kasvukauden jälkeen antaneet runsaasti erilaisia tuloksia. Puolukkaa voidaan lisätä luonnonvaraisista taimista, pistokkaista, maarönsyn palasista ja siemenistä.

Luonnollisin ja helpoimmin suoritettava puolukan lisäysmuoto on luonnontaimien hyväksikäyttö. Haittatekijöinä ovat usein aineiston epätasaisuus, sen hankala saanti ja kuljetus istutuspaikalle sekä taimien suhteellisen heikko kasvuunlähtö.

Parhaaksi lisäysajankohdaksi on pistokkaita ja maarönsyn palasia käytettäessä osoittautunut kevät ja syksy. Automatiikalla varustetussa sumumonistushuoneessa on pistokkaiden juurtuminen ollut kasvuturpeella keskimäärin 85 %. Parhaat juurtumistulokset maarönsyn palasilla ovat vaihdelleet 60—85 %:iin.

Kasvukauden 1973 aikana on jo saavutettu parhailla idätysalustoilla ja hyvissä idätysoloissa keskimäärin 50 %:n itävyystaso.

Idätyskokeiden hyvät tulokset vahvistavat tutkimusten tämänhetkistä käsitystä siitä, että siemenlisäys jäänee sittenkin puolukan tärkeimmäksi lisäystavaksi. Pistokaslisäyksen edullisuutta rajoittaa erittäin paljon kasvukaudella 1973 tehty havainto, että pistokastaimien kasvullinen leviämiskyky on heikko. Kuitenkin hyvän suvuttoman lisäysmenetelmän kehittäminen on välttämätöntä, jotta tietyissä luonnonkannoissa voitaisiin säilyttää valitut, hyvät ominaisuudet.

ANNALES AGRICULTURAE FENNIAE, VOL. 14: 334–337 (1975)
Seria ANIMALIA NOCENTIA N. 74 — Sarja TUHOELÄIMET n:o 74

PESTS OF CULTIVATED PLANTS IN FINLAND IN 1974

MARTTI MARKKULA

MARKKULA, M. 1975. **Pests of cultivated plants in Finland in 1974.** Ann. Agric. Fenn. 14: 334–337.
(Agricultural Research Centre, Inst. of Pest Investigation, SF-01300 Vantaa 30, Finland)

Pests were considerably less abundant than normal in 1974, primarily owing to the exceptionally heavy rainfall during the growing season but also to the low temperatures. Responses to inquiries showed that the average abundance of all pests, in terms of a five-value scale, was 2.4, whereas during the ten-year period 1964–1973 it had been 2.7. Only apple trees were subject to severe damage. During the winter, bark damage was caused chiefly by *Lepus europaeus*. The apple yield was severely damaged by *Argyresthia conjugella* and *Cydia pomonella*. The abundance of *Heterodera rostochiensis* had increased sufficiently for it to cause damage on several farms specializing in potato cultivation. The incidence of aphids was particularly low on all plants.

As in previous years (e.g. MARKKULA 1974), the present survey is based chiefly on replies to inquiries sent to the advisers at Agricultural Centres. Inquiries were sent to 187 advisers, and replies were received as follows:

Inquiry	Replies	%	Communes	%
Spring	136	73	168	35
First summer	135	72	158	33
Second summer .	149	80	164	34
Autumn	144	77	177	37

A general estimate of the abundance of pests for the whole growing season was given by 122 advisers from 134 communes. The estimate was based on a five-value scale (MARKKULA 1969). In the year under review, the country was divided into 397 rural communes, 21 country towns and 63 towns having a total of 483 communes.

The growing season was cool and rainy. In 1974, the temperatures for May, July and August were 0.5° to 1.5° C below norma in all parts of the country. In June, the temperature was normal and in September it was above normal.

At the beginning of the summer, rainfall was slightly below average, but from July till the end of the growing season it was considerably above normal. In some parts of the country it was even twice or three times the average. The excessive rain spoilt the crop yields, delaying and in some areas preventing the harvest. It is some decades since so much rain was experienced during the growing season.

Results and discussion

The exceptional rainfall and cool temperatures appear to have been harmful to most pest species. According to the replies received,

the average abundance of pests was 2.4 for the whole growing season. This was distinctly lower than in the previous summer, when the value was 3.3 (MARKKULA 1974). In the ten-year period 1964—1973, the average pest abundance was 2.7.

The abundance of pests on cereals was low. *Rhopalosiphum padi* whose incidence had been exceptionally high in summer 1973 occurred infrequently, and the cereal leaf beetle *Oulema melanopus* (L.) was absent.

In all plants, except apple trees, pest abundance and damage were below average. *Argyresthia conjugella* and *Cydia pomonella*, which attack apples, caused unusually heavy damage. The following table shows the percentages of apples damaged.

	1974	1973	1964—1973	Replies
Argyresthia conjugella	64	18	29	96
Cydia pomonella .	35	24	20	69

During the ten-year period 1964—1973, equally severe damage was reported only in 1968. It should be noted however, that the information provided by the agricultural advisers covers all apple orchards and probably puts undue emphasis on the situation in small household apple orchards, where pest control is often quite inadequate. In commercial apple orchards, where pest control is efficient, the damage caused by *A. conjugella* and *C. pomonella* was relatively slight.

After a long pause, *Lepus europaeus* again caused considerable damage during the winter by eating bark and buds, especially on young apple trees. *Microtus agrestis* also occurred abundantly but the damage was slighter than expected.

Heterodera rostochiensis Woll. had become sufficiently abundant to cause damage on several farms and potato cultivation was particularly affected, especially in Häme.

The distribution of *H. rostochiensis*, was examined by taking 4 000 soil samples from the western parts of the country in autum 1974. The results will be obtained in 1975.

Some Colorado beetles *Leptinotarsa decemlineata* (Say), were again found in consignments of early potatoes from Bulgaria. The potatoes were returned. One female Colorado beetle was found on the roof of a car parked in a courtyard in Helsinki, and laid eggs in the laboratory. This was the second beetle found at large in Finland (see MARKKULA 1974).

