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EFFECT OF LITTER PEAT, STRAW AND SAWDUST ON THE VALUE OF COW MANURE

ERKKI KEMPPAINEN

KEMPPAINEN, E. 1987. **Effect of litter peat, straw and sawdust on the value of cow manure.** Ann. Agric. Fenn. 26: 79—88. (Agric. Res. Centre, Dept. Agric. Chem. Phys., SF-31600 Jokioinen, Finland.)

Dairy cow manure was collected for analysis and experiments from 15 farms in southern and central Finland. In autumn 1983, five of the farms used straw, five used sawdust and five used peat as litter. In spring 1984, all of the farms used peat litter. Manure samples were taken from manure stores in December 1983 and again in March-April 1984. Samples were analyzed for total N, soluble N, P, K, Ca, Mg, dry matter and pH, and a pot experiment was carried out to examine the availability of nitrogen in the different manure samples.

Significant differences among the samples were found in the content of dry matter, total nitrogen and magnesium. Contents were highest in peat manures and lowest in sawdust manures. The replacement of straw and sawdust with peat clearly increased the nutrient content of manure. Significant differences were also found in the pot experiment. Peat manures were superior to straw and sawdust manures. Apparent recovery of total nitrogen was 14,7 % for the straw manures, 14,8 % for the sawdust manures and 23,7 % for the peat manures. The soluble nitrogen of peat manures was fully comparable to nitrogen in artificial fertilizer, whereas the value of soluble nitrogen in straw manures was about 70 % and that in sawdust manures less than 60 % compared to artificial nitrogen. Replacement of straw with peat increased the immediate nitrogen effect of manure by 1,8 kg of nitrogen/m^3 of peat, and replacement of sawdust with peat by 2,2 kg of nitrogen/m^3 of peat.

Index words: manure, peat, straw, sawdust, litter.

INTRODUCTION

Litter can influence the value of manure in many ways. It binds urine to solid faeces and increases thus the amount of plant nutrients in manure. This is very important in conditions where the utilization of liquid manure is difficult. On the other hand, litter materials generally contain only small amounts of plant nutrients. If litter is added to excrement in great amounts, it can decrease the percentage of plant nutrients in manure (KEMPPAINEN 1984). Straw and sawdust, moreover, can bind chemically only small amounts of ammonia. As the litter decomposes, ammonia is easily lost by volatilization, and a part of it is fixed to microbe cells into a form unavailable to plants (ANON. 1930, IVERSEN and DORPH-PETERSEN 1949).

In Finland, peat has always been regarded as the best litter. It binds the ammonia of urine much more effectively than do other litter materials (TUORILA 1929, KAILA 1950). In the 1930s it was already shown on practical farms that the content of soluble nitrogen is much higher in peat manure than in straw manure (KERÄNEN 1937). Nitrogen bound to peat is also conserved well in poor stores (von FEILITZEN 1914, SVINHUFVUD 1925). SVINHUFVUD (1925) showed that in optimal storage conditions (watertight covered store, manure tightly compressed) straw and sawdust litter decrease the fertilizing value of faeces, whereas peat litter manure retains its value as well as faeces without any litter.

The use of peat litter, however, is quite small. This is partly due to the high price of peat. The profitability of peat litter cannot be assessed on the basis of old experiments. Thus, the objective of this study was to determine how different litters influence the value of manure using modern manure handling systems and equipment. The study is a part of a larger research project examining the use of peat litter for dairy cows (PELTOLA et al. 1986).

MATERIAL AND METHODS

Dairy cow manure was collected for analysis and experiments from 15 farms in southern and central Finland. In autumn 1983, five of the farms used straw, five used sawdust and five used peat as litter. In spring 1984, all of the farms used peat litter. Manure samples were taken from manure stores in December 1983 and again in March—April 1984. The total number of manure samples was 30, five of which were straw manures, five sawdust manures and 20 peat manures. Manure samples were stored at +4 °C until analysis and then used in a pot experiment.

On some farms, a liquid manure sample was also taken in order to analyze the nutrient content of stored urine. Liquid manure sample was not obtained on every farm, because urine was not collected on all farms. The amount of manure produced per month was assessed visually during sample collection.

Straw and sawdust came from the farms but the peat was supplied by VAPO (a peat producing and processing company) and it is especially sold for use as litter. The peat was undecomposed *Sphagnum*-peat consisting mainly of *S. fuscum*. The amount of litter used per day varied considerably but averaged 2,3 kg peat/cow, 2,4 kg straw/cow and 3,8 kg sawdust/cow.

Manure samples were analyzed for total nitrogen, soluble nitrogen, phosphorus, potassium, calcium, magnesium, dry matter and pH. Soluble nitrogen was determined by extracting the sample with a HCl-$CaCl_2$-solution and by distilling ammonia with MgO. This method is traditionally used in Finland and the results obtained by it correlate well with those by direct distillation of manure ammonia with MgO (KEMPPAINEN 1984).

A pot experiment was carried out in order to examine the availability of nitrogen in different manure samples. The experimental plant was Italian ryegrass (*Lolium multiflorum* L.). Five kilograms of air-dry fine sand clay was weighed per six-liter pots. Manure pots were fertilized with 400 g manure/pot and controls with 0, 500, 1000, 1500 or 2000 mg nitrogen in artificial fertilizer/pot. In addition, into all the pots were added 400 mg P, 1000 mg K and 200 mg Mg in artificial fertilizer. Each treatment had four replicates. During the experiment, grass was cut four times and the content of nitrogen in grass analyzed by the Kjeldahl method.

RESULTS

Nutrient content of manure

The greatest differences between the manures were found in the dry matter and the total nitrogen content (Table 1). Due to the small number of farms, the differences were not statistically significant if only the samples from autumn 1983 were examined. If the 15 peat manure samples from spring 1984 were also taken into consideration, the reliability of the results increased so much that there were significant differences in the content of dry matter, total nitrogen and magnesium. The content of nutrients was highest in peat manures and lowest in sawdust manures.

As the results of the manure analyses were examined with respect to the replacement of sawdust or straw with peat at the end of December 1983, significant differences were found in the content of dry matter, total nitrogen and magnesium (Table 2). The change of litter always increased the nutrient content. On the farms with peat litter both in autumn 1983 and spring 1984, no differences were found between autumn and spring manure.

On each farm the amount of manure

Table 1. Effect of litter on the chemical properties of manure.

Litter (and time of manure collection)	Property of manure (nutrients = g/kg)								
	pH	DM %	Ntot.	Nsol.	P	K	Ca	Mg	Nsol./Ntot. %
Straw (autumn)	7,52	14,9	4,42	1,22	1,35	3,54	1,48	0,70	27
Sawdust (autumn)	7,54	14,2	3,69	1,23	0,91	3,43	1,25	0,55	32
Peat (autumn + spring)	7,70	16,9	4,99	1,51	1,10	4,02	1,71	0,74	30
F-value		6,4**	8,1**					4,4*	
Peat (autumn)	7,88	16,6	4,81	1,55	1,01	3,75	1,87	0,72	31

* = significant at 5 % level (P = 0,05), ** = significant at 1 % level (P = 0,01)

Table 2. Effect of replacement of straw and sawdust with peat on the chemical properties of manure.

Collection time of manure	Straw in autumn 1983 Peat in spring 1984	Sawdust in autumn 1983 Peat in spring 1984		
	Ntot. g/kg	DM %	Ntot. g/kg	Mg g/kg
Autumn 1983	4,42	14,2	3,69	0,55
Spring 1984	5,42	16,9	4,72	0,71
F-value	6,1*	7,5*	7,9*	6,2*

* = significant at 5 % level (P = 0,05)

produced per month was assessed both in autumn 1983 and spring 1984. The aim was to examine whether the change of litter had any influence on the total amount of nutrients in the manure. The only statistically significant change (P = 0,05) was an increase in the amount of soluble nitrogen by more than 100 % when sawdust was replaced with peat. It was very difficult to assess the amount of manure.

No statistically significant differences were found between the liquid manure samples from different farms.

Value of manures in the pot experiment

There were significant differences between the fertilizing effect of different manures (Fig. 1). Peat manures were the most effective and sawdust manures the least effective. The superiority of peat manures was especially clear in the results of the second cut. No differences were found in the results of the first cut, but this was only because the amount of nitrogen was not yet limiting growth. When the results of the four cuts were combined, the peat manures produced more than a 100 % higher yield increase compared to the sawdust manures. Fig. 1 presents only the results of manure samples collected in December 1983.

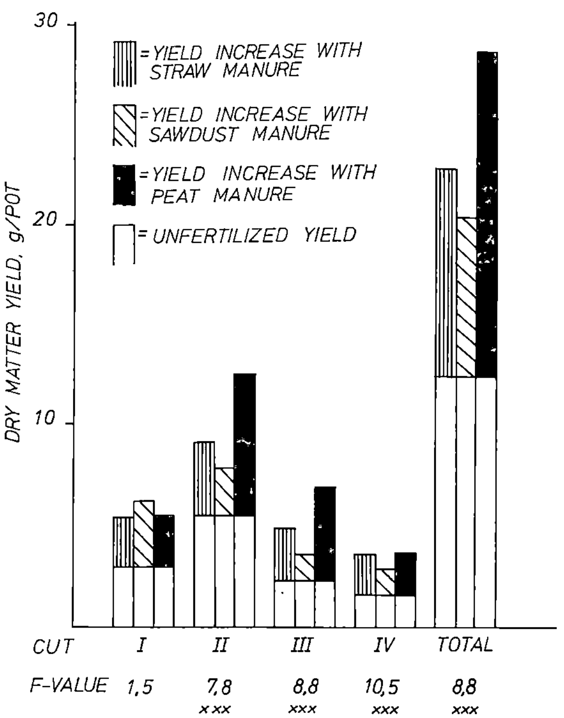

Fig. 1. Effect of litter on the fertilizing value of manure in the pot experiment. (*** = significant at 0,1 % level (P = 0,001))

The replacement of straw or sawdust with peat at the end of December 1983 clearly improved the fertilizing value of manure (Fig. 2). On farms with peat both in autumn 1983 and spring 1984, there was no significant difference between the effect of autumn manure and spring manure.

Since the soil used in the pot experiment was fertile top soil from a cultivated field supplied with P, K and Mg, yield increase was mainly caused by the nitrogen in manure. This was also seen in the correlation of yield increase with manure properties. Yield increase correlated significantly only with the content of total and soluble nitrogen in manure.

Apparent recovery of nitrogen

The apparent recovery of nitrogen was obtained by calculating the percentage of extra nitrogen uptake (compared to unfertilized) from the amount of nitrogen added in manure or fertilizer (Table 3). In the first cut, the apparent recovery of nitrogen was the highest for sawdust manures, but in the second and third cuts, and in the total yield it was clearly the highest for peat manures. In the total yield, the apparent recovery of manure total nitrogen was almost the same for straw manures and sawdust manures, but apparent recovery of manure soluble nitrogen was clearly higher for straw manures than that for sawdust manures.

In the first cut, the plants had taken up a far higher percentage of manure soluble nitrogen

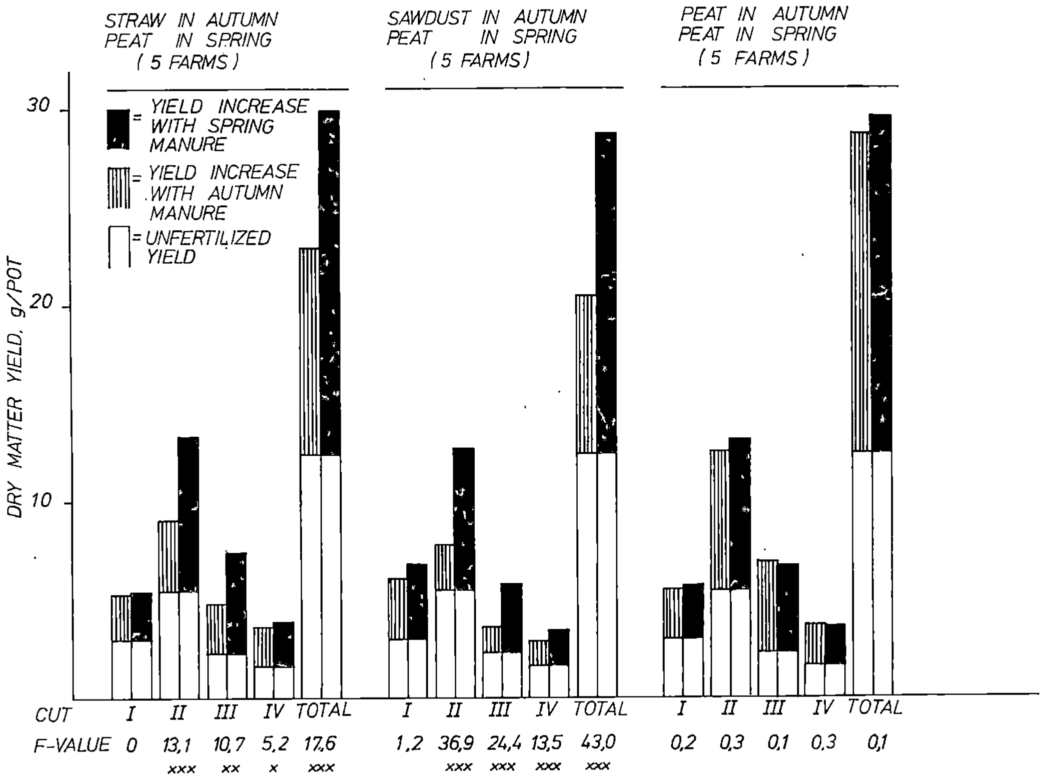

Fig. 2. Effect of replacement of litter on the fertilizing value of manure in the pot experiment. (* = significant at 5 % level (P = 0,05), ** = significant at 1 % level (P = 0,01), *** = significant at 0,1 % level (P = 0,001))

Table 3. Apparent recovery of nitrogen in the pot experiment.

Manure or fertilizer and the amount of N contained	Apparent recovery of nitrogen, %				
	1st cut	2nd cut	3rd cut	4th cut	Total yield
		Total nitrogen of manure			
Straw manure 1748 mg/pot	6,6	4,4	1,8	1,9	14,7
Sawdust manure 1476 mg/pot	9,6	2,5	1,2	1,5	14,8
Peat manure 1996 mg/pot	8,1	11,2	2,7	1,7	23,7
F-value	3,3*	8,4***	9,5***	3,0	7,5**
		Soluble nitrogen of manure			
Straw manure 488 mg/pot	26,4	12,0	6,7	8,3	53,6
Sawdust manure 492 mg/pot	30,9	4,3	3,8	5,4	44,7
Peat manure 604 mg/pot	30,1	36,8	9,9	7,4	84,5
F-value	0,5	14,8***	11,4***	2,0	18,8***
		Nitrogen in artificial fertilizer			
Fertilizer 500 mg/pot	7,4	55,1	12,7	1,2	76,6
Fertilizer 1000 mg/pot	2,6	50,3	22,2	2,4	77,6
Fertilizer 1500 mg/pot	1,5	34,3	38,2	4,1	78,2
Fertilizer 2000 mg/pot	2,1	26,3	45,2	5,0	78,7

* = significant at 5 % level (P = 0,05), ** = significant at 1 % level (P = 0,01), *** = significant at 0,1 % level (P = 0,001)

Table 4. Percentage of manure nitrogen comparable to nitrogen in artificial fertilizer.

Manure type	% of manure nitrogen comparable to artificial nitrogen	
	Total nitrogen	Soluble nitrogen
Straw manure	18,9	68,9
Sawdust manure	19,0	57,4
Peat manure	30,9	108,6
F-value	7,5*	18,8***

* = significant at 5 % level (P = 0,05), *** = significant at 0,1 % level (P = 0,001)

than of the corresponding amount of nitrogen in artificial fertilizer. The effect of artificial nitrogen was highest in the second and the third cuts, where the recovery of straw manure nitrogen and sawdust manure nitrogen was already quite small. In the fourth cut, however, the apparent recovery of manure soluble nitrogen was clearly higher than that of artificial nitrogen.

Since the apparent recovery of nitrogen in artificial fertilizer averaged 77,8 %, varying only slightly, the value of manure nitrogen compared to artificial nitrogen could be calculated (Table 4). The soluble nitrogen of peat manure was as effective as nitrogen in artificial fertilizer, but the value of soluble nitrogen of straw manure was about 70 % and that of sawdust manure less than 60 % compared to nitrogen in artificial fertilizer. The amount of nitrogen in the four grass yields correlated significantly (P = 0,001, r = 0,90—0,95) with the amount of total and soluble nitrogen added into the pots via manure. The correlations were almost the same for the different manures.

The apparent recovery of nitrogen and the value of manure nitrogen compared to that of artificial nitrogen fertilizer were both calculated from the results obtained with manure samples collected in autumn 1983. If the peat manure samples collected in spring 1984 are also taken into consideration, the results are the same, but the statistical significance is still higher.

The replacement of straw and sawdust with peat at the end of December 1983 resulted in an increase of the effectiveness of manure nitrogen. In the manures collected from the farms using straw litter in autumn 1983, the apparent recovery of total nitrogen increased from 14,7 % to 22,5 %, and the apparent recovery of soluble nitrogen increased from 53,6 % to 78,9 %. In the manures collected from the farms using sawdust litter in autumn 1983, the corresponding increases were from 14,8 % to 23,6 % and from 44,7 % to 76,1 %. All of these increases were statistically significant (P = 0,001). The apparent recovery of nitrogen from peat manure changed only slightly from autumn 1983 to spring 1984. The apparent recovery of total nitrogen decreased from 23,7 % to 23,1 % and the apparent recovery of soluble nitrogen increased from 84,5 % to 90,5 %, but these changes were not statistically significant.

Profitability of peat litter

The effectiveness of different litters was measured by calculating how they influenced the nutrient content of manure and the availability of its nitrogen. Replacement of straw with peat increased the immediate nitrogen effect of manure by 0,66 kg of nitrogen/1000 kg of manure. Replacement of sawdust with peat resulted in an increase of 0,80 kg of nitrogen/1000 kg of manure. Since the average amount of peat litter used was 360 l/1000 kg of manure, peat increased the immediate nitrogen effect of manure by 1,8 kg of nitrogen/m^3 of peat, replacing straw with it and by 2,2 kg of nitrogen/m^3 of peat, as sawdust was replaced with it. The cost of 1,8 kg of nitrogen in the least expensive nitrogen fertilizer was in autumn 1984 5,5 FIM and the cost of 2,2 kg nitrogen was 6,7 FIM, respectively.

DISCUSSION

The differences in the nutrient content of the manures examined are mainly explained by the effect of different litters. Peat was the most effective in binding urine to solid manure. Sawdust manure contained slightly less nutrients than the other manures and this may result from the fact that sawdust was added to the faeces in larger amounts than other litters. Differences among the manures, however, were surprisingly small compared to the results of earlier experiments (von FEILITZEN 1911, KERÄNEN 1937). The difference between this experiment and earlier experiments may be due to differences in the storing of manure. The manure samples examined in this study were collected and stored during the cold autumn and winter months and thus may have retained their nutrients relatively well.

Differences among the manures, however, were clearly seen in the results of the pot experiment. There were significant differences in the growth of ryegrass and apparent recovery of nitrogen. Peat was always superior to the other litters. The results are analogous to those obtained by von FEILITZEN (1914) and SVINHUFVUD (1925).

The most important single finding of this study was that ryegrass was able to utilize all of the soluble nitrogen from peat manure but only about 70 % of the soluble nitrogen provided by straw manure and less than 60 % of the soluble nitrogen in sawdust manure. However, this may not be the rule. Apparently, the availability of nitrogen from straw manure and sawdust manure depends on the degree of decomposition of the litter. It can be calculated from the manure analysis data presented by KERÄNEN (1937) that the content of soluble nitrogen in straw manure did not at all depend on the content of total nitrogen ($r = -0{,}06$). The content of soluble nitrogen was thus determined by some other factor; apparently by the degree of decomposition of litter. In peat manures, however, the correlation between the content of soluble nitrogen and total nitrogen was very clear ($r = 0{,}78$, $P = 0{,}001$). No sawdust manures were analyzed by KERÄNEN (1937). If manure contains an abundance of undecomposed straw or sawdust litter, the value of soluble nitrogen analysis may be poor because the amount of nitrogen volatilized or fixed during decomposition cannot be assessed precisely. If the litter, however, is decomposed during the storing of manure, it will not fix nitrogen in the soil anymore. It should be studied whether the degree of decomposition of manure can be determined reliably and if this determination can be used in assessing the availability of manure nitrogen. For peat manures, however, the content of soluble nitrogen expresses the availability of nitrogen to plants rather well, which may be due to the slow decomposition rate of peat.

Stored manure may contain large amounts of soluble nitrogen, which, however, is not available to plants as manure is mixed with the soil. This has been demonstrated for example by von FEILITZEN (1911, 1914), who found that sawdust manure contained much more soluble nitrogen than did straw manure, but, its value as a fertilizer was clearly smaller than that of straw manure, however. Obviously sawdust fixes more nitrogen than straw does during decomposition in the soil, a phenomenon seen also in this study. The decomposition of litter in a manure heap and thus the fixation of soluble nitrogen into an organic form may be retarded, for instance, by a shortage of oxygen, high salt concentration or low temperature. As the manure is mixed into warm soil, decomposition begins immediately and a part of the soluble nitrogen is fixed. It has been shown in experiments using a stable nitrogen isotope that also a part of the soluble nitrogen of slurry can be fixed in the soil into a form unavailable to plants (RAUHE et al. 1973).

The apparent recovery of manure total nitrogen averaged 14,7 % for straw manures, 14,8 % for sawdust manures and 23,7 % for peat manures. The percentage of total nitrogen comparable to nitrogen in artificial fertilizer was 18,9 % for straw manures, 19,0 % for sawdust manures and 30,9 % for peat manures, respectively. These figures correspond with those in the literature. In the first year, the apparent recovery of total nitrogen of solid cow manure and the solid phase of cow slurry is 15—27 % (RAUHE and KOEPKE 1968, RAUHE et al. 1973, WEDEKIND 1983, ZHAO-LIANG et al. 1983). The percentage of total nitrogen comparable to the nitrogen in artificial fertilizer is 10—45 % (KOFOED 1977, SLUIJSMANS and KOLENBRANDER 1977, PRATT and CASTELLANOS 1981, ANON. 1982, NEMMING 1982, LARSEN and KOFOED 1983, ZHAO-LIANG et al. 1983). In this study, the percentage of total nitrogen in straw manures and sawdust manures comparable to nitrogen in artificial fertilizer was almost the same as that reported to be the percentage of soluble nitrogen of total nitrogen in solid cow manure (KERÄNEN 1937, 1966, YLÄNEN 1958, ASMUS et al. 1971).

It was calculated that replacement of straw and sawdust litter with peat increased the value of manure by 1,8—2,2 kg of nitrogen/m^3 of peat or by 5,5—6,7 FIM/m^3 of peat. This is a rather low figure compared to the cost of peat, which generally is 20—30 FIM/m^3. Peat may, however, have other positive effets which have to be taken into consideration in assessing its profitability. For instance, it decreases the ammonia concentration in cowshed air. According to a recent comprehensive study by PELTOLA et al. (1986) peat litter is competitive with straw and sawdust, at least if other litters are not supplied by the farm itself. The advantage obtained by replacing straw or sawdust with peat, however, is quite high compared to the differences in the ammonia binding capacity of litters. On the basis of ammonia binding capacity, the advantage of peat compared to straw or sawdust is about 1 kg of nitrogen/m^3 of peat. Comparison of different litters on the basis of their ammonia binding capacity may lead to erroneous results because the nitrogen effect of manure depends also on other factors.

It remains unclear in this study, whether peat really binds more urine than do straw and sawdust, and whether its use thus is especially advantageous with respect to the environment. Differences in the nutrient content of manure may also be explained by a smaller nutrient loss from peat manure than from other manures during storage. The liquid binding capacity of peat is in practice twice that of straw and three times that of sawdust (PELTOLA et al. 1986). Peat, however, cannot retain liquid effectively under pressure, and in experiments with compressed manure (pressure up to 50 N/cm^2) the liquid binding capacity of peat decreased to a lower level than that of straw and sawdust (PELTOLA et al. 1986).

The advantage of peat litter may be much higher in poor storage conditions than it was in this study. It may also be higher when the manure is spread during autumn or winter. Peat manure retains its nutrients much better than straw manure or sawdust manure do in unfavourable conditions (SVINHUFVUD 1925).

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SELOSTUS

Kuiviketurpeen, -oljen ja -sahanpurun vaikutus lannan arvoon

ERKKI KEMPPAINEN

Maatalouden tutkimuskeskus

Oljen, sahanpurun ja turpeen vaikutusta lannan arvoon tutkittiin 15 maatilalla syksyn 1983 ja kevään 1984 aikana. Syksyllä viisi tiloista käytti kuivikkeena olkea, viisi sahanpurua ja viisi turvetta. Keväällä kaikilla tiloilla oli kuivikkeena turve. Tiloilta otettiin lantanäytteet varastoidusta lannasta joulukuussa 1983 ja maalis—huhtikuussa 1984. Lantojen ravinnepitoisuus analysoitiin ja niillä tehtiin astiakoe typen käyttökelpoisuuden selvittämiseksi.

Eri kuivikelantojen välillä oli tilastollisesti merkitseviä eroja kuiva-aine-, kokonaistyppi- ja magnesiumpitoisuudessa. Turvelantojen pitoisuudet olivat suurimpia. Vuoden vaihteessa 1983—1984 tehty kuivikkeen vaihdos turpeeseen kohotti merkitsevästi aiemmin olkea käyttäneiden tilojen lannan kokonaistyppipitoisuutta sekä aiemmin purua käyttäneiden tilojen lannan kuiva-aine-, kokonaistyppi- ja magnesiumpitoisuutta.

Kuivikkeella oli hyvin selvä vaikutus lannan arvoon raiheinän lannoitteena astiakokeessa. Vaikutus tuli ilmi sekä vertailtaessa syksyn 1983 aikana kerättyjä eri kuivikkeita sisältäneitä lantoja keskenään että selvitettäessä kuivikkeen vaihdon vaikutusta. Turvelannat olivat ylivoimaisia olki- ja sahanpurulantoihin verrattuina. Tutkittaessa lannassa annetun typen hyväksikäyttöä todettiin, että olki- ja sahanpurulannan kokonaistypestä oli väkilannoitetypen veroista noin 19 %, turvelannan typestä noin 30 %. Lannan liukoisesta typestä oli väkilannoitetypen veroista olkilannassa 69 %, purulannassa 57 % ja turvelannassa hieman yli 100 %. Vain turvelannan liukoinen typpi oli kokonaisuudessaan kasveille käyttökelpoista.

Turvelanta sisälsi käytettyä turvekuutiota kohden 1,8 kg enemmän väkilannoitetypen veroista typpeä kuin olkilanta ja 2,2 kg enemmän kuin purulanta. Lokakuun 1984 hintatasossa turpeen etu oli 5,5—6,7 mk/m^3 turvetta.

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Seria AGROGEOLOGIA ET -CHIMICA N. 142 — Sarja MAA JA LANNOITUS n:o 142

AMMONIA BINDING CAPACITY OF PEAT, STRAW, SAWDUST AND CUTTER SHAVINGS

ERKKI KEMPPAINEN

KEMPPAINEN, E. 1987. **Ammonia binding capacity of peat, straw, sawdust and cutter shavings.** Ann. Agric. Fenn. 26: 89—94. (Agric. Res. Centre, Dept. Agric. Chem. Phys., SF-31600 Jokioinen, Finland.)

The ammonia binding capacities of *Sphagnum* peat, sawdust, cutter shavings, barley straw and oat straw were determined. Determinations were carried out by adding to the litter a known amount of ammonia solution and measuring the amount of ammonia liberated during vacuum drying.

Peat samples were superior to the other litters with respect to ammonia binding capacity. When the moisture content of the litter-water mixture was 10 %, peat bound ammonia 2,3 % per dry matter, barley straw 0,6 %, long oat straw 0,4 %, chaffed oat straw 0,5 %, cutter shavings 0,7 % and sawdust 0,5 % per dry matter. Ammonia binding capacity increased somewhat with a higher moisture content. Chaffing seemed to increase the ammonia binding capacity of oat straw, but did not influence the effectiveness of barley straw. The procedure employed for the determination of ammonia binding capacity was both easy and reliable.

Index words: ammonia, litter, peat, straw, sawdust, cutter shavings, manure, urine.

INTRODUCTION

The effect of litter on the value of manure is closely correlated with its ability to bind urinary ammonia. According to TUORILA (1929), peat moss consisting of *Sphagnum fuscum* is the most effective litter with respect to ammonia binding capacity. Peat moss has been reported to bind ammonia by as much as 1,9—3,5 % per dry matter (ref. TUORILA 1929). The degree of decomposition of peat has only a minor influence on its ammonia binding capacity according to TUORILA (1929) and PUUSTJÄRVI (1956).