During winter 1973—1974, some Colorado beetles were put to overwinter outside. A small number were still alive in June, which proves that the beetle can overwinter in Finland.

Apart from the pests attacking apple trees mentioned above, only snails, *Deroceras agreste* etc., and *Elateridae* reached the normal level of abundance, even slightly exceeding it. Especially low figures were received for the incidence of aphids, *Phaedon cochleariae*, *Lygus rugulipennis*, *Silpha opaca*, *Hyponomeuta malinellus* and *Zophodia convolutella*.

No pests new to Finland were reported.

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Table 1. Results of questionnaires. Severity of damage estimated according to a scale of 0—10. Frequency of damage calculated as the percentage of crops in which damage was observed.

	Number of observation 1974	Severity of damage		Frequency of damage	
		1974	1964—73	1974	1964—73
CEREALS					
Elateridae	98	**1.3**	1.2	14	16
Macrosiphum avenae (F.)	84	0.8	1.7	12	27
Phyllotreta vittula (Redtb.)	102	0.7	1.1	15	21
Oscinella frit (L.)	158	0.6	1.2	7	15
Rhopalosiphum padi (L.)	88	0.4	1.2	6	19
FORAGE PLANTS					
Amaurosoma spp.	101	1.0	1.7	18	32
Apion spp.	70	0.6	1.2	10	19
ROOT CROPS AND VEGETABLES					
Halticinae, crucifers	99	1.7	2.1	32	40
Pieris brassicae (L.) etc.	69	1.5	1.9	22	31
Hylemya brassicae (Bchè) and *H. floralis* (Fall.)	158	1.5	2.1	25	30
Hylema antiqua (Meig.)	83	1.3	2.0	12	24
Plutella maculipennis (Curt.)	74	1.2	1.8	14	24
Mamestra brassicae (L.)	42	0.9	1.3	13	23
Trioza apicalis (Först.)	77	0.8	1.5	14	26
Psila rosae (F.)	58	0.7	1.0	5	13
Brevicoryne brassicae (L.)	44	0.6	0.9	12	15
Phaedon cochleariae (F.)	65	0.6	1.3	12	22
TURNIP RAPE					
Meligethes aeneus (F.)	46	1.5	1.8	40	44
SUGAR BEET					
Chaetocnema concinna (Marsch.)	78	1.3	1.7	**42**	42
Pegomya betae (Curt.)	161	1.3	2.0	40	51
Lygus regulipennis Popp. etc.	64	1.0	2.1	34	50
Silpha opaca L.	53	0.6	1.5	17	37
PEAS					
Cydia nigricana (F.)	66	1.5	2.0	**43**	36
APPLES					
Argyresthia conjugella Zell.	103	**5.6**	3.1	**78**	43
Lepus europaeus Pallas and *L. timidus* L.	89	**3.0**	1.6	**42**	13
Cydia pomonella (L.)	77	**2.9**	2.5	**53**	42
Microtus agrestis (L.)	59	**1.8**	1.0	**12**	7
Panonychus ulmi (Koch.)	72	1.0	1.4	15	23
Aphis pomi (Deg.)	59	0.9	1.7	18	27
Hyponomeuta malinellus (Zell.)	51	0.7	1.7	10	26
Psylla mali (Schmidbg.)	37	0.6	1.0	10	16
Arvicola terrestris (L.)	44	**0.5**	0.5	**4**	4
Xyleborus dispar (F.)	33	0.5	0.6	3	5
BERRIES					
Cecidophyopsis ribis (Wettw.)	94	2.1	2.2	28	31
Incurvaria capitella Cl.	68	1.9	2.0	18	25
Tarsonemus pallidus Bks	100	1.8	2.1	28	29
Byturus urbanus (Lndb.)	66	1.5	1.8	28	31
Nematus ribesii (Scop.) and *Pristiphora pallipes* Lep.	82	1.5	1.8	13	19
Anthonomus rubi (Hbst.)	60	1.4	1.7	25	28
Pachynematus pumilio Knw.	78	1.3	1.5	17	24
Aphididae, on Ribes species	77	1.1	1.9	13	29
Tetranychus urticae (Koch.)	61	0.8	1.4	11	24
Zophodia convolutella (Hbn.)	56	0.3	1.1	3	15
PESTS ON SEVERAL PLANTS					
Deroceras agreste (L.) etc.	66	**1.5**	1.4	**31**	25
Hydroecia micacea (Esp.)	71	1.1	1.2	17	22

SELOSTUS

Viljelykasvien tuhoeläimet 1974

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Tuhoeläimiä oli huomattavasti tavanomaista vähemmän, ja tuhot olivat siten pieniä. Maatalouskeskusten piiriagrologien antamien tietojen mukaan tuhoeläinten runsausluku oli katsausvuotena 2,4 ja kymmenvuotiskautena 1964—1973, 2,7. Tuholaisten niukkuuteen ja tuhojen vähäisyyteen oli ensisijaisena syynä kasvukauden poikkeuksellinen sateisuus ja osin myös viileys.

Ainoastaan omenapuut olivat pahojen tuhojen kohteena. Kaikki muut kasvit selviytyivät tavallista pienemmin tuholaisvahingoin. Jänikset ja myyrät vikuuttivat omenapuita talvella. Loppukesällä tulivat ilmi poikkeuksellisen ankarat pihlajanmarjakoin ja omenakääriäisen tuhot. Tiedusteluihin saatujen vastausten mukaan oli omenoista pihlajanmarjakoin vioittamia peräti 64 % ja omenakääriäisen vioittamia 35 %. Luvut ilmoittavat tilannetta lähinnä omaa tarvetta varten viljellyissä pikku tarhoissa, joissa tuholaistorjunta lyödään nykyisin laimin varsin yleisesti. Varsinaisten omenanviljelijöiden tarhoissa tuhot olivat tehokkaan torjunnan ansiosta huomattavasti pienempiä.