The binding of ammonia to peat is the result of a chemical reaction, whereby free NH_3 molecules are transformed into fixed NH_4^+ cations. The higher the base-neutralizing capacity of peat, the greater its ammonia binding capacity. Furthermore the capacity to bind ammonia is highly variable for different types of peat (TUORILA 1929).

The capacity of litters to bind positively charged ions (and ammonia) can be measured in many ways. TUORILA (1929) measured it by adding to peat a known amount of ammonia in a water solution and then determined the amount of ammonia liberated during vacuum drying. The binding of cations into peat has also been studied by shaking a peat sample in a solution of a known cation content, and then determining the decrease in the cation content of the solution. In addition, a procedure has been used where the cation content of a test solution is determined after eluting it through a peat column (TUMMAVUORI and AHO 1980a, 1980b, TUMMAVUORI et al. 1983, AHO and TUMMAVUORI 1984). PUUSTJÄRVI (1956) measured the exchange capacity of peat by extracting a hydrogen saturated peat sample with barium acetate solution then titrating the solution with alkali. However, PUUSTJÄRVI (1956) and TUMMAVUORI and AHO (1980a) all emphasized, that the exchange capacity and the cation binding capacity of peat are not absolute quantities, but instead depend strongly on the method of determination, on the conditions during determination and on sample preparation. In addition, both peat type and geographic location of the peatland can influence the ion exchange properties of peat (TUMMAVUORI and AHO 1980a).

The aim of this study was to examine whether the ammonia binding capacities as determined by TUORILA (1929) are still applicable when assessing modern peat products and to estimate the advantage of peat compared to other litter materials. A further aim was to test the reliability of the determination method used by TUORILA (1929).

MATERIAL AND METHODS

Ammonia binding capacities of peat, sawdust, cutter shavings, barley straw and oat straw were determined in laboratory experiments. Three commercial peat products were employed: general peat 100, horticultural peat and peat for oil removal, all supplied by VAPO, a Finnish company that produces and processes peat. All peat products consisted mainly of *Sphagnum fuscum* and were similar in appearance. They also behaved similarly in the determinations and, consequently, the results are not presented for different peat products separately, but instead one common value is given. Ammonia binding capacity was determined both for long (about 5 cm) and chaffed (0,5—1,0 cm) straw. The original pH value, as measured in deionized water, was 3,85 for peat, 5,28 for sawdust, 4,64 for cutter shavings, 5,88 for barley straw and 5,85 for oat straw.

In principle ammonia binding capacity of the litters was determined by the same method used by TUORILA (1929). A litter sample, corresponding to five grams of dry matter, was inserted into a thickwalled flask. 75 ml of ammonia solution containing 360—390 mg of ammonia was then added to the sample and the flask tightly closed with a rubber stopper.

After a two-day incubation period the amount of ammonia volatilizable from the flask was determined by vacuum drying. At the same time the amount of water volatilized from the flask was measured. The flasks were evacuated by a water suction pump in a water bath at 70—80 °C. Placed between the flask and the pump were two glass tubes each containing 30 ml of 1 N H_2SO_4. These tubes and their contents were replaced and the evacuation flask weighed at 30, 60, 90, 120, 180, 240 and 300 min after the start of evacuation. The amount of nitrogen in the glass test tubes was determined by distilling it to a boric acid solution and by titrating the receiver solution. All determinations were carried out five times, and the results presented later are averages for these determinations. The equipment used for the determinations is shown in Fig. 1. In some experiments, 50 ml of 10 N NaOH was added to the litter after evacuation. The amount of

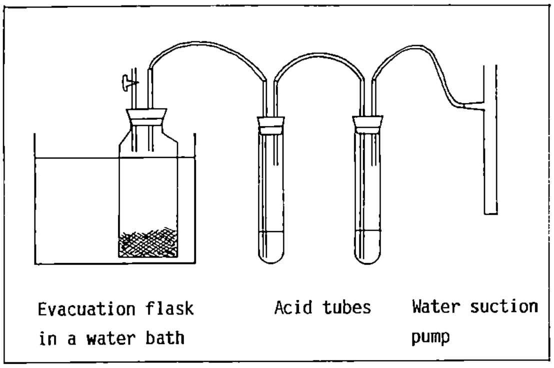

Fig. 1. Equipment used for determining ammonia binding capacity of the litters.

nitrogen liberated was then measured again.

Ammonia loss during the procedure was measured five times using a flask in which only ammonia solution, but no litter, was added. The amount of ammonia lost averaged 5,2 mg, which was 1,3 % (s = 0,56) of the amount added to the flask. As the amount of litter in a flask in the actual experiments was five grams of dry matter, ammonia loss may have increased the value of ammonia binding capacity on average by 0,10 % (s = 0,04) per dry matter of the litter. This error has not been subtracted from the results presented later.

In the results, ammonia binding capacity is expressed as corresponding to a 70 % and a 10 % moisture content of a litter-water mixture. According to TUORILA (1929) the moisture content of 70 % corresponds to that of manure only slightly dried on the field, and the moisture content of 10 % corresponds to that of manure heavily dried in warm sunshine.

RESULTS

During vacuum drying, the content of ammonia per dry matter of peat decreased very rapidly to 2,8 %, but thereafter decreased slowly. Fig. 2 presents the content of ammonia in a peat sample during evacuation. When the moisture content of the peat-water mixture was 70 %, the content of ammonia per dry matter of peat was 2,7 %, and when the moisture content was 10 %, the respective ammonia content was 2,3 % (Table 1).

Sawdust and cutter shavings bound only a small amount of ammonia compared to peat (Table 1). Cutter shavings were more effective than sawdust. Barley straw was as effective as cutter shavings, but the effectiveness of oat straw was on the same order as that of sawdust. Chaffing had practically no influence on the ammonia binding capacity of barley straw, but did seem to increase the effectiveness of oat straw.

Most ammonia bound by the litter could be liberated by adding NaOH (Table 1). However, some ammonia was retained by the litter also following treatment with NaOH.

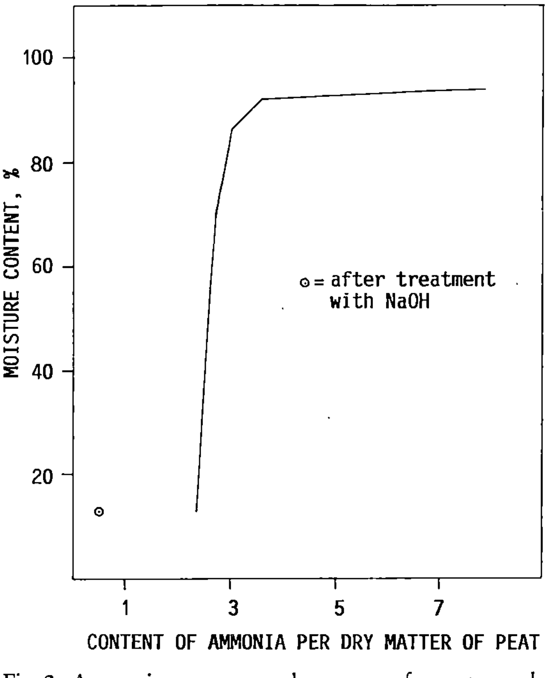

Fig. 2. Ammonia content per dry matter of a peat sample during drying.

Table 1. Ammonia binding capacity of different litters.

Litter	Ammonia bound, % per dry matter of the litter		
	70 % moisture content	10 % moisture content	After treatment with NaOH
Sphagnum peat	2,72	2,32	0,40
Barley straw, long	0,82	0,64	0,15
Barley straw, chaffed	0,84	0,64	0,15
Oat straw, long	0,50	0,38	0,10
Oat straw, chaffed	0,66	0,52	0,15
Cutter shavings	0,80	0,66	0,15
Sawdust	0,58	0,46	0,10
Tukey's HSD (P = 0,05)	0,20	0,21	

DISCUSSION

Peat was superior to other litters with respect to ammonia binding capacity. In this study, peat was clearly able to bind ammonia better (2,3—2,7 %) compared to that reported in the study of TUORILA (1929) in which peat bound ammonia about 2 % per dry matter. However, many experiments have been carried out where the ammonia binding capacity of peat is on the same order as in this study or even higher, up to 3,5 % per dry matter (ref. TUORILA 1929). It is evident that the ammonia binding capacity of peat varies considerably, ranging from 1,5 to 3,5 % per dry matter for *Sphagnum* peats. However, it can be concluded on the basis of the literature that the average approximates 2 % per dry matter.

High ammonia binding capacity may also partly result from experimental errors. As ammonia binding capacity was determined as the difference between the amount of ammonia added to the flask and the amount of ammonia liberated during vacuum drying, ammonia loss may have increased its value. With flasks containing only ammonia solution it was shown that on the average, ammonia loss increased the calculated value of ammonia binding capacity by 0,10 %. This error has not been subtracted from the results.

Barley straw bound ammonia more effectively than did oat straw. According to PELTOLA et al. (1986), barley straw also absorbs liquid more effectively than does oat straw. In general, the ammonia binding capacities of straw, sawdust and cutter shavings were on the same order as those presented in the literature, or slightly higher. According to TUORILA (1929), straw, sawdust and cutter shavings have been reported to bind ammonia 0,2—0,6 % per dry matter.

Most ammonia could be liberated from the litter by adding NaOH. However, part of the ammonia appeared to be bound so tightly that it was not replaced by NaOH. Of the amount of ammonia bound by peat, about 15 % was retained also after treatment with NaOH, and for straw, sawdust and cutter shavings the corresponding percentage was about 20 %. Thus, all of the ammonia bound by litter is not available to plants. Ammonia can be bound tightly to litter both by a chemical reaction and by incorporation into microbe cells. It should however, be noted that the amount of ammonia not liberated, even by treatment with NaOH, also contains the experimental error caused by nitrogen loss.

The method for determining ammonia binding capacity appeared to be rather reliable. Successive determinations often gave identical results. However, it is recommended that each determination be repeated 3—4 times. The equipment required for the determination is quite simple, and the determinations are easy, as well.

It can be concluded that acid *Sphagnum* peat binds urinary ammonia far more effectively than do other litters. If it is assessed that in practice the moisture content of peat and sawdust is about 40 %, and that of straw and cutter shavings 20 %, then about 8 kg of peat, 21 kg of barley straw, 21 kg of cutter shavings and 38 kg of sawdust are needed to bind 120 g of ammonia (the amount of ammonia in cow urine per day). However, according to TUORILA (1929) and VIRRI (1941), urine can be also collected and stored satisfactorily with a significantly smaller amount of peat if the volatilization of ammonia is prevented by a physical means, i.e. by compressing and covering the manure heap carefully.

However, the effect of litter on the value of manure does not depend only on its capacity to bind ammonia in urine. Peat is also superior to other litters because it decomposes very slowly and does not cause the fixing of ammonia into an organic form, as do other litters. In a pot experiment carried out by KEMPPAINEN (1987) it was found that the soluble nitrogen in peat manure is as effective as the nitrogen in artificial fertilizer, whereas the effectiveness of soluble nitrogen in straw manure is only 69 %, and that in sawdust manure 57 % compared to the nitrogen in artificial fertilizer. Significant immobilization of soluble nitrogen in straw and sawdust manure seems to occur during decomposition in the soil.

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SELOSTUS

Turpeen, oljen, sahanpurun ja kutterinlastun ammoniakinsitomiskyky

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Maatalouden tutkimuskeskus

Rahkakaturpeen, ohran ja kauran oljen sekä sahanpurun ja kutterinlastun ammoniakinsitomiskyky mitattiin lisäämällä kuivikkeeseen tietty määrä ammoniakkia ja määrittämällä siitä alipainekuivauksessa pois haihtuvan ammoniakin määrä. Turve sitoi ammoniakkia 10 %:n kosteudessa 2,3 % kuivapainostaan, ohran olki 0,6 %, pitkä kauran olki 0,4 % ja silputtu kauran olki 0,5 %. Silppuaminen ei vaikuttanut ohran oljen kykyyn sitoa ammoniakkia. Kutterinlastu sitoi 10 %:n kosteudessa ammoniakkia 0,7 % kuivapainostaan ja sahanpuru 0,5 %. Suuremmalla kosteustasolla (kuivike-vesiseos, 70 % vettä) ammoniakinsitomiskyvyt olivat jonkin verran suurempia.

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SILAGE EFFLUENT: NUTRIENT CONTENT AND CAPACITY TO REDUCE AMMONIA LOSS WHEN MIXED WITH URINE OR SLURRY

ERKKI KEMPPAINEN

KEMPPAINEN, E. 1987. **Silage effluent: nutrient content and capacity to reduce ammonia loss when mixed with urine or slurry.** Ann. Agric. Fenn. 26: 95—105. (Agric. Res. Centre, Dept. Agric. Chem. Phys., SF-31600 Jokioinen, Finland.)

Laboratory determinations, tests and a pot experiment were carried out to examine the chemical properties of silage effluent and its effectiveness as an ammonia conserving agent when mixed with cow urine or slurry.

On average, silage effluent contained 4,69 % dry matter, 2,01 g/l total nitrogen, 0,17 g/l soluble nitrogen, 0,49 g/l phosphorus, 5,45 g/l potassium, 0,65 g/l calcium and 0,33 g/l magnesium. Its pH was 4,29, and it neutralized 125 meq of NaOH/liter at pH 7,0. Nutrient content and base-neutralizing capacity of silage effluent correlated significantly with dry matter content.

Silage effluent decreased nitrogen loss during storage of urine and slurry. However, small amounts of silage effluent mixed with urine or slurry (5 %, 10 % or 20 % of the amount of manure) had no effect on the growth of Italian rye grass in the pot experiment. Urine and slurry proved to be effective fertilizers. Calculated from the apparent recovery of nitrogen, the effectiveness of total nitrogen in urine was 73 % (surface application) and 90 % (mixed into soil) compared to that of artificial nitrogen fertilizer. The effectiveness of its soluble nitrogen was correspondingly 77 % and 95 %. In slurry the effectiveness of total nitrogen was 65 % (surface application) and 70 % (mixed into soil) compared to that of artificial nitrogen fertilizer. The effectiveness of slurry soluble nitrogen was correspondingly 91 % and 98 %.

Index words: ammonia loss, silage effluent, slurry, urine.

INTRODUCTION

In Finland, the utilization of silage effluent is rather poor. According to an inquiry by KEMPPAINEN (1986), silage effluent is collected and stored for utilization only by 37 % of farms producing silage. However, as it is a valuable source of nutrients all silage effluent ought to be collected and stored for use. In addition, the harmful effects of silage effluent escaping from silos are well known (ANON. 1983).

Many experiments have been carried out studying the formation of silage effluent and its use as a feed for cows. However, the use of silage effluent as a fertilizer has been little studied. In general silage effluent has been shown to increase the yield of cultivated plants, but occasionally harmful effects also have been shown to occur (GILBERT and HAMMEREN 1972, COLLINS and FLYNN 1974, SKARDA et al. 1975, GIBBS 1977, ROPS 1978, HÅLAND 1979, STEWART 1980). The acidity of silage effluent may damage grasses and such damage is increased by more concentrated effluent, higher amount spread per area, longer grass and warmer weather (SKARDA et al. 1975, HÅLAND 1979, STEWART 1980, ANON. 1983). It has been shown by STEWART (1980) that such damage can be prevented by neutralizing silage effluent with lime.

In general silage effluent contains 3,5—6,0 % dry matter, 1,5—2,0 g/l total nitrogen, 0,1—0,2 g/l ammonia nitrogen, 0,1—0,2 g/l nitrate nitrogen, 0,3—0,6 g/l phosphorus, 3,5—5,2 g/l potassium, 0,5—1,5 g/l calcium and 0,2—0,3 g/l magnesium, and its pH is about 4, or slightly higher (JENSEN 1954, PURVES and MCDONALD 1963, JANSSON 1970, GILBERT and HAMMEREN 1972, WOOLFORD 1978, HÅLAND 1979). HÅLAND (1979) showed that the nutrient content of silage effluent is closely correlated with its dry matter content.

The aim of this study was to examine the chemical properties of silage effluent and its effectiveness as an ammonia conserving agent when mixed with urine or slurry. Laboratory determinations, tests and a pot experiment were carried out.

MATERIAL AND METHODS

Silage effluent analysis. The nutrient content and base-neutralizing capacity of 19 silage effluent samples were determined during 1982—1985. Samples were collected from both practical and experimental farms in Southern and Northern Finland. Base-neutralizing capacity was determined by adding 0, 1, 3, 5, 8 or 10 ml of 1,0 M NaOH to a 50 ml sample, and then measuring pH after two hours. In the results, the base-neutralizing capacity is usually expressed as the amount of NaOH (meq) required to raise the pH of one liter of silage effluent to 7,0.

Dry matter content was determined by drying the samples at 105 °C for 24 hours. Soluble nitrogen was determined by extracting samples with a $CaCl_2$—HCl-solution and by distilling the extracts with MgO. This method is traditionally used in Finland for manure analysis, and its results are quite comparable to those obtained by direct distillation of manure ammonia (KEMPPAINEN 1984). Total nitrogen was determined by the Kjeldahl method, phosphorus by spectrophotometery, and potassium, calcium and magnesium by atomic absorption spectrophotometery. Nitrate was not determined.

During drying, silage effluent was transformed into a treacly paste and thus the figures for dry matter content may not be very accurate. It is possible that some water was retained in the samples or that some organic compounds were lost by volatilization during drying. However, the nutrient contents presented later are accurate, as the determinations were always started with non-dried samples, i.e. the whole nutrient contents of non-dried samples were analyzed.

Ammonia loss from manure. Storage experiment I: 300 ml cow slurry or urine was measured per two-liter plastic pots. 0, 15, 30 or 60 ml silage effluent was then added per pot. Deionized water was added so that the final liquid volume was 360 ml in every pot. Each treatment had three replicates.

Silage effluent, slurry and urine were analyzed, and pH of the mixtures determined two hours after the start of the experiment. The pots were covered by plastic lids and stored at room temperature (approx. 20 °C) for 37 days. During this period, fresh air was administered to the pots by removing the lids for some minutes every second day. At the end of the storage period pH, the contents of total nitrogen and soluble nitrogen were determined. Before nitrogen determinations all pots received deionized water up to 500 ml final volume. In addition, pH of pure silage effluent was determined at the beginning and at the end of the storage experiment.

Cow urine contained 1,95 % dry matter, 4,57 g/l total nitrogen and 4,38 g/l soluble nitrogen. Cow slurry contained 1,90 % dry matter, 1,97 g/l total nitrogen and 1,40 g/l soluble nitrogen. Silage effluent contained 5,15 % dry matter, 2,15 g/l total nitrogen and 0,08 g/l soluble nitrogen. Silage effluent neutralized 138 meq of NaOH/l at pH 7,0, and its original pH was 4,39.

Storage experiment II: 200 ml cow urine was measured per one-liter plastic pots. 0, 50, 150 or 250 ml silage effluent was then added. Half of the pots were stored at 4 °C and half at room temperature (approx. 20 °C). Each treatment had three replicates. Urine and silage effluent were analyzed and pH of the mixtures determined two hours after the start of the experiment. Pots were covered by plastic lids and stored for 43 days. Fresh air was given to the mixtures every second day. After the storage period, pH and the contents of total nitrogen and soluble nitrogen were determined. Before nitrogen analysis deionized water up to 500 ml final volume was added to all pots.

Silage effluent contained 5,26 % dry matter, 2,19 g/l total nitrogen, 0,06 g/l soluble nitrogen, its pH was 4,33 and it neutralized 98 meq of NaOH/l at pH 7,0. Cow urine contained 1,12 % dry matter, 1,83 g/l total nitrogen, 1,73 g/l soluble nitrogen, its pH was 7,85 and it neutralized 46 meq of HCl/l at pH 7,0.

Pot experiment with mixtures. 300 ml samples of cow urine and cow slurry were measured into small plastic pots, and 0, 15, 30 or 60 ml silage effluent was added to both. After mixing, urine and slurry were added to 6-liter plastic pots containing 5 kg of fine sand clay soil each. Half of the pots were manured by surface spreading and half by mixing carefully urine and slurry with the whole amount of soil. After manuring, the pots were kept at room temperature for one day. Italian rye grass (*Lolium multiflorum* L.) was then sown and the seeds covered by a thin layer of soil.

In addition to the pots containing urine and slurry, there were also treatments without manuring; with 15, 30 or 60 ml silage effluent per pot; and with 500, 1000 or 1500 mg nitrogen in artificial fertilizer per pot. 400 mg phosphorus, 2500 mg potassium and 200 mg magnesium was added to all pots, as well. Pots were abundantly watered with deionized water. The rye grass was cut three times, and its nitrogen content determined. All treatments had three replicates. The same urine, slurry and silage effluent were used in the pot experiment as in the first storage experiment. Apparent recovery of nitrogen in silage effluent-manure-mixtures was determined by calculating the proportion of extra nitrogen yield (compared to unfertilized) of the amount of nitrogen in urine or slurry. The amount of nitrogen in silage effluent was omitted.

RESULTS

Silage effluent analysis. On average, silage effluent neutralized 125 meq of NaOH/liter (Table 1). Its dry matter content was 4,69 % and pH 4,29. Potassium was the most abundant

Table 1. Analytical results of silage effluent.

Analysis	No. of samples	$\bar{x}$	s	Range
Base-neutralizing capacity at pH 7,0, meq NaOH/l	18	125	23	82 —166
Dry matter, %	19	4,69	1,03	2,65— 6,73
pH	19	4,29	0,13	4,05— 4,65
Total nitrogen, g/kg of dry matter	19	43,1	6,4	33,5 — 57,5
Soluble nitrogen, —"—	19	4,1	2,9	0,1 — 12,4
P —"—	17	10,5	1,7	7,4 — 12,8
K —"—	18	118,1	11,4	98,7 —138,3
Ca —"—	18	14,3	3,9	9,1 — 25,7
Mg —"—	18	7,1	1,4	5,2 — 10,1
Total N, g/l of fresh effluent	19	2,01	0,53	1,17— 3,34
Soluble N, g/l of fresh effluent	19	0,17	0,09	0,04— 0,43
P, g/l of fresh effluent	17	0,49	0,11	0,31— 0,75
K, —"—	18	5,45	1,07	3,53— 7,25
Ca, —"—	18	0,65	0,21	0,38— 1,33
Mg, —"—	18	0,33	0,53	0,18— 0,60
Soluble N/total N, %	19	9,2	5,6	2,5 — 21,5

plant nutrient. The ratio between total N, P and K was 1,00:0,24:2,74. The proportion of soluble nitrogen in total nitrogen was 9,2 %. Variation between samples was surprisingly low. On a dry weight basis the coefficient of variation for total nitrogen was 15 %, for phosphorus 16 % and 10 % for potassium. However, variation was significantly higher on a fresh weight basis, because the dry matter content varied, as well.

The buffering capacity of silage effluent was lowest between pH 6,0—8,5 (Fig. 1). Moreover the variation of pH was highest near the neutralization point. From the titration curves it was calculated that about 112 meq NaOH was needed to raise the pH of one liter of silage effluent to 6,5, 96 meq NaOH/l was required to reach 6,0, and 77 meq/l to reach pH 5,5, respectively.

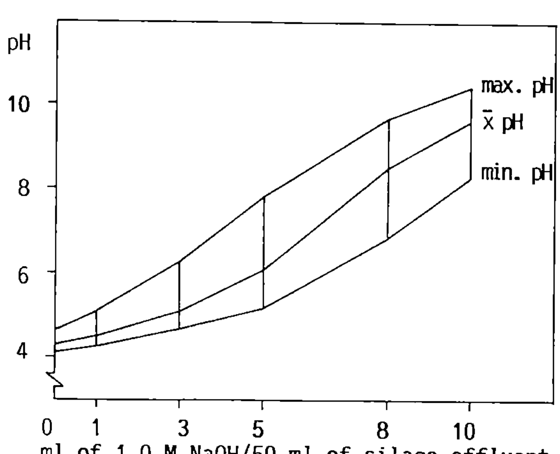

Fig. 1. Titration curves for silage effluent samples.

The base-neutralizing capacity of silage effluent correlated significantly with its dry matter content and pH (Table 2). A higher base-neutralizing capacity correlated with a higher dry matter content and lower pH. Base-neutralizing capacity correlated better with nutrients on a fresh weight basis than on a dry weight basis, however, it was interpreted best by the dry matter content. As the dry matter content increased by 1,0 %, the base-neutralizing capacity increased by 28 meq/l (s = 6 meq/l). Dry matter content and pH together explained 40 % of the variation of base-neutralizing capacity (R = 0,63, P = 0,05). The most significant regression equations are presented in Table 3.

A higher pH of silage effluent correlated with a higher content of total nitrogen and soluble nitrogen on a dry weight basis and a higher content of soluble nitrogen on a fresh weight basis. Dry matter content correlated

Table 2. Correlations between the chemical properties of silage effluent.

	No. of samples	Coefficient of correlation, r			
		Base-neutralizing capacity at pH 7,0, meq NaOH/l	pH	Dry matter, %	Soluble N/total N %
Base-neutralizing capacity at pH 7,0, meq NaOH/l	17		−0,42*	0,59**	0,01
pH	19	−0,42*		−0,20	0,26
Dry matter, %	19	0,59**	−0,20		−0,69***
Nutrients per dry matter					
Total N, g/kg	19	−0,04	0,60**	−0,12	0,38
Soluble N, g/kg	19	−0,07	0,44*	−0,65***	0,96***
P, g/kg	17	−0,08	0,40	−0,39	0,46*
K, g/kg	18	−0,29	0,23	−0,54**	0,30
Ca, g/kg	18	−0,15	0,36	−0,31	0,44*
Mg, g/kg	18	−0,00	0,09	−0,10	0,11
Nutrients per fresh effluent					
Total N, g/l	19	0,53*	0,11	0,84***	−0,41*
Soluble N, g/l	19	0,20	0,40*	−0,36	0,86***
P, g/l	17	0,53*	−0,15	0,76***	−0,39
K, g/l	18	0,52*	−0,16	0,90***	−0,67***
Ca, g/l	18	0,26	0,15	0,45*	−0,15
Mg, g/l	18	0,46*	−0,11	0,71***	−0,47*

* = significant at 5 % level (P = 0,05), ** = significant at 1 % level (P = 0,01), *** = significant at 0,1 % level (P = 0,001). Coefficients without asterisks are not significant at 5 % level.

Table 3. Regression equations presenting the dependence of base-neutralizing capacity, total N, soluble N, P and K of silage effluent on its dry matter content.

Base-neutralizing capacity, meq/l	= 73,32 + 11,35 * dry matter content, %
Total nitrogen, g/l	= 0,02 + 0,43 * dry matter content, %
Phosphorus, g/l	= 0,09 + 0,08 * dry matter content, %
Potassium, g/l	= 1,29 + 0,89 * dry matter content, %

negatively with nutrient content on a dry weight basis, but in general the correlation was positive on a fresh weight basis. Only the content of soluble nitrogen decreased when dry matter content increased. The proportion of soluble nitrogen in total nitrogen correlated significantly with the contents of soluble N, P and Ca on a dry weight basis, and with the contents of total N, soluble N, K and Mg on a fresh weight basis.

Ammonia loss from manure. Storage experiment I: The amount of silage effluent used in the experiment was so small, that pH of mixtures could not be kept under pH 7,0. Nor could it cause a decrease in the pH of cow urine to pH 7,0 at the start of the experiment (Table 4). Nitrogen loss during storage was consequently very high. However, an increasing amount of silage effluent slightly decreased nitrogen loss from urine and that from slurry significantly. Variation between replicates was quite high, and the final pH did not always correlate clearly with the amount of silage effluent. In a visual study it was found that the growth of microbes, apparently fungi, varied considerably between replicates of the same treatment. In some pots there was distinct mucous microbe growth which seemed to raise pH of those mixtures. As the pH of pure silage effluent stored at room temperature for 37 days was determined, the following values were obtained for the three replicates: 4,49, 4,62 and

Table 4. Effect of different amounts of silage effluent on the pH and nitrogen loss from cow urine and cow slurry in storage experiment I. Amount of urine and slurry was 300 ml per pot and the storage period was 37 days at room temperature.

Amount of silage effluent ml per pot	Initial pH			Final pH			Loss of total N, %			Loss of soluble N, %		
	Slurry	Urine	$\bar{x}$	Slurry	Urine	$\bar{x}$	Slurry	Urine	$\bar{x}$	Slurry	Urine	$\bar{x}$
0	6,95	8,84	7,90	8,92	8,54	8,73	51	86	69	94	96	95
15	6,78	8,76	7,77	7,91	8,23	8,07	46	82	64	83	95	89
30	6,66	8,67	7,67	7,73	8,33	8,03	42	80	61	88	93	91
60	6,45	8,45	7,45	8,36	8,67	8,51	38	78	58	56	92	74
$\bar{x}$	6,71	8,68	7,70	8,23	8,44	8,34	44	82	63	80	94	87
Tukey's HSD (P = 0,05) for means:												
type of manure					0,36			2			4	
amount of silage effluent					0,69			5			8	

Table 5. Effect of different amounts of silage effluent on the pH and nitrogen loss from cow urine, stored either at 4 °C or 20 °C. Storage experiment II. Amount of urine was 200 ml per pot and the storage period was 43 days.