Peruna-ankeroisen havaittiin lisääntyneen tuhoa tuottavaan määrään useilla perunan viljelyyn erikoistuneilla tiloilla, erityisesti Hämeessä.

Bulgarialaisista varhaisperunalasteista löydettiin jälleen joitakin koloradonkuoriaisia. Lastit palautettiin. Kesäkuussa löydettiin Helsingistä talon pihalle pysäköidyn auton katolta koloradonkuoriainen, joka laboratorioon vietynä alkoi munia.

Yksityiskohtainen katsaus on julkaistu Koetoiminta ja Käytäntö-lehdessä n:o 3/1975.

ANNALES AGRICULTURAE FENNIAE, VOL. 14: 338–348 (1975)
Seria ANIMALIA DOMESTICA N. 40 — Sarja KOTIELÄIMET n:o 40

LIVE-WEIGHT GAIN, FEED INTAKE AND WOOL GROWTH OF LAMBS ON DIFFERENT GRASS SILAGES AND SUCROSE AND STARCH SUPPLEMENTS

LIISA SYRJÄLÄ

SYRJÄLÄ, L. 1975. **Live-weight gain, feed intake and wool growth of lambs on different grass silages and sucrose and starch supplements.** Ann. Agric. Fenn. 14: 338–348.
(University of Helsinki, Department of Animal Husbandry, SF-00710 Helsinki 71, Finland)

A feeding experiment was performed with 91 finnsheep lambs in the age period 8–23 weeks, in order to compare various grass silages used as the only feed, and the effect of sucrose and starch supplements given at the rate of 15 % of the dry matter of the daily ration. The silages were prepared: (1) without any preservatives, (2) with AIV I solution (25 % formic acid and 20 % hydrochloric acid), (3) with Viher solution (26 % formic acid and 70 % formalin) and (4) with formic acid.

Live-weight gain, silage intake and the values describing feed utilization were best on formic acid silage, which had the lowest fermentation level, and lowest on silage prepared without any preservatives, where the fermentation level was highest. The carbohydrate supplements increased live-weight gain, silage intake and feed utilization on all the silages, but especially on the silage without any preservatives, the effect of sucrose being slightly better than that of starch.

Wool growth was about same on the different silage diets. The best wool growth rates were obtained on diet supplemented with sucrose, and the poorest on the pure silage diets.

In earlier investigations of grass silage used as the main feed for sheep, its nutritive value has generally been tested with adult, or nearly adult, experimental animals fed at maintenance level. The productive effect of silage has also been examined with pregnant or lactating ewes (SAUE 1968, NEDKVITNE 1969, SYRJÄLÄ 1973); but only few growth experiments have been undertaken with lambs fed on grass silage (ANTILA 1974), and in these the animals had generally already passed their most intensive growth stage (SAUE 1968).

The purpose of the present study was to elucidate the suitability of grass silage as a feed for lamds aged about two months, and to compare silages prepared with different preservatives. The effect of sucrose and starch supplements was also examined, this part of the experiment complementing earlier investigations devoted to the effect of different carbohydrate supplements on the utilization of grass silages by ruminants (SYRJÄLÄ 1972). The experiment was performed at the South Savo Experimen Station and the Institute of Animal Husbandry of the Agricultural Research Centre.

Experimental animals and their feeding

The experimental animals were 91 finnsheep lambs born in June 1971. To obtain animals of as nearly the same age as possible, the oestrus of 62 ewes was synchronized by using tampons containing the synthetic compounds gestagen and mestranol, which have the same effect as the hormones progesterone and oestrogen (KANGASNIEMI 1971). The tampons were kept in the vaginae of the ewes for 16 days (Table 1). Immediately after the tampons were removed the ewes were divided into four groups of 15—16 animals and ram was allowed to go to each group. All the lambs born from the first or second mating were taken for this experiment. Sixty-six lambs were born from the first mating and 25 from the second. The lambs were obtained from 46 ewes.

Table 1. Schedule of the experiment.

Time	Procedures
December 30 1970	Tampons inserted in ewes.
January 15 1971	Tampons removed, ewes divided into groups, rams allowed into groups.
June 6—11 1971	First lambs born.
June 19—28 1971	Second lambs born.
July 26 1971	Lambs weaned from mothers.
August 9 1971	Lambs weighed and divided into groups. Start of preliminary period.
August 30 1971	Start of experiment proper.
January 17 1972	End of axperiment.

When all the lambs were at least one month old they were weaned from their mothers and fed for two weeks with a commercial concentrate feed (Sampo), hay and silage. Each food-stuff was given *ad libitum*.

The preliminary period of three weeks started when the oldest lambs were about two months and the youngest one about six weeks old. At the beginning of the period the lambs were weighed and divided into 12 experimental groups of 7—8 animals. The groups were similar to each other as regards the distribution of the lambs by sex, parents, age and weight. Since the male lambs were not castrated, each groupf was further divided into two feeding groups according to sex. There were thus 24 feeding groups, each containing 3—4 animals.

In the preliminary period the lambs were accustomed to silage feeding. In the first week of the period the lambs were given small amounts of concentrate in addition to silage; in the second and third weeks they received only silage. The experimental period proper started when the lambs were 2—3 months old and lasted 20 weeks.

The experiment was performed according to a factorial design comprising 4 silages, each with 3 different levels of carbohydrate supplements: 0 % carbohydrate (= only silage), 15 % sucrose and 15 % starch.

Silage was given *ad libitum* in every group. In the carbohydrate groups, the amounts of sucrose or starch given daily were changed every weeks to make their dry matter contents 15 % of the total dry matter content of the average daily ration consumed in the preceding week. The dry matter content of the sucrose was assumed to be 100 %, but the dry matter content of the starch was determined every week. The sucrose was pure sucrose and the starch powder pure potato starch. All the groups had free access to a mineral mixture, which contained 80 % of commercial product (Kultalypsy) and 20 % NaCl. Kultalypsy contains 10.0 % P, 23.5 % Ca, 12.9 % NaCl and 2.0 % Mg, plus trace elements of Fe, Cu, Co, Zn and J, and vitamins A, D_3 and E. The animals also had free access to water.