Amount of silage effluent ml per pot	Initial pH	Final pH			Loss of total N, %			Loss of soluble N, %		
		+4 °C	+20 °C	$\bar{x}$	+4 °C	+20 °C	$\bar{x}$	+4 °C	+20 °C	$\bar{x}$
0	8,03	8,78	8,50	8,64	16	76	46	20	80	50
50	7,15	8,06	8,53	8,30	4	58	31	23	67	45
150	6,60	4,57	5,48	5,03	1	3	2	0	0	0
250	6,26	4,61	4,02	4,31	0	0	0	0	0	0
$\bar{x}$	7,01	6,50	6,63	6,57	5	35	20	11	37	24
Tukey's HSD (P = 0,05) for means:										
temperature			0,11			2			4	
amount of silage effluent			0,20			5			7	

6,50, respectively. The highest pH was associated with a very dense microbe growth.

For slurry samples, nitrogen loss during storage and final pH had no correlation at all. For urine, the loss of soluble nitrogen correlated significantly with the final pH (r = 0,67, P = 0,01).

Storage experiment II: Nitrogen loss during storage and final pH were significantly decreased by silage effluent (Table 5). Nitrogen loss was negligible already with a mixture having a silage effluent-urine-ratio of 0,75 and an initial pH of 6,60. During storage, the pH of pure urine and that of urine with the least amount of silage effluent rose, while the pH of urine with increased amounts of silage effluent decreased. Storage temperature also had a significant effect. At low temperatures only a small amount of nitrogen was lost. At room temperature the loss of nitrogen in pure urine was almost 80 %.

The cow urine used in the second storage experiment neutralized 46 meq of HCl/liter, while silage effluent neutralized 98 meq of NaOH/liter. On this basis, silage effluent neutralized 0 %, 53 %, 160 % or 266 % of the alkalinity of urine in different treatments. This calculation corresponds well with the results (Fig. 2). The point of neutralization was between the silage effluent-urine-ratios 0,25 and 0,75. It can also be seen from Fig. 2, that nitrogen loss correlated with both initial pH and final pH. Correlation of total nitrogen loss and soluble nitrogen loss with final pH was r = 0,95 (P = 0,001) at room temperature. At a low temperature (4 °C), the correlation of final pH

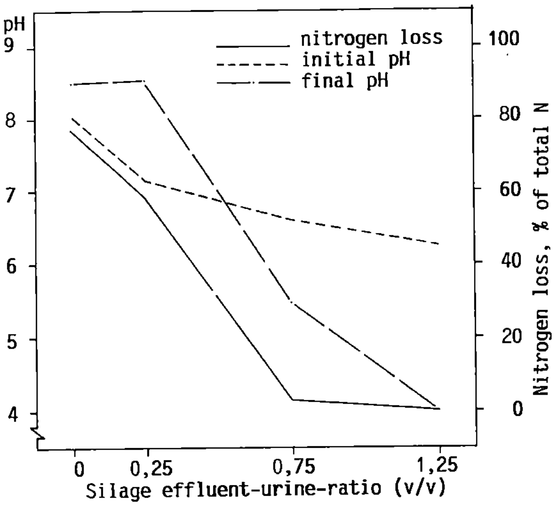

Fig. 2. The effect of silage effluent on the pH and nitrogen loss from urine during a storing period of 43 days at 20 °C.

with total nitrogen loss was r = 0,83 (P = 0,001) and that with soluble nitrogen loss r = 0,92 (P = 0,001).

Pot experiment with mixtures. Silage effluent had no significant effect on grass yields nor on apparent recovery of nitrogen (Tables 6 and 7). Urine was obviously a more effective fertilizer than slurry. Compared to surface spreading, mixing into the soil clearly improved the fertilizing effect of urine. However, the effect of surface applied slurry was slightly better than that of slurry mixed into soil.

Apparent recovery of total nitrogen in pure silage effluent was from 4 to 22 %, and the apparent recovery of its soluble nitrogen was from 115 to 695 %. The apparent recovery of nitrogen in artificial fertilizer was 82 % on average. Compared to artificial fertilizer, the effectiveness of the total nitrogen of pure urine was 73 % (surface spreading) and 90 % (mixed with soil), and the effectiveness of its soluble nitrogen correspondingly 77 % and 95 %. Compared to artificial fertilizer, the effectiveness of total nitrogen in pure slurry was 65 % (surface spreading) and 70 % (mixed with soil), and the effectiveness of its soluble nitrogen correspondingly 91 and 98 %.

Table 6. Effect of silage effluent-slurry-mixtures and silage effluent-urine-mixtures on grass yields in the pot experiment.

Amount per pot of		Method of application[1)]	1st yield, g/pot			2nd yield, g/pot			3rd yield, g/pot			Total yield, g/pot		
manure	sil. effl.		Slurry	Urine	$\bar{x}$	Slurry	Urine	$\bar{x}$	Slurry	Urine	$\bar{x}$	Slurry	Urine	$\bar{x}$
300 ml	0 ml	surf.	12,5	8,9	9,8	5,9	18,9	12,9	3,2	6,5	5,1	21,6	34,3	27,7
”	”	mixed	8,5	9,4		5,9	20,7		2,8	7,8		17,2	37,9	
”	15 ml	surf.	12,0	10,5	10,0	6,1	18,7	12,7	3,2	5,9	4,9	21,2	35,0	27,6
”	”	mixed	9,2	8,5		5,9	20,1		2,9	7,7		18,0	36,2	
”	30 ml	surf.	13,2	10,9	11,1	5,5	17,4	12,1	3,2	6,3	4,9	21,8	34,6	28,1
”	”	mixed	8,8	11,5		6,2	19,4		3,1	7,1		18,0	37,9	
”	60 ml	surf.	12,9	9,1	10,9	6,2	19,4	12,5	3,6	7,3	5,1	22,7	35,8	28,5
”	”	mixed	9,7	12,0		6,1	18,4		3,0	6,6		18,8	37,0	
$\bar{x}$			10,8	10,1	10,5	6,0	19,1	12,6	3,1	6,9	5,0	19,9	36,1	28,0
$\bar{x}$ surface application =				11,2			12,3			4,9			28,4	
$\bar{x}$ mixed with soil =				9,7			12,8			5,1			27,6	
Tukey's HSD (P = 0,05) for means:														
Type of manure				2,2			0,6			0,4			0,8	
Amount of silage effluent				2,2			1,1			0,8			1,6	
Method of application				1,2			0,6			0,4			0,8	

1) surf. = surface application, mixed = mixed with soil

Table 7. Apparent recovery of nitrogen in silage effluent-slurry-mixtures and silage effluent-urine-mixtures in the pot experiment.

Amount per pot of		Method of application[1)]	Apparent recovery of total nitrogen			Apparent recovery of soluble nitrogen		
manure	sil. effl.		Slurry	Urine	$\bar{x}$	Slurry	Urine	$\bar{x}$
300 ml	0 ml	surf.	53	60	61	75	63	74
”	”	mixed	57	74		80	78	
”	15 ml	surf.	56	64	61	79	67	74
”	”	mixed	58	67		82	70	
”	30 ml	surf.	56	65	63	78	67	76
”	”	mixed	57	74		80	77	
”	60 ml	surf.	56	66	63	79	69	75
”	”	mixed	55	73		77	76	
$\bar{x}$			56	68	62	79	71	75
$\bar{x}$ surface application =				60			72	
$\bar{x}$ mixed with soil =				64			77	
Tukey's HSD (P = 0,05) for means:								
Type of manure				3			3	
Amount of silage effluent				5			6	
Method of application				3			3	

1) surf. = surface application, mixed = mixed with soil

DISCUSSION

Silage effluent analysis. The results corresponded fairly well with those in the literature. Dry matter and nutrient contents averaged from 20 to 30 % higher than those reported by JENSEN (1954), PURVES and MCDONALD (1963), GILBERT and HAMMEREN (1972) and HÅLAND (1979). However, nutrient content was almost exactly the same as that reported by JANSSON (1970) in Sweden. According to HÅLAND (1979), about 14 % of the total nitrogen in silage effluent is present as ammonia and approximately 6 % as nitrate. In this study, where nitrate was not determined at all, about 9 % of the total nitrogen proved to be soluble.

The base-neutralizing capacity of silage effluent (125 meq/l) was almost the same as that determined by JENSEN (1954), 130 meq/l. STEWART (1980) has reported the somewhat higher figure of 176 meq/l. According to STEWART (1980), grass is not damaged even by high amounts of silage effluent per area, if the effluent is spread soon after mowing the ley. However, if silage effluent is spread several weeks after mowing, damage is likely even by 50 m^3/ha of effluent neutralizing 120 meq/l. The acidity (base-neutralizing capacity) of silage effluent should be lowered to under 40 meq/l, either by liming or by dilution with water, as it is spread to long grass in warm weather (STEWART 1980).

It can be concluded that the nutrient content and the base-neutralizing capacity of silage effluent can be assessed best on the basis of its dry matter content. The correlations found in this study correspond well with those presented by HÅLAND (1979).

Ammonia loss from manure. Silage effluent lowered pH and decreased nitrogen loss during the storage of cow urine in the second storage experiment. The results correspond well with those obtained by JENSEN (1954). The amount of silage effluent needed for a known amount of urine can be assessed if the acidity (base-neutralizing capacity) of silage effluent and the alkalinity (acid-neutralizing capacity) of urine are known. According to KAILA (1950), 30—40 meq of acid is needed to neutralize one liter of cow urine. One liter of silage effluent can thus neutralize 3—4 liters of urine at pH 7,0. However, according to TUORILA (1929), the nitrogen from urine does not store well at pH 7,0 and a pH 6,5 or lower is needed. Half a liter of silage effluent is required to lower the pH of one liter of urine to 6,5. Accordingly, it can be calculated that 0,7 liter of silage effluent is needed per one liter of urine to obtain pH 6,0 and about 1,1 l/l to obtain pH 5,5. Urine has a high buffering capacity determined mainly by its high content of carbon dioxide (KAILA 1950).

Silage effluent can lower pH and decrease nitrogen loss during the storage of cow slurry, as well. In the first storage experiment, silage effluent decreased the nitrogen loss from slurry more effectively than that from urine. However, the amounts of silage effluent were so small, that nitrogen loss from slurry could not entirely be prevented. In practice, far more nitrogen is lost from urine than from slurry during storage. Consequently, it can be assumed that silage effluent may not have such a significant nitrogen conserving role when mixed with slurry. The results of nitrogen loss obtained in laboratory experiments are not comparable to that which occurs in practical slurry tanks.

It would seem advantageous to collect silage effluent into a slurry tank or liquid manure cistern. However, one must remember that in order to avoid the danger of hydrogen sulphide, no silage effluent should be collected into a cistern having a direct air connection to the cow shed (ANON. 1983). In addition, the corrosive effect of silage effluent on concrete has to be taken into consideration.

In the second storage experiment, temperature significantly influenced nitrogen loss. This was also expected as temperature is known to have a decisive effect on the solubility of gases. However, low temperature does not entirely stop ammonia volatilization, but only retards it. It has been shown by IVERSEN (1924) that in practice as much as half of the amount of nitrogen can be lost from a poorly covered liquid manure cistern during a storage period of seven months.

In many pots the pH of silage effluent-urine-mixtures was lowered during storage. The same phenomenon was noticed by JENSEN (1954) who deduced that the decrease was due to the fermentation of sugars into organic acids. In JENSEN's (1954) experiments a significant proportion of the ammonia nitrogen in silage effluent-urine-mixtures changed into organic form during storage but its availability, as measured by a nitrification test, was not decreased. Silage effluent-urine-mixtures seem to be very favourable growth medias for microbes as also noted in the present experiments. It is very likely that microbial growth is caused by silage effluent. MOORE et al. (1961) have reported, that the fungus, *Geotrichum candidum*, very often found in silage effluent, can even block the effluent pipe of a silage silo.

Pot experiment with mixtures. In the pot experiment, silage effluent had no significant effect on grass yields nor on the apparent recovery of nitrogen. It might have reduced ammonia loss from surface spread manure, but apparently the amounts of silage effluent were too small. As already seen in the results of the first storage experiment, the same amounts of silage effluent could not lower the pH of urine to neutrality, and the effect on slurry was also negligible.

Urine mixed with soil was more effective than surface spread urine, but the reverse was true for slurry. Surface spread slurry was more effective than slurry mixed with soil, and the difference was apparent especially in the first grass yield. It appeared that slurry, mixed with soil, had some disadvantageous effects. This phenomenon was not examined closely, but may be explained by harmful compounds originally present in the slurry (salts, hydrogen sulphide); by harmful compounds produced during the decomposition of slurry (ethylen); or by oxygen depletion caused by the rapid decomposition of slurry (BURFORD 1976). Oxygen depletion and harmful products of decomposition may be significant factors in the present type of pot experiment where the soil is kept moist by abundant watering.

Compared to artificial fertilizer, the effectiveness of soluble nitrogen in urine was, at best, 95 % and the effectiveness of soluble nitrogen in slurry 98 %. This proves that the analysis of manure soluble nitrogen provides a reliable picture of the immediate nitrogenic effect of urine and slurry. The results obtained on the effectiveness of total nitrogen in slurry and urine correspond well with those presented by SALONEN (1949), DURING and MCNAUGHT (1961) and KLAUSEN (1985).

The apparent recovery of soluble nitrogen in pure silage effluent ranged from 115 % to 695 %. Such high figures are partly explained by nitrate nitrogen, which was not included in the soluble nitrogen determination. However, mobilization of organically bound nitrogen is likely to be the most important factor, as the content of nitrate nitrogen in silage effluent is quite small, in general.

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SELOSTUS

Säilörehun puristenesteen ravinnepitoisuus ja sen kyky estää ammoniakin haihtumista lannasta

ERKKI KEMPPAINEN

Maatalouden tutkimuskeskus

Tutkimuksessa määritettiin säilörehun puristenesteen kemiallisia ominaisuuksia. Lisäksi tutkittiin laboratoriokokein, voidaanko lietelannan ja virtsan varastointiaikaista typpihäviötä pienentää lisäämällä lantaan hapanta puristenestettä. Astiakokeessa selvitettiin virtsa-puristeneste- ja virtsa-lietelantaseosten vaikutusta italianraiheinän kasvuun.

Säilörehun puristeneste sisältää kuiva-ainetta keskimäärin 4,69 %, kokonaistyppeä 2,01 g/l, liukoista typpeä 0,17 g/l, fosforia 0,49 g/l, kaliumia 5,45 g/l, kalsiumia 0,65 g/l ja magnesiumia 0,33 g/l. Sen pH on keskimäärin 4,29, ja se neutraloi emästä pH 7,0:ssa 125 mekv/l. Puristenesteen neutralointikyky ja ravinnepitoisuus riippuvat sen kuiva-ainepitoisuudesta, joten kuiva-ainemääritystä voidaan käyttää sen lannoitusarvon ja kasvien polttovaikutuksen arvioinnissa.

Virtsaan tai lietelantaan sekoitettu säilörehun puristeneste estää ammoniakkitypen haihtumista lannan varastoinnin aikana. Puristenesteen tehokkuus typen häviön estäjänä riippuu sekä sen happamuudesta (emäksenneutralointikyvystä) että lannan emäksisyydestä (haponneutralointikyvystä). Käytännössä puristeneste vaikuttaa edullisemmin virtsaan kuin lietelantaan, sillä typen haihtuminen lietelannasta varastoinnin aikana on melko hidasta.

Virtsaan tai lietelantaan sekoitetuilla pienillä puristenestemäärillä (5, 10 tai 20 % lannan määrästä) ei ollut vaikutusta raiheinän kasvuun astiakokeessa. Virtsa ja lietelanta kohottivat raiheinän satoa selvästi. Typen näennäisen hyväksikäytön perusteella laskettuna virtsan kokonaistypen arvo väkilannoitetyppeen verrattuna oli 73 % (pintalevitys) ja 90 % (sekoitus koemaahan) ja sen liukoisen typen arvo vastaavasti 77 % ja 95 %. Lietelannan kokonaistypen arvo väkilannoitetyppeen verrattuna oli 65 % (pintalevitys) ja 70 % (sekoitus koemaahan) ja sen liukoisen typen arvo vastaavasti 91 % ja 98 %.

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FERTILIZER VALUE OF SILAGE EFFLUENT

ERKKI KEMPPAINEN

KEMPPAINEN, E. 1987. **Fertilizer value of silage effluent.** Ann. Agric. Fenn. 26: 107—115. (Agric. Res. Centre, Dept. Agric. Chem. Phys., SF-31600 Jokioinen, Finland.)

The value of silage effluent as a fertilizer was examined in two pot experiments. In the first pot experiment silage effluent was mixed with the soil before sowing Italian rye grass. In the second pot experiment silage effluent was applied onto the grass surface after the first cut. In both experiments silage effluent was compared to artificial fertilizer.

Silage effluent proved to be a valuable fertilizer. About 50 % of its total nitrogen was as effective as the nitrogen in artificial fertilizer. Effectiveness of potassium in silage effluent equalled that in artificial fertilizer. Phosphorus in silage effluent seemed to be at least as effective as the phosphorus in artificial fertilizer. On average one cubic meter of silage effluent corresponds to 1 kg of the nitrogen, 0,5 kg of the phosphorus and 5,5 kg of the potassium in artificial fertilizer. High rates of application, however, may damage grasses especially when spread on vegetation. Apparently the damage is due to oxygen depletion in the soil. With silage effluent nitrogen is mostly needed as a supplementary fertilizer for grasses.

Index words: silage effluent, nitrogen, phosphorus, potassium, fertilizer value.

INTRODUCTION

The utilization of silage effluent as a fertilizer is well grounded. On the one hand it is a valuable source of plant nutrients and, on the other hand, when discharged into the environment without control it poses a serious threat of pollution (JENSEN 1954, PURVES and MCDONALD 1963, JANSSON 1970, GILBERT and HAMMEREN 1972, WOOLFORD 1978, HÅLAND 1979, ANON. 1983, KEMPPAINEN 1987).

Silage effluent has been shown to increase the yield of cultivated plants, but occasionally harmful effects have also been known to occur (GILBERT and HAMMEREN 1972, COLLINS and FLYNN 1974, SKARDA et al. 1975, GIBBS 1977, ROPS 1978, HÅLAND 1979, STEWART 1980). The acidity of silage effluent may damage grasses, and damage is greater the more concentrated the effluent, the higher the amount spread per area, the longer the grass and the warmer the weather. In addition, the rapid decomposition of silage effluent is assumed to damage grasses by depleting oxygen in the soil (WOOLFORD 1978).

According to GILBERT and HAMMEREN (1972), from 50 to 60 % of the total nitrogen in silage effluent is as effective as the nitrogen in artificial fertilizer. HÅLAND (1979) has reported a slightly lower figure of about 40 %. The effectiveness of phosphorus and potassium in silage effluent is about the same as in artificial fertilizer (JENSEN 1954, GILBERT and HAMMEREN 1972). It has been found, that silage effluent also has a significant residual effect (PESTALOZZI 1972, HÅLAND 1979).

The object of this study was to examine the availability to plants of the nitrogen, phosphorus and potassium in silage effluent. In addition, the tolerance of grass was examined by increasing rates of silage effluent. Two pot experiments were carried out.

MATERIAL AND METHODS

Pot experiment I. Five kilograms of dry clay soil was weighed per six-liter plastic pots. Half of the pots were manured with silage effluent (300 ml/pot). Nitrogen, phosphorus, potassium and combinations of these (NP, NK, PK, NPK) were applied as artificial fertilizers both to pots manured with silage effluent and unmanured pots. The dosage of nutrients per pot in the inorganic form was: 1000 mg nitrogen, 400 mg phosphorus and 1000 mg potassium. In addition, there were control pots with no fertilization at all or with additions of 100 ml, 300 ml, 600 ml or 900 ml silage effluent per pot. Silage effluent and inorganic fertilizers were carefully mixed with the whole amount of soil. Italian rye grass (*Lolium multiflorum* L.) was sown and the seeds then covered by a thin layer of soil. Pots were abundantly watered with deionized water. The grass was cut three times and its nitrogen, phosphorus and potassium contents were determined. All treatments had four replicates.

The silage effluent contained 4,58 % dry matter, 1,75 g/l total nitrogen, 0,11 g/l soluble nitrogen, 0,56 g/l phosphorus, 5,63 g/l potassium, and its pH was 4,26. Soluble nitrogen was determined by extracting silage effluent by a HCl—$CaCl_2$-mixture and distilling the extract in the presence of MgO. This method is traditionally used for analysis of organic manure in Finland and provides results quite comparable to those obtained by direct distillation of ammonia with MgO (KEMPPAINEN 1984).

Pot experiment II. Five kilograms of dry clay soil was weighed per six-liter plastic pots. 300 mg of nitrogen in artificial fertilizer was added to all pots and Italian rye grass was sown. After the first cut, 0, 300 or 600 ml of silage effluent was added to the pots. At each level of silage effluent, there were three levels of artificial fertilizer: 0, 2,5, or 5,0 grams NPK (20—4—8) per pot. Silage effluent and artificial fertilizer were added by surface application. Pots were abundantly watered and the grass was cut five times after the treatments. Nitrogen, phosphorus and potassium contents in the grass were determined. The same silage effluent was used in both pot experiments. All treatments had four replicates.

The apparent recovery of N, P and K was achieved by calculating the proportion of extra nutrient uptake (compared to unfertilized) of the amount of nutrient added in silage effluent or artificial fertilizer in both pot experiments.

RESULTS

Pot experiment I. Silage effluent increased the yield of grass significantly (Table 1). The most efficient nutrient in artificial fertilizer was nitrogen. The apparent recovery of total nitrogen in silage effluent averaged 37 % (range 28—43 %) and the apparent recovery of its soluble nitrogen was 592 % (range 442—688 %) (Table 2). As the apparent recovery of nitrogen in artificial fertilizer averaged 74 %, about 50 % of the total nitrogen in silage effluent was as effective as the nitrogen in artificial fertilizer.

The apparent recovery of phosphorus in silage effluent averaged 17 % and ranged from 11 to 21 % (Table 2). It was thus clearly higher than the apparent recovery of phosphorus in artificial fertilizer, which averaged 6 % and ranged from 4 to 9 %. The apparent recovery of potassium in silage effluent ranged from 23 to 47 % (Table 2). It was highest in treatments in which artificial N or NP were also applied.

Table 1. Effect of silage effluent and nutrients in artificial fertilizers (N = 1000 mg/pot, P = 400 mg/pot, K = 1000 mg/pot) on grass yields (g of dry matter/pot) in pot experiment I. Fertilizers and silage effluent were mixed with the soil before sowing.

Artificial fertilization	1st yield			2nd yield			3rd yield			Total yield		
	Silage effluent ml/pot			Silage effluent ml/pot			Silage effluent ml/pot			Silage effluent ml/pot		
	0	300	x̄	0	300	x̄	0	300	x̄	0	300	x̄
—	5,2	7,0	6,1	3,7	6,4	5,0	1,9	3,2	2,5	10,8	16,6	13,7
N	5,5	7,5	6,5	12,3	16,1	14,2	11,7	9,8	10,7	29,5	33,4	31,4
P	7,1	8,3	7,7	3,5	6,2	4,8	1,8	3,3	2,5	12,4	17,7	15,1
K	4,9	7,0	5,9	4,3	7,0	5,6	1,6	2,9	2,3	10,8	16,8	13,8
NP	9,0	9,8	9,4	14,3	16,9	15,6	7,5	8,4	8,0	30,9	35,1	33,0
NK	4,6	7,3	5,9	12,0	16,1	14,1	14,2	10,4	12,3	30,8	33,8	32,3
PK	6,5	8,5	7,5	3,8	6,2	5,0	1,9	3,1	2,5	12,1	17,7	14,9
NPK	7,9	9,0	8,4	14,9	17,6	16,3	8,0	8,7	8,3	30,8	35,3	33,0
x̄	6,3	8,0	7,2	8,6	11,6	10,1	6,1	6,2	6,1	21,0	25,8	23,4
Tukey's HSD (P = 0,05) for means:												
Silage effluent	0,5			0,5			0,5			0,6		
Artificial fert.	1,4			1,4			1,5			1,9		

Table 2. Apparent recovery (%) of nitrogen, phosphorus and potassium in silage effluent and artificial fertilizers in pot experiment I. Figures for artificial fertilizers are for pots without silage effluent. The lowest line presents the amount of nutrients applied in silage effluent and artificial fertilizer, respectively.

Artificial fertilization	Apparent recovery of nitrogen			Apparent recovery of phosphorus		Apparent recovery of potassium	
	Artificial fertilizer	Silage effluent		Artificial fertilizer	Silage effluent	Artificial fertilizer	Silage effluent
		tot. N	sol. N				
—		38	609		19		27
N	73	42	670		17		43
P		43	688	4	21		26
K		37	588		18	7	24
NP	78	31	500	9	17		47
NK	73	39	627		13	39	27
PK		39	615	5	19	9	24
NPK	74	28	442	6	11	47	23
Amount of nutrient applied/pot, mg	1000	525	33	400	168	1000	1689

Table 3. The effect of different artificial fertilizers on grass yields in pot experiment I. SE = silage effluent.

Fertilizer	Yield increase compared to unfertilized, g of dry matter/pot							
	1st yield		2nd yield		3rd yield		Total yield	
	Without SE	With SE	Without SE	With SE	Without SE	With SE	Without SE	With SE
N	0,81**	0,71	9,57***	10,26***	8,57***	6,19***	18,95***	17,16***
P	2,57***	1,70***	1,04**	0,34	−2,55***	−0,72*	1,06*	1,31*
K	−0,75*	−0,21	0,30	0,32	0,69	0,11	0,22	0,21
P without N	1,72} **	1,40	−0,33} ***	−0,51} *	0,06} ***	0,12} *	1,44	1,01
P with N	3,42}	2,00	2,43}	1,17}	−5,17}	−1,56}	0,69	1,61
K without N	−0,47	0,07	0,44	0,28	−0,08} *	−0,26	−0,14	0,11
K with N	−1,03	−0,50	0,15	0,35	1,46}	0,46	0,59	0,32

* = significant at 5 % level (P = 0,05), ** = significant at 1 % level (P = 0,01), *** = significant at 0,1 % level (P = 0,001), figures with no asterisks are not significant at 5 % level.

In these treatments the grass grew well and utilization of the potassium supplied by silage effluent was the best. As the apparent recovery of potassium in artificial fertilizer was, at its best (in combination with N and NP), 39 % and 47 %, the potassium in silage effluent can be regarded as effective as the potassium in artificial fertilizer.

The effect on grass yields of different nutrients with or without silage effluent was examined and nitrogen was found to be the most effective nutrient (Table 3). Silage effluent decreased the effect of artificial nitrogen on the first, third and total yields, but increased the effect of artificial nitrogen on the second yield. Silage effluent decreased the advantageous effect of artificial phosphorus on the first and the second yields, and it decreased the disadvantageous effect of artificial phosphorus on the third yield. The effect of artificial phosphorus on total yield was slightly higher with silage effluent than without it. Its effect depended significantly on nitrogen fertilization. Potassium had only a small influence on grass yields. Silage effluent seemed to diminish its disadvantageous effect on the first yield and its advantageous effect on the third yield. The effect of potassium on the third yield depended on nitrogen fertilization.

As the treatments with different amounts of silage effluent were compared, increasing amounts of silage effluent increased grass yields almost without exception (Table 4). Only the highest amount of silage effluent (900 ml/pot) had a slightly disadvantageous effect, as was seen in the first grass yield. The apparent recovery of total nitrogen in silage effluent averaged 35 %, and the apparent recovery of its soluble nitrogen 550 % (Table 5). As the apparent recovery of the nitrogen in artificial fertilizer averaged 74 %, about 47 % (range 35—53 %) of the total nitrogen in silage effluent was as effective as the nitrogen in artificial fertilizer. The apparent recovery of phosphorus in silage effluent averaged 16 % and the apparent recovery of potassium 23 %. The apparent recovery of phosphorus in silage effluent thus remained at a high level even when spreading high amounts per pot. However, the apparent recovery of potassium in

Table 4. Grass yields with different amounts of silage effluent in pot experiment I.

Silage effluent ml/pot	Grass yield, g of dry matter per pot			
	1st yield	2nd yield	3rd yield	Total yield
0	5,2	3,7	1,9	10,8
100	5,9	4,2	2,2	12,3
300	7,0	6,4	3,2	16,6
600	8,9	9,8	4,5	23,1
900	6,7	12,3	8,1	27,1
Tukey's HSD (P = 0,05)	3,5	3,1	4,6	3,1

Table 5. Apparent recovery of nitrogen, phosphorus and potassium in different amounts per pot of silage effluent in pot experiment I.

Silage effluent ml/pot	Apparent recovery, %			
	Total nitrogen	Soluble nitrogen	Phosphorus	Potassium
100	36	579	14	21
300	39	612	19	27
600	37	589	17	25
900	26	421	15	20
100 ml contained, mg	175	11	56	563

silage effluent was rather low because the shortage of nitrogen restricted its uptake.