The animals were fed twice a day. They were first given the carbohydrate supplements, and immediately after these had been consumed they received the silage. The animals were weighed every second week.

Experimental silages

Conservation and analyses

The silages were prepared from the first cutting of sward, in which meadow fescue predominated. A basic fertilizing mixture was applied in spring, comprising 26 kg P, 50 kg K and 104 Kg N per hectare. The harvesting time was 13—16 June 1971, when the grass was about 25—30 cm high and the first ears near emergence or just formed.

The grass was chopped and the preservatives added during harvesting. 20 000 kg of grass was ensiled for each of four experimental silages. For three silages preservatives were used as follows:

AIV I solution 4.7 l/1 000 kg grass
Viher solution 4.0 »
Formic acid 4.3 »
AIV I: 25 % formic acid (86 %)
20 % hydrochloric acid (37 %)
Viher solution: 20 % formic acid (86 %)
70 % formalin (37 % formaldehyde)

The grass for the fourth silage was ensiled without any preservatives.

All the silages were conserved in tower silos, the silos being filled simultaneously. The pressure was 300 kg/m².

During the experiment samples were taken from the silages every week for dry matter determinations, and every second week for complete feed analyses.

The silage samples were subjected to standard food analyses and analysed for the properties used as criteria of the quality of silage. The methods used are explained in an earlier study (SYRJÄLÄ 1972).

Chemical composition and quality

The chemical composition of the dry matter was fairly similar in all the silages (Table 2), the differences being statistically significant in only a few cases ($P < 0.05$, $P < 0.01$).

Table 2. The mean chemical composition of the different silages.

Silage	Without preservatives	AIV I	Viher solution	Formic acid
Dry matter	21.1^{bd}	21.7^{abd}	21.3^{bd}	23.0^{ad}
% of dry matter:				
Ash	8.9	9.6	9.5	10.0
Organic matter .	91.1	90.4	90.5	90.0
Crude protein	20.2	22.0	23.2	20.6
True protein	9.2^{ae}	10.2^{ab}	12.0^{bd}	10.3^{ab}
Crude fat	7.1^{ae}	6.8^{ade}	7.0^{ade}	5.8^{bd}
N-free extract ...	39.1^{ab}	37.8^{ab}	36.3^{bd}	39.9^{ad}
Crude fibre	24.7	23.8	24.0	23.7
Crude carbohydrates	63.8	61.6	60.3	62.6

The Tukey test (STEELE and TORRIE 1960) was used for testing 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. The meaning of the index letters is the same in the other tables.

The dry matter content of the fromic acid silage was higher than that of the other silages. The fermentation of the carbohydrates was less in the formic acid silage than in the others. This reflects not only its higher content of N-free extract and lower crude protein content ($P < 0.05$ or $P < 0.01$), but also its higher sugar content and

Table 3. Data used as criteria of the quality of the different silages.

Silage	Without preservatives	AIV I	Viher solution	Formic acid
pH	4.18	4.12	4.23	4.25
% of fresh silage (20 % dry matter)				
Acetic acid ...	0.49^{bce}	0.55^{be}	0.79^{ad}	0.36^{ce}
Propionic acid	0.01	0.01	0.02	0.02
Butyric acid .	—	—	—	—
Lactic acid ...	2.99^{ad}	2.52^{abd}	2.37^{bd}	1.11^{ce}
Sugars as glucose	0.45^{ab}	0.39^{ab}	0.21^{bd}	2.16^{ad}
NH_3-N	0.05	0.05	0.05	0.03
% of total N				
NH_3-N	7.2	6.3	6.6	4.9
Soluble N	63.2	61.5	55.8	60.3

statistically significantly ($P < 0.05$ or $P < 0.01$) lower acetic acid and lactic acid contents (Table 3).

The true protein content was highest in Viher solution silage and lowest in silage without any preservatives ($P < 0.01$). The true protein proportion of the crude protein was 51.7 % in Viher solution silage, 50.0 % in formic acid silage, 46.4 % in AIV I silage and 45.5 % in silage without any preservatives. The soluble N fraction of total N was lowest in Viher solution silage, 55,8 %, and highest in silage without any preservatives, 63.2 %. The degradation of the crude protein fraction was thus less in Viher solution than in other silages, especially silage prepared without any preservatives, although the differences are not always statistically significant ($P > 0.05$). This is probably due to the formaldehyde contained by Viher solution, which has been shown to protect proteins against degradation (FERGUSON et al. 1967).

The quality of the silages was good. The pH of all of them was fairly low, between 4.12 and 4.25. Butyric acid did not occur in any of the samples. The NH_3 fraction of total N was less than 8 %, which is the maximum for silage of good quality (BREIREM and ULVESLI 1960, WIERINGA 1966).

Effect of preservatives on live-weight gain and feed intake

In the comparison of the growth and feed intake of the lambs on different silages, the results were calculated for both the diets consisting entirely of silage (0 % carbohydrate) (Figs. 1—3) and the diets with the two carbohydrate supplements (Table 4).

The growth of the lambs was significantly better on formic acid silage than on the other silages ($P < 0.01$ or $P < 0.05$). In the case of the diets consisting entirely of silage, the average growth on formic acid silage was about 30 % better than on AIV I and Viher solution silages and about 50 % better than on silage without any preservatives. This is at

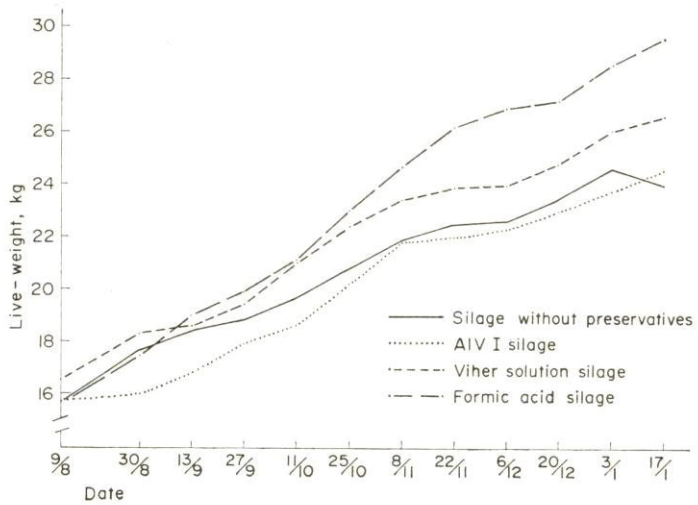

Figure 1. Live-weight gain of the lambs on different pure silage diets.

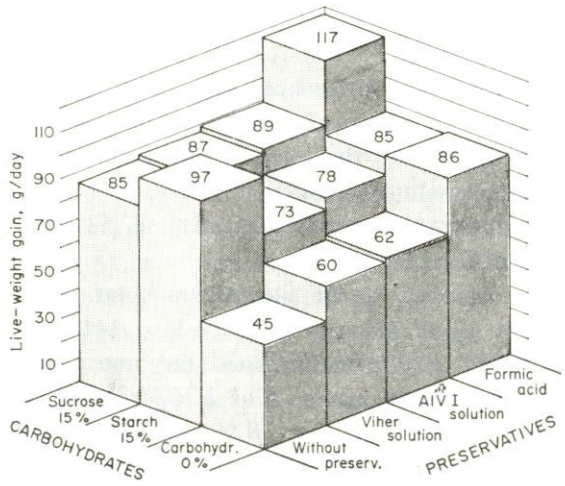

Figure 2. Average live-weight gain of the lambs on different diets.

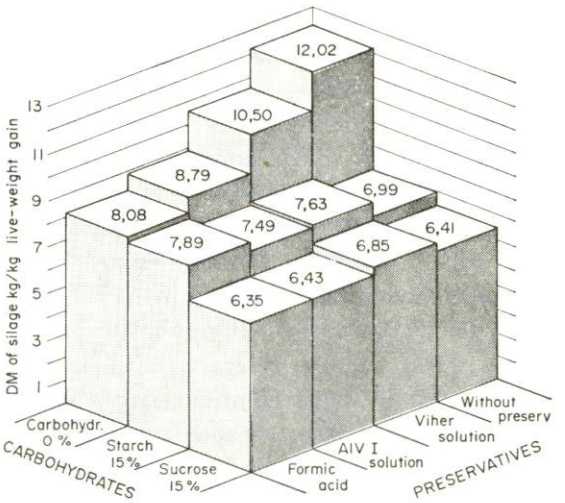

Figure 3. Average silage dry matter consumption/kg live-weight gain of the lambs on different diets.

Table 4. Live-weight gain and feed intake of lambs calculated for different silages and carbohudrate levels.

	Silages				Carbohydrate levels		
	Without preser-vatives	AIV I	Viher solution	Formic acid	0 % carboh.	15 % sucrose	15 % starch
Number of animals	22	22	23	21	31	29	28
Live-weight gain, g/day	75^{ade}	76^{ade}	74^{ad}	96^{be}	63^{d}	94^{ae}	83^{ae}
Silage intake							
fresh kg/day	2.72	2.62	2.78	3.00	2.73	2.78	2.83
dry matter, g/day	588^{bde}	567^{be}	594^{ab}	703^{ad}	603	614	623
Energy supply, total f.u./day	0.52	0.50	0.52	0.62	0.43^{d}	0.59^{ae}	0.60^{ae}
DCP supply, g/day	92^{bde}	89^{be}	93^{ab}	110^{ad}	95	96	98
Feed utilization, f.u./kg live-wight gain	6.93	6.58	7.03	6.46	6.83	6.28	7.23

least partly due to the differences in intake of the silages. The average daily consumption of formic acid silage was 3 kg/animal. The consumption of Viher solution silage was similar and that of the other silages about 2.5 kg/animal. As the dry matter content of formic acid silage is higher, the intake of dry matter was higher with it than with the other silages. The higher intake of the formic acid and Viher solution silages is probably partly attributable to the fact that the fermentation of carbohydrates in the former silage and that of crude protein in the latter had not gone as far as in the two other silages (Tables 2—3). It has been shown that an increase in the amount of fermentation products decreases the intake of silage (MOORE et al. 1960, EMERGY et al. 1961, THOMAS et al. 1961, SAUE 1968).

Although the total daily intake of the dry matter of formic acid silage was highest, its consumption per kg of live-weight gain was lowest, averaging 8.1 kg. The corresponding values for the other silages were 8.8 for AIV I silage, 10.5 for Viher solution silage and 12.0 for silage without any preservatives.

The utilization of silages was also assessed by calculating the number of feed units

(f.u.) needed by the lambs per kg of live-weight gain. The bulk of the silages was assumed to average 1.4 kg dry matter/f.u. (DM/f.u.) and the digestible crude protein (DCP) content was taken as 15.7 % of dry matter (ANON. 1969, SYRJÄLÄ 1972, 1974). When the dry matter contents of the silages are taken into account, 6.1 kg of formic acid is found to represent one feed unit and the values of the other silages are 6.5—6.6 kg/f.u. For the sucrose and starch, a value of 0.7 kg/f.u. was used.

The number of feed units per kg live-weight gain was lowest for formic acid silage, being 5.81. It was about 33 % lower than that of silage without any preservatives, what was 8.67. However, this differences diminished to 7 %, when the values were calculated for the diets with carbohydrate supplements (Table 4). The corresponding values for AIV I and Vihersolution silages on the diets containing only silage were 6.29 and 7.50, simultaneously.