Pot experiment II. The disadvantageous effect of high amounts of silage effluent was clearly seen when silage effluent was applied to grass after the first cut (Table 6). In treatments with 600 ml of silage effluent per pot, grass growth entirely ceased for some weeks. A very distinct odor of fermentation was noticed in these treatments. 600 ml of silage effluent had a disadvantageous effect on the second and the third yields, but a clearly positive effect on successive yields. Artificial fertilizer increased the third, fourth, fifth, sixth and total yield. Its effect on the third, fourth and fifth yields depended on silage effluent. Artificial fertilizer increased the third yield in treatments without silage effluent or with 300 ml of silage effluent per pot. The effect of artificial fertilizer on the fourth and fifth yields was correspondingly higher the higher the amount of silage effluent per pot.

The apparent recovery of total nitrogen in silage effluent was 47 % when the amount spread was 300 ml per pot, and 36 %, when spreading 600 ml per pot (Table 7). It is evident that the easily mobilizable nitrogen in 600 ml of silage effluent was not entirely utilized by the grass at the end of the experiment. On average 51 % of the total nitrogen in silage effluent was as effective as the nitrogen in artificial fertilizer. With the lower amount of application this figure was 57 %, and with the higher 44 %.

The apparent recovery of phosphorus in 300 ml of silage effluent was higher than that in artificial fertilizer (Table 7). The apparent recovery of phosphorus in 600 ml of silage effluent was lower than that in artificial fertilizer, but the amount of phosphorus in 600 ml of silage effluent was significantly higher than the amount of P in either amount of artificial fertilizer. The apparent recovery of potassium in artificial fertilizer was well over 200 %. In comparison the apparent recovery of potassium in silage effluent was very low. The amounts of silage effluent used in the experiment contained about eight times more potassium than that in artificial fertilizer.

Table 6. Effect of silage effluent and artificial fertilizer (N : P : K = 20 : 4 : 8) on grass yields (g of dry matter/pot) in pot experiment II. Silage effluent and fertilizer were applied to grass surface two days after the first cut.

Silage effluent ml/pot	2nd yield				3rd yield				4th yield				5th yield				6th yield				Total yield			
	NPK, g/pot				NPK, g/pot				NPK, g/pot				NPK, g/pot				NPK, g/pot				NPK, g/pot			
	0	2,5	5,0	$\bar{x}$	0	2,5	5,0	$\bar{x}$	0	2,5	5,0	$\bar{x}$	0	2,5	5,0	$\bar{x}$	0	2,5	5,0	$\bar{x}$	0	2,5	5,0	$\bar{x}$
0 ml	8,6	9,6	10,4	9,5	4,7	9,1	11,8	8,5	2,1	4,7	9,1	5,3	1,5	2,0	3,4	2,3	2,9	2,9	3,4	3,1	19,7	28,2	38,1	28,7
300 "	8,8	9,1	7,7	8,5	6,9	11,8	13,2	10,6	3,2	6,6	13,1	7,6	2,6	2,7	5,0	3,4	4,7	4,9	5,0	4,9	26,1	35,1	43,9	35,0
600 "	2,7	2,0	1,9	2,2	9,8	9,3	9,1	9,4	8,1	15,1	18,9	14,0	3,6	6,5	10,6	6,9	5,8	6,2	7,2	6,4	30,0	39,2	47,7	38,9
$\bar{x}$	6,7	6,9	6,7	6,8	7,1	10,1	11,4	9,5	4,5	8,8	13,7	9,0	2,5	3,7	6,3	4,2	4,5	4,7	5,2	4,8	25,3	34,1	43,2	34,2
Tukey's HSD (P = 0,05) for means:																								
Silage effluent																								
NPK		1,6				1,1				1,4				0,8				0,5				1,1		

Table 7. Apparent recovery of nitrogen, phosphorus and potassium in silage effluent and artificial fertilizer in pot experiment II.

Fertilizer	Apparent recovery, %							
	Total N		Soluble N		Phosphorus		Potassium	
2,5 g NPK	82	82	82	82	31	29	229	221
5,0 g NPK	81		81		26		213	
300 ml silage effluent	47	42	753	660	39	32	34	31
600 ml silage effluent	36		566		24		28	
2,5 g NKP contained, mg	500		500		110		208	
300 ml silage effluent contained, mg	525		33		168		1689	

DISCUSSION

Pot experiment I. The apparent recovery of soluble nitrogen in silage effluent ranged from 442 to 688 %. These high figures are partly explained by nitrate nitrogen which was not included in the determination of nitrogen in silage effluent. However, the nitrate content in silage effluent is generally very small. According to HÅLAND (1979), the content of nitrate nitrogen is only about 40 % of the content of ammonia nitrogen, which was the basis for these calculations. The most important reason for these high figures is the mobilization of organically bound nitrogen in silage effluent. Thus it seems that the analysis of mineral nitrogen does not provide a reliable picture of the nitrogen effect of silage effluent. A significant part of the organically bound nitrogen in silage effluent seems to be liberated rather rapidly in the soil. The apparent recovery of total nitrogen in silage effluent averaged 37 % although only about 6 % proved to be soluble by chemical analysis. JENSEN (1954) found that silage effluent decomposed very quickly in the soil; about half of its organic carbon changed into carbon dioxide within a week at 8—10 °C (JENSEN 1954).

The phosphorus in silage effluent proved to be even more effective than the phosphorus in artificial fertilizer. This may be explained by several factors. The organic matter in silage effluent can protect its inorganic phosphorus from being adsorbed by soil particles. On the other hand, the organic phosphorus in silage effluent can be liberated into an inorganic form at a suitable speed compared to its uptake by plants and thus avoid adsorption by soil particles. In addition, silage effluent may dissolve the phosphorus originally present in the soil. It seems that the phosphorus in silage effluent is rather fast-acting as it diminished the effect of artificial phosphorus fertilizer especially at the start of grass growth (1st yield). It should be studied in which chemical form phosphorus is present in silage effluent. A beneficial phosphorus effect is by no means exceptional for organic manure. In several studies the phosphorus in livestock manure has proved to be as effective as the phosphorus in artificial fertilizer, or even more so (KAILA 1950, ASMUS et al. 1971, SHARMA et al. 1980, TUNNEY 1980, AMBERGER 1982).

The potassium in silage effluent can be regarded to be as effective as the potassium in artificial fertilizer. This corresponds well to the literature describing the potassium efficiency of organic manures (HAUGLAND 1942, JENSEN 1954, GILBERT and HAMMEREN 1972, SHARMA et al. 1980, TUNNEY 1980, AMBERGER 1982). Very often, the amount of potassium applied in silage effluent is excessively high compared to the requirements of cultivated plants and consequently the recovery of potassium decreases. It has been reported that silage effluent often increases the content of potassium in the soil (GILBERT and HAMMEREN 1972, SKARDA et al. 1975, HÅLAND 1979).

For silage effluent nitrogen is mostly needed as a supplementary fertilizer. Supplementary phosphorus may also be useful, but potassium is not necessary. On the other hand, the soil used in the pot experiment contained so much potassium that there was no benefit from K fertilizer even without silage effluent. It is interesting to note that silage effluent seemed to decrease the disadvantageous effect of fertilizer potassium on the first yield. Silage effluent improved the growth of grass significantly, and the grass took up great amounts of potassium. The disadvantageous effect (salt effect) of fertilizer potassium was then smaller in treatments with silage effluent than in treatments without it. It is noteworthy that silage effluent improved grass growth at the beginning clearly more effectively than did the nitrogen in artificial fertilizer. The disadvantageous effect of artificial phosphorus on the third grass yield was due to its growth-promoting effect at the beginning of the experiment. Nutrients, especially nitrogen, were consumed already by the preceeding grass yields.

Silage effluent seemed to have a disadvantageous effect on grass growth only, when its amount was 900 ml per pot. The harmful effect was surprisingly small, because 900 ml per pot corresponds to 287 m^3/ha, as calculated by area.

Pot experiment II. Silage effluent clearly reduced grass growth when it was applied after the first cut. It was deduced, that the harmful effect was mainly caused by oxygen depletion in the soil. This corresponds to the assumption by WOOLFORD (1978). In addition, silage effluent may have caused grass burn. The disadvantageous effect was apparent with 600 ml of silage effluent per pot (about 192 m^3/ha), but 300 ml per pot (96 m^3/ha) had only a slightly negative effect. Silage effluent was harmful to grass growth at the beginning (2nd and 3rd yields), but for the successive yields, the effect of great amounts of silage effluent was clearly positive.

About 51 % of the total nitrogen in silage effluent was as effective as the nitrogen in artificial fertilizer. This figure corresponds well with the literature (GILBERT and HAMMEREN 1972, HÅLAND 1979). The phosphorus in silage effluent seemed to be at least as effective as the phosphorus in artificial fertilizer in this experiment, too. The effectiveness of potassium in silage effluent compared to that in artificial fertilizer seemed to be rather low, but this was only because the apparent recovery of potassium in artificial fertilizer was exceedingly high. The high apparent recovery of potassium in artificial fertilizer was due to the fact that the fertilizer always contained nitrogen in addition to potassium. Nitrogen improved the growth of grass and the uptake of potassium, but in control pots with no fertilization at all, potassium uptake was quite small due to the shortage of nitrogen. Other reasons for the high apparent recovery of potassium in artificial fertilizer were that the content of potassium in artificial fertilizer was quite small, and the potassium status in the soil was rather high. The apparent recovery of potassium in silage effluent was of the same order as in pot experiment I where silage effluent was mixed with the soil before sowing.

In Finland, silage effluent contains about 2,0 g/l total nitrogen, 0,5 g/l phosphorus and 5,5 g/l potassium (KEMPPAINEN 1987). When the effectiveness of N, P and K, presented in this paper is taken into consideration, one cubic meter of silage effluent corresponds to 1 kg of the nitrogen, 0,5 kg of the phosphorus and 5,5 kg of the potassium in artificial fertilizer.

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SELOSTUS

Säilörehun puristenesteen lannoitusarvo

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Maatalouden tutkimuskeskus

Säilörehun puristenesteen lannoitusarvoa tutkittiin kahdella astiakokeella. Toisessa kokeessa puristeneste sekoitettiin maahan ennen italianraiheinän kylvöä, ja toisessa se levitettiin heinän pintaan ensimmäisen niiton jälkeen. Kummassakin kokeessa puristenesteen lannoitusarvoa verrattiin väkilannoiteravinteiden tehoon.

Säilörehun puristeneste osoittautui arvokkaaksi lannoitteeksi. Keskimäärin 50 % sen kokonaistypestä oli väkilannoitetypen veroista. Puristenesteen kalium oli väkilannoitekaliumin veroista ja sen fosfori jopa tehokkaampaa kuin väkilannoitefosfori. Yksi kuutiometri säilörehun puristenestettä vastaa lannoitusvaikutukseltaan keskimäärin yhtä kiloa väkilannoitetyppeä, puolta kiloa väkilannoitefosforia ja viittä ja puolta kiloa väkilannoitekaliumia. Suuri puristenestemäärä saattaa kuitenkin vahingoittaa heinäkasveja, etenkin kasvustoon levitettynä. Haittavaikutus johtunee puristenesteen nopeasta hajoamisesta maassa, jolloin kasvien juuret kärsivät hapen puutteesta.

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USE OF COW SLURRY IN ESTABLISHING GRASS SWARDS

ERKKI KEMPPAINEN

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Two field experiments were carried out in Northern Finland to investigate the fertilizer value of cow slurry when establishing grass swards. The effects of various nurse crops, differing rates and two methods of slurry application were examined.

In the year of sward establishment, increasing rates of slurry and injection both raised yields, nitrogen uptake and the N and K contents of plants. In one case, P content was also raised by increasing rates of slurry. By the injection of slurry the Ca content of plants decreased compared to that by surface application. Increasing rates of slurry and injection both increased barley lodgment.

The residual effect of slurry was slight. Use of a nurse crop, however, had a significant effect on the first grass yield in the second experimental year at Ruukki. A barley grain crop proved to be the poorest alternative. The density of grass was poorest and winter damage greatest in plots with a barley grain crop. In addition, injection affected the density of grass, negatively. The residual effect of an increasing rate of slurry was seen by an increasing K content, but by decreasing Ca and Mg contents of plants. No significant differences were found in the third experimental year.

The effectiveness of slurry nitrogen was calculated by comparing the apparent recoveries of nitrogen from slurry and artificial fertilizer. In plots without a nurse crop, 44 % of the total nitrogen and 72 % of the soluble nitrogen in slurry proved to be as effective as the nitrogen in artificial fertilizer. In plots with a barley green forage crop the corresponding efficiencies were 49 % for total N and 80 % for soluble N. In plots with a barley grain crop the effectiveness of slurry nitrogen was negligible.

Injection increased yields, on average, by 150 kg/ha compared to surface application. Yield increase by injection was the greatest with the lowest rate of slurry application. The apparent recovery of slurry total nitrogen averaged 8 % higher with injection than by surface application.

Index words: grass establishment, injection, nurse crop, slurry.

INTRODUCTION

In Finland, about 80 % of livestock manure originates from dairy cows fed predominantly grass silage. The utilization of livestock manure as a grassland fertilizer is therefore of great importance. The use of manure on grassland is far more difficult than on grain crops because grass swards are renewed only after 3—4 years, and application of manure onto vegetation may cause damage to grasses. In addition, slurry may worsen the microbiological quality of grass forage. Since the establishment of grass swards is very expensive, no damage should result from the use of manure.

Grass is considered to be a very effective utilizer of the nutrients in livestock manure. Owing to its long period of growth grass can also utilize the slowly mineralizable nutrients of manure (SLUIJSMANS and KOLENBRANDER 1977). In Finland, no great differences have been found between the effect of livestock manure and artificial fertilizer on grasslands (LAINE 1967, 1970, RINNE 1977, HAKKOLA 1980). The differences that exist can be explained by the various nutrient contents in manure and artificial fertilizer. Often the content of potassium in livestock manure is very high, thus causing an excessive potassium content in grass forage (HERRIOTT et al. 1965, HOVDE 1972, NAESS and MYHR 1976, HÅLAND 1984, REID et al. 1984). Red clover is often reported to fare worse in treatments with manure compared with artificial fertilizer (SALONEN 1969, GRACEY 1981). However, manure may have a positive effect on clover, if it is already applied onto the preceeding crop, or if it is supplemented by phosphorus and potassium through artificial fertilizer (SALONEN 1969, GRACEY 1981).

The aim of this study was to examine the use of cow slurry when establishing grass swards. The positive and negative effects of slurry were investigated. The use of solid manure as a fertilizer has been examined considerably in Finland but only a few studies on slurry have been carried out.