Both the growth rates and the values describing the utilization of feeds were very poor in this experiment. The amounts of energy received daily, on average 0.54 f.u. were also scanty. It is remarkable that the increase in silage intake between the beginning and the end of the trial was only 0.5 kg. The energy obtained thus appears to have been insufficient, especially towards the end of the experiment. According to KELLNER and BECKER (1970), the energy requirement of 4—5 month-old lambs weighing 30 kg is 0.9 f.u./day, and the requirement of digestible crude protein is 105 g/day. The lambs in this experiment received protein about at this level; their intake of digestible crude protein with all the diets averaged 96 g/day.

The growth of the male lambs was about 16 % better than that of the female lambs

Table 5. Live-weight gain and feed consumption of male and female lambs.

	Males	Females	Average
Number of animals	46	42	88
Live weight at start of exp., kg	17.3	17.6	17.5
Live weight at end of exp., kg	29.3	27.9	28.6
Live-weight gain, g/day	86[ad]	74[bd]	80
Silage intake, DM g/day	601	635	618
Feed utilization, f.u./kg live-weight gain	6.12[ad]	7.41[bd]	6.77

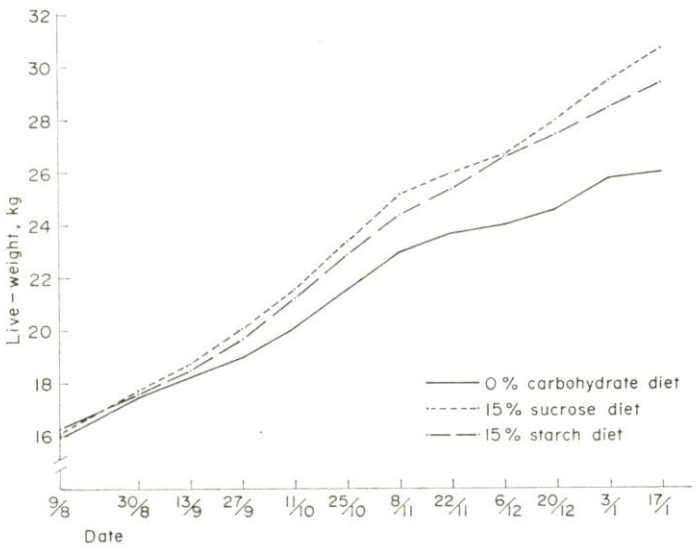

Figure 4. Live-weight gain of the lambs on different carbohydrate diets.

(Table 5). This was not due to a difference in the feed intake, since the females consumed more silage than the males, but the utilization of the feed was better in the males, 6.12 f.u./kg live-weight gain, than in the females, 7.41 f.u./kg live-weight gain ($P < 0.05$). This was due at least partly to the periods of oestrus occurring in the females during the experiment.

Effect of carbohydrate supplements on live-weight gain and feed intake

The effect of the sucrose and starch supplements is presented separately for each silage (Figures 2—3) and for all the silage diets together (Table 4, Fig. 4).

The growth of the lambs was significantly ($P < 0.01$) better when they received a sucrose or starch supplement with the silage than on silage alone. This is directly attributable to the fact that the animals received significantly ($P < 0.01$) more energy on the carbohydrate diets than on the pure silage diets, 0.59 and 0.60 f.u./ day on the former diets and 0.43 on the latter. This extra energy was mainly from sucrose or starch, for the intake of silage on the different diets did not differ significantly ($P > 0.05$). The sucrose and starch supplements probably also increased the utilization of silage in this experiment, in the same way as in earlier trials (SYRJÄLÄ 1972).

The average growth of the lambs on sucrose diet was better, though not significantly so ($P > 0.05$), than on starch diets. Feed utilization was also better on the sucrose diets than on the others.

The favourable effect of the sucrose and strach supplements on the utilization of silage is especially clear in the case of silage without any preservatives (Fig. 2). The growth of the lambs receiving sucrose and starch supplements was about 100 % better than that of the animals on silage alone ($P < 0.05$ and $P < 0.01$). On the AIV I and Viher solution silages, the lambs grew 44 and 45 % better with sucrose and 26 and 22 % better with starch supplements. On formic acid silage, the sucrose supplement increased the growth of the lambs by 36 %, whereas the starch supplement had no effect as compared with the pure silage diet.

The reason why the sucrose and starch supplements had a more favourable effect when given with silage without any preservatives than with formic acid silage is probably connected with differences in the fermentation levels of these silages (Table 3). The formic acid silage itself provided more soluble carbohydrates as an energy source for rumen microbes than the silage without any preservatives. Thus the carbohydrates were not so beneficial when given as supplements.

Wool growth on different silage and carbohydrate diets

For the determination of wool length growth and density, 10-cm^2 areas were clipped in the middle of both the scapula and femur of every lamb at the beginning of the experiment. At the end of the experiment, the wool length was measured on the same areas, and the wool was then clipped and weighed. In addition the total weight of the wool grown from the birth of the lambs to the end of the experiment was determined. The lenghts and weights of the wool are presented for the different silages and the different carbohydrate levels (Table 6).

The differences in wool growth rates between the lambs on the different silages were not statistically significant ($P > 0.05$).

Table 6. Wool growth on different diets.

Diets	Silages				Carbohydrate levels			Average
	Without any preservatives	AIV I	Viher solution	Formic acid	0 % carboh.	15 % sucrose	15 % starch	
Length of wool on scapula, cm	4.2	4.5	4.2	4.3	4.2	4.5	4.3	4.3
Length of wool on fumar cm	4.1	3.8	3.7	4.0	3.6^{ad}	4.2^{bd}	4.0^{ab}	3.9
Average length of wool, cm	4.2	4.2	4.0	4.2	3.9	4.4	4.2	4.1
[1]) Weight of wool, g/20 cm^2	11	11	10	12	10^{ad}	12^{bd}	11^{ab}	11
[2])Total weight of wool, g	724	721	767	903	668^{ad}	873^{bd}	799^{ab}	777

[1]) Washed
[2])From birth to end of exp., not wasned

However, the total amount of wool was greater on the formic acid diets than on the other silage diets, which can be explained by the larger size of the lambs on those diets at the end of the experiment.

A large number of experiments have shown that formaldehyde, by protecting dietary protein from ruminal degradation, has a beneficial influence on wool growth (FERGUSON et al. 1967, REIS and TUNKS 1969, BARRY 1972, BARRY and ANDREWS 1973). In this experiment, the wool growth rates on the silage preserved with Viher solution, which contains formaldehyde, were roughly similar to the rates on the other silages. The formaldehyde content was probably too low in this case to increase wool growth. In addition, it was evident that the wool growth rates were affected by the relatively low energy intake on all the silage diets, as vill be shown here.

The carbohydrate supplements increased the wool growth rates significantly ($P < 0.05$). The best results were obtained on the diets supplemented with sucrose. This was most probably because the energy intake was highest on precisely those diets. Wool growth depends closely on the level of feeding (MARSTON 1948), and this concerns not only the protein but also the energy intake (MARSTON 1955, SAUE 1968). When the energy supply in the diet is insufficient, protein is utilized as energy and too little protein is left for wool synthesis.

General remarks

The expressed results show that grass silage, if it is of good quality, is a good basic feed for growing lambs. Good quality means here that the content of fermentation products in the silage is relatively low. Formic acid silage, where the fermantation of carbohydrates was least, was clearly the best silage in this experiment. It seems that lambs are very sensitive to the quality of silage. Similar results have also been obtained in the case of ewes by NEDKVITNE (1969).

Silage is not sufficient as the only feed of growing lambs. This is not primarily due to a deficiency of protein, especially if the raw material of silage has been harvested at the young growth stage (SYRJÄLÄ 1974); the problem with very young lambs, as with pregnant and lactating ewes (SYRJÄLÄ

1972), is rather the bulk. The animals cannot eat silage in such large amounts that their energy requirement is satisfied. When the silage is supplemented with sucrose or starch, as in this experiment or with concentrates containing those carbohydrates, the growth of lamds can be increased significantly. This is due partly to increased energy intake and partly to increased silage utilization (SYRJÄLÄ 1972).

The beneficial effect of carbohydrate supplements on the growth rate and silage intake of lambs is most pronounced when the fermentation rate of silage is high, as without any preservatives. Sucrose generally gave better growth rate and feed utilization results than starch, but the differences were not significant.

There was no significant differences in wool growth between the different silage diets, in contrast to the position with the different carbohydrate levels. Besides protein, an ample energy supply is very important for wool growth.

The growth and other results achieved in this experiment remained rather modest. This may be due to the fact that the lambs were too young when they were changed to pure silage diets. The rumen of 2-month-old lambs should be sufficiently developed for utilizing forage, especially if the animals have been accustomed to it, but in practice the age of 3 months may be better for this kind of feeding. It should be mentioned that the low growth results in this experiment may be partly ascribable to the heterogeneity and rather poor genetic properties of the animal material. Some of the lambs finished their growth completely during the experimental period, which of course influenced the average values. Three lambs died during the experiment. Although the results thus fail to give a true picture of the growth rates of finnsheep, they do show the differences between the different diets.

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SELOSTUS

Karitsoiden kasvu, rehunkulutus ja villan kasvu eri säilörehu- ja hiilihydraattiruokinnoilla

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Tämän tutkimuksen tarkoituksena oli selvittää eri säilöntäaineilla valmistettujen nurmisäilörehujen soveltuvuutta karitsoiden kasvatusrehuksi sekä miten säilörehuruokinnan yhteydessä annettu sokeri- tai tärkkelyslisäys vaikuttaa karitsoiden kasvuun ja rehunkulutukseen sekä villan kasvuun.

Koe-eläimiä oli 91 suomenlampaan karitsaa, joiden ikä säilörehuruokinnalle siirrettäessä oli 8 viikkoa. Valmistuskauden pituus oli 3 viikkoa ja varsinaisen koekauden 20 viikkoa. Koe suoritettiin faktoriaalisen koekaavion mukaan, jossa tekijöinä oli neljä eri säilörehua; painorehu, AIV I, Viherliuos ja muurahaishapporehu, sekä kolme hiilihydraattitasoa: 0 % hiilihydraattia, 15 % sokeria ja 15 % tärkkelystä. Kokeessa seurattiin eläinten kasvua, rehunkulutusta ja villankasvua.

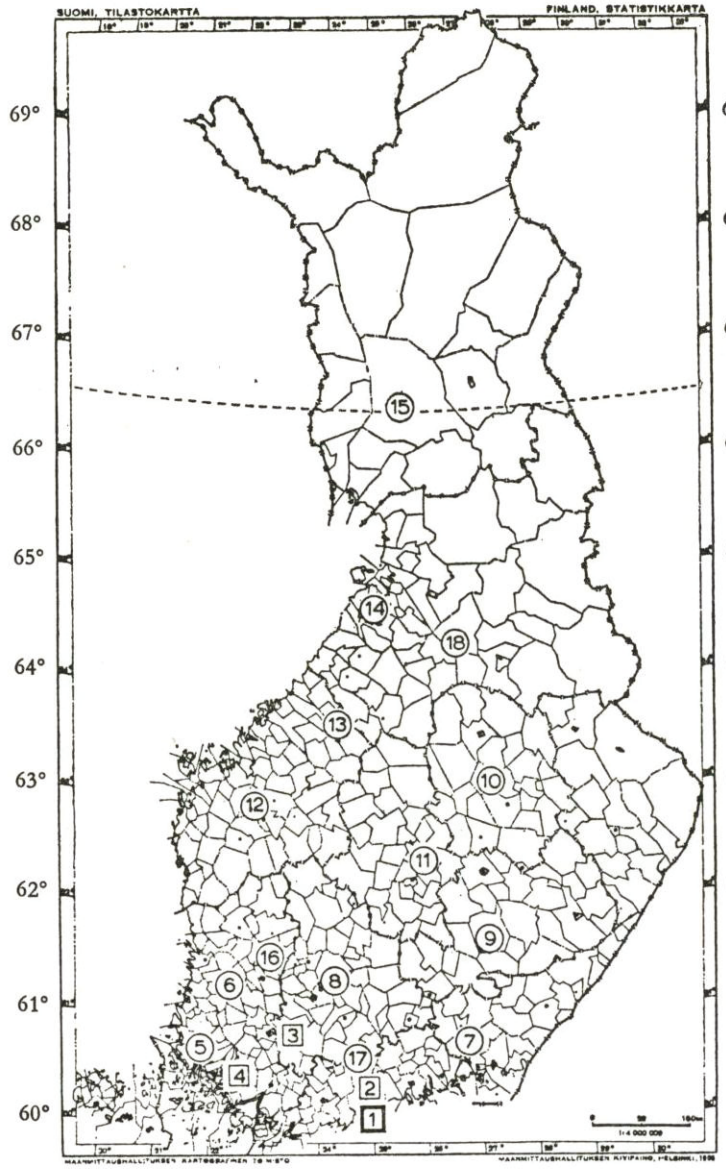
Tulokset osoittavat, että nurmisäilörehu, jos se on hyvänlaatuista, soveltuu hyvin karitsoiden kasvatusrehuksi. Hyvänlaatuinen tarkoittaa tässä sitä, että käymistulosten määrä pysyy suhteellisen alhaisena. Muurahaishapporehu, jossa hiilihydraattien käyminen oli vähäisintä, osoittautui selvästi parhaimmaksi rehuksi. Karitsat söivät sitä eniten ja kasvu sekä rehun hyväksikäyttö oli parempi kuin muilla säilörehuilla. Karitsat tuntuvat siis olevan erityisen herkkiä säilörehun laadun vaikutukselle.

Säilörehu karitsoiden ainoana kasvatusrehuna ei ole riittävää. Valkuaisesta ei niinkään tule puutetta, varsinkin silloin kun säilörehu on tehty nuorella kasvuasteella olevasta nurmesta. Ongelmaksi tulee kasvavilla karitsoilla, samoin kuin tiineillä ja imettävillä uuhillakin, lähinnä rehun täyttävyys. Karitsat eivät pysty syömään säilörehua niin paljon, että niiden energian tarve tulisi tyydytetyksi. Tämän vuoksi ne tarvitsevat lisäenergian lähteen rehuannoksen väkevöittämiseksi. Tähän tarkoitukseen sopivat hyvin kotoiset viljaväkirehut. Kun tässä kokeessa säilörehun lisäksi annettiin sokeria tai tärkkelystä 15 % koko rehuannoksen kuiva-ainemäärästä, parani karitsoiden kasvu merkitsevästi. Tämä johtui osittain siitä, että päivittäisen rehuannoksen energiasisältö tällöin nousi, sillä säilörehun syönti pysyi näillä hiilihydraattidieeteillä lähes samana kuin pelkillä säilörehudieeteillä. Myös sokeri- ja tärkkelyslisäysten aiheuttama säilörehun eri aineosien, erityisesti sen raakavalkuaisen hyväksikäyttöä parantava vaikutus tuli esiin tässä kokeessa. Tätä osoittaa mm. se, että lisäkasvukiloa kohti tarvittava ry-määrä oli sokeri- ja

tärkkelysdieeteillä pienempi kuin pelkällä säilörehudieetillä. Koska säilörehu oli ainoa valkuaisen lähde tässä kokeessa, pysyi näin ollen myös valkuaisen saanti lähes samanlaisena eri dieeteillä. Edullisin vaikutus karitsoiden kasvuun ja rehunkulutukseen saatiin sekä sokeri- että tärkkelyslisäyksellä painorehun yhteydessä eli sen säilörehun yhteydessä, jonka käyminen oli pisimmälle edennyt ja joka ainoana rehuna ollessaan antoi heikoimmat tulokset. Sokerilisäykset taas antoivat yleensä paremmat kasvu- ja rehunhyväksikäyttötulokset kuin tärkkelys, joskaan erot näiden välillä eivät olleet merkitseviä.

Villan kasvussa ei eri säilörehudieeteillä ollut merkitseviä eroja, eri hiilihydraattidieettien välillä sitä vastoin oli. Paras villankasvu saavutettiin sokeridieeteillä ja heikoin pelkällä säilörehulla. Syyn voidaan olettaa olevan karitsoiden hiilihydraattidieeteillä ja pelkällä säilörehudieetillä saadusta erilaisesta energiamäärästä.

Karitsoiden kasvu- ym. tulokset jäivät tässä kokeessa melko vaatimattomiksi. Tähän saattoi vaikuttaa se, että karitsat olivat liian nuoria kokeen alkaessa. Toisaalta kyllä 2 kk:n ikäisen karitsan pötsin pitäisi olla tarpeeksi kehittynyt käyttämään hyväksi karkearehua, varsinkin kun se on siihen totutettu. Käytännössä ehkä 3 kk:n ikä vastaavaan ruokintaan olisi sopivampi. On syytä mainita, että alhaisiin kasvutuloksiin voi myös tässä kokeessa vaikuttaa se, että eläinaines oli heterogeenista ja perinnöllisiltä ominaisuuksiltaan heikkoa. Kolme karitsaa kuoli kokeen aikana todennäköisesti elimellisiin vikoihin. Eräät karitsat lopettivat kasvun kokonaan, mikä tietenkin vaikuttaa keskiarvolukuihin. Vaikka saadut tulokset eivät tässä mielessä annakaan todellista kuvaa suomenlampaan kasvusta, osoittavat ne kuitenkin eri dieettien väliset erot.



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