MATERIAL AND METHODS

Two field experiments were performed, one at the North Ostrobothnia Research Station at Ruukki (64°40′ N, 25°00′ E), and the other at the North Savo Research Station at Maaninka (63°10′ N, 27°20′ E). The experiment at Maaninka lasted for two years (1982—1983), and for three years (1982—1984) at Ruukki. Since no significant differences were found in the third experimental year at Ruukki, only the results of two years are presented for that experiment. The experiments had a split-split-plot design employing different nurse crops, varying rates of slurry and two methods of application (Table 1). In addition, there were control treatments without fertilization and with 500 kg/ha of NPK (16—7—13). The same barley variety was sown for A1 and A2 plots. On A1 plots barley was cut twice for green forage but on A2 plots it was harvested for grain yield.

The size of the experimental plots was 3 m × 15 m. Each treatment had four replicates. Both

Table 1. Treatments in the experiments.

Plot	Split-plot	Split-split-plot	Controls
A Nurse crop	B Rate of slurry	C Method of application	D Controls
A0 No nurse crop	B1 30 m^3/ha	C1 Surface application	D0 Unfertilized
A1 Barley green forage crop	B2 60 m^3/ha	C2 Injection	D1 500 kg of NPK/ha
A2 Barley grain crop	B3 90 m^3/ha		

Table 2. Soil analysis results for experimental soils.

Soil	pH[1)]	Nutrient content, mg/l of soil			
		P	K	Ca	Mg
Ruukki, 0—20 cm	4,98	13,4	70	975	115
" 20—40 cm	4,65	6,3	18	150	20
Maaninka, 0—20 cm	5,68	15,8	123	1040	106
" 20—40 cm	5,94	4,6	101	800	100

1) soil: deionized water = 1 : 2,5

experiments were conducted on fine sand soils. The experimental soil at Maaninka was slightly more fertile than that at Ruukki (Table 2). Results of soil analysis show the nutrient contents (mg/l) exractable by an acid mixture (pH 4,65) of 0,5 M CH_3COONH_4 and 0,5 M CH_3COOH (VUORINEN and MÄKITIE 1955). The nutrient content of cow slurry and the rates of nutrients applied per hectare are presented in Table 3. A control plot treated with 500 kg NPK/ha received 80 kg/ha nitrogen, 35 kg/ha phosphorus and 65 kg/ha potassium, respectively.

Slurry was applied by a Finnish 6,8 m^3 Teho-Lotina tank at Ruukki. The tank had six injection coulters with a working width of 3 m. At Maaninka a 5 m^3 Alfa-Laval tank with four injection coulters and working width of 2,2 m was used. Slurry was always applied through the coulters, also for surface applications. At Ruukki, a specially-designed iron plate was used beneath the coulters during spreading to ensure more even distribution. Before spreading the amounts released by the tank at different adjustments were carefully examined. Surface-spread slurry was allowed to dry out for at least two days before being covered by harrowing. Artificial fertilizer was applied onto control plots by the placement method.

During the first year, no artificial fertilizer was applied to plots manured with slurry. In the second year, 500 kg/ha of NPK (16—7—13) was applied for the first grass yield, 400 kg/ha for the second grass yield and, at Maaninka, 300 kg/ha for the third grass yield. When establishing the swards, 150 kg/ha of barley (*Hordeum vulgare*, var. Hankkija-673) was sown into plots with a nurse crop, and then 30 kg/ha of grass seed mixture (60 % *Phleum pratense*, var. Tammisto and 40 % *Festuca pratensis*, var. Boris) was sown upon the whole experimental field. At Ruukki, the experiment was established from 4. to 11.6.1982, and at Maaninka, from 28.5. to 4.6.1982.

Harvesting and cutting dates are shown in Table 4. In 1983, grass was cut twice at Ruukki, but three times at Maaninka. Yields were weighed and the contents of dry matter, nitrogen, phosphorus, potassium, calcium and magnesium determined. Density of the grass and barley lodgment were also assessed. Winter damage was calculated on the basis of density estimations.

Table 3. Nutrient content of cow slurry, and rates of N, P and K applied/ha.

	Ruukki				Maaninka			
	Ntotal	Nsoluble	P	K	Ntotal	Nsoluble	P	K
Nutrient content, kg/m^3	2,31	1,35	0,41	1,81	1,62	1,02	0,34	1,89
30 m^3 contained, kg	69	41	12	54	49	31	10	57
60 m^3 " "	139	81	25	109	97	61	20	113
90 m^3 " "	208	122	37	163	146	92	31	170

Table 4. Harvesting dates for barley, and cutting dates for grass and barley green forage crop.

Nurse crop in 1982	1982		1983 (grass in all plots)		
	1st yield	2nd yield	1st yield	2nd yield	3rd yield
Ruukki:					
No nurse crop	2.9.	—	29.6.	17.8.	—
Barley green forage crop	27.7.	8.9.			
Barley grain crop	16.9.	—			
Maaninka:					
No nurse crop	17.8.	—	13.6.	25.7.	1.9.
Barley green forage crop	21.7.	27.8			
Barley grain crop	1.9.	—			

RESULTS

Yields

In the first year (1982) significant differences were found between slurry treatments on plots without a nurse crop and plots with a barley green forage crop (Tables 5—6). An increasing rate of slurry produced better yields, and injected slurry was more effective than surface-applied slurry. No significant differences were found in plots with a barley grain crop (Table 5). At Ruukki, the highest rate of slurry produced at least as big a yield as that by artificial fertilizer, but at Maaninka the effect of slurry was significantly lower. In some cases, a negative effect by slurry compared to that without fertilization was found at Maaninka.

In the second year (1983) no significant differences were found at Maaninka. The first yield was slightly lower for plots with a barley grain crop in 1982 than for the other plots but the difference was not statistically significant. The residual effect of slurry was of the same

Table 5. Yields in 1982 for plots without a nurse crop and plots with a barley grain crop.

Rate of slurry m^3/ha	Method of application	No nurse crop: Grass yield, kg of dry matter/ha				Barley as a nurse crop: Barley grain yield, kg/ha (85 % dry matter)			
		Ruukki		Maaninka		Ruukki		Maaninka	
30	surface	1730	2220	2590	2890	3130	3430	3800	3920
,,	injection	2720		3190		3740		4050	
60	surface	2150	2550	3240	3260	3630	3770	4120	4180
,,	injection	2960		3290		3900		4230	
90	surface	3880	3630	3470	3590	4230	4010	4240	4320
,,	injection	3370		3700		3790		4400	
$\bar{x}$ surface application		2580		3100		3660		4050	
$\bar{x}$ injection		3020		3390		3810		4220	
Tukey's HSD (P = 0,05) for means:									
amount of slurry		1090		1290.		820		590	
method of application		570		270		390		210	
Unfertilized yield, kg/ha		310		2420		2690		4030	
Yield by NPK (500 kg/ha), kg/ha		3260		4230		4130		4120	

Table 6. Yields in 1982 for plots with a barley green forage crop.

Rate of slurry m³/ha	Method of application	Ruukki, kg of dry matter/ha 1st yield		2nd yield		Total yield		Maaninka, kg of dry matter/ha 1st yield		2nd yield		Total yield	
30	surface	1770	1940	690	720	2460	2660	2540	2580	720	700	3260	3280
”	injection	2110		760		2870		2630		670		3300	
60	surface	1940	2080	440	730	2380	2810	2550	2750	590	600	3140	3350
”	injection	2210		1030		3250		2950		600		3550	
90	surface	2890	2800	840	1050	3730	3850	3060	3040	670	740	3730	3790
”	injection	2700		1260		3960		3030		820		3850	
x̄ surface application		2200		650		2850		2710		660		3380	
x̄ injection		2340		1020		3360		2870		700		3570	
Tukey's HSD (P = 0,05) for means:													
amount of slurry		520		480		610		410		560		800	
method of appl.		370		200		330		210		90		240	
Unfertilized, kg/ha		1210		460		1670		2620		530		3150	
500 kg NPK/ha, kg/ha		3020		740		3760		3890		1110		5000	

order as that of artificial fertilizer. The 1982 nurse crop at Ruukki significantly affected the first grass yield of 1983 (Table 7). The lowest yield was cut from plots with a barley grain crop in 1982. However, no significant differences were found in the second or total grass yield of 1983 at Ruukki. Neither the rate of slurry nor method of application had a significant effect on the yields of 1983. The residual effect of slurry seemed to surpass that of artificial fertilizer on plots without a nurse crop and on plots with a barley green forage crop in 1982. For the plots with a barley grain crop in 1982, the residual effect of slurry appeared to be lower than that of artificial fertilizer; in some cases it was even negative compared to that without fertilizer.

Table 7. Effect of slurry treatments in 1982 on the 1st grass yield in 1983 at Ruukki.

Nurse crop in 1982	Amount of slurry, m³/ha	1st grass yield, kg of dry matter/ha Surface appl.	Injection	x̄
No nurse crop	30	7180	6710	6950
—”—	60	7300	7190	7250
—”—	90	7730	7160	7450
	x̄	7400	7020	7210
Barley green	30	6600	7030	6820
forage crop	60	6550	6790	6670
—”—	90	7210	6900	7060
	x̄	6790	6910	6850
Barley grain	30	6040	5590	5820
crop	60	5580	4980	5280
—”—	90	5490	5180	5340
	x̄	5700	5250	5480

Tukey's HSD (P = 0,05)
for means: nurse crop in 1982 = 1060 kg/ha
amount of slurry = 590 ”
method of appl. = 250 ”

Uptake of nitrogen and nutrient content of plants

Slurry treatments clearly influenced the nitrogen uptake by plants in the first year (1982) (Tables 8—11). A higher rate of slurry was matched by a higher nitrogen uptake. Nitrogen uptake was higher by slurry injection than by surface application. The effect of slurry on nitrogen uptake was parallel to its effect on plant yields, but often more significant. This was because slurry often increased the nitrogen content of plants. In the second year (1983), significant differences were seen only in the nitrogen uptake of plots with different nurse crops at Ruukki. The respective nitrogen

Table 8. Nitrogen uptake, and the content of P, K and Ca in 1982 yields for plots without a nurse crop. Results with significant differences are presented only.

Rate of slurry m^3/ha	Method of application	Maaninka	Ruukki			
		N uptake, kg/ha	N uptake, kg/ha	P, g/kg	K, g/kg	Ca, g/kg
30	surface	48 } 55	37 } 47	3,21 } 3,34	28,8 } 30,4	3,49 } 3,27
,,	injection	61	56	3,47	32,1	3,06
60	surface	59 } 62	42 } 51	3,53 } 3,45	32,0 } 31,9	3,16 } 2,98
,,	injection	64	59	3,38	31,8	2,80
90	surface	69 } 78	85 } 83	3,74 } 3,69	37,3 } 38,8	2,77 } 2,71
,,	injection	88	81	3,64	40,4	2,65
$\bar{x}$ surface application		59	55	3,49	32,7	3,14
$\bar{x}$ injection		71	65	3,50	34,7	2,84
Tukey's HSD (P = 0,05) for means:						
amount of slurry		26	24	0,20	3,1	0,41
method of application		6	13	0,13	1,4	0,26
Unfertilized		52	7	3,34	28,7	3,05
500 kg NPK/ha		98	78	3,67	34,1	3,30

Table 9. Nitrogen uptake, and the content of N and K in yields in 1982 for plots with a barley green forage crop at Ruukki. Results with significant differences are presented only.

Rate of slurry m^3/ha	Method of application	1st yield			2nd yield	Total yield
		N uptake, kg/ha	N, g/kg	K, g/kg	N uptake, kg/ha	N uptake, kg/ha
30	surface	27 } 32	14,9 } 16,5	25,1 } 27,0	15 } 15	42 } 48
,,	injection	38	18,1	28,9	15	54
60	surface	30 } 36	15,1 } 17,1	26,2 } 28,8	10 } 16	39 } 51
,,	injection	42	19,0	31,4	22	63
90	surface	54 } 61	18,4 } 21,5	31,0 } 32,8	20 } 23	74 } 84
,,	injection	67	24,6	34,7	27	94
$\bar{x}$ surface application		37	16,2	27,4	15	52
$\bar{x}$ injection		49	20,6	31,7	21	70
Tukey's HSD (P = 0,05) for means:						
amount of slurry		18	2,9	3,3	9	18
method of application		7	1,3	2,1	4	6
Unfertilized		18	14,3	21,3	9	27
500 kg NPK/ha		55	17,9	27,5	15	70

uptakes were 111, 104 and 79 kg/ha for plots without a nurse crop, with a barley green forage crop and a barley grain crop in the preceeding year (HSD P = 0,05 = 28).

Compared to the nitrogen uptake of plots treated with artificial fertilizer, the effect of slurry was slight at Maaninka. At Ruukki, the highest rate of slurry resulted in a higher nitrogen uptake than that by artificial fertilizer in the first year. The effect of slurry was especially clear on the second yield of barley green forage (Table 9). In addition, nitrogen uptake in the second year at Ruukki was generally higher for plots manured with slurry than for plots receiving artificial fertilizer.

In 1982, slurry treatments most influenced the nitrogen and potassium contents of plants (Tables 8—11). Their contents were correspondingly higher, the higher the rate of slurry. In addition, contents were higher with injection

Table 10. Nitrogen uptake, and the content of N, K and Ca in 1982 yields for plots with a barley green forage crop at Maaninka. Results with significant differences are presented only.

Rate of slurry m³/ha	Method of application	1st yield N uptake, kg/ha	1st yield N, g/kg	1st yield K, g/kg	2nd yield N, g/kg	2nd yield K, g/kg	2nd yield Ca, g/kg	Total yield N uptake, kg/ha
30 ,,	surface injection	49 51 } 50	19,3 19,4 } 19,4	27,3 27,6 } 27,5	22,5 22,5 } 22,5	19,3 18,8 } 19,0	3,38 3,14 } 3,26	65 66 } 66
60 ,,	surface injection	49 60 } 54	19,0 20,2 } 19,6	27,9 30,1 } 29,0	24,6 23,1 } 23,9	20,2 19,4 } 19,8	3,50 3,12 } 3,31	63 74 } 69
90 ,,	surface injection	59 64 } 62	19,3 21,3 } 20,3	28,7 32,4 } 30,5	22,9 24,7 } 23,8	22,1 24,1 } 23,1	3,60 3,53 } 3,56	74 85 } 79
x̄ surface application		52	19,2	27,9	23,3	20,5	3,49	67
x̄ injection		58	20,3	30,0	23,4	20,7	3,26	75
Tukey's HSD (P = 0,05) for means:								
amount of slurry		9	1,4	2,4	1,7	1,5	0,29	20
method of appl.		4	0,5	1,0	0,6	1,1	0,13	5
Unfertilized		49	18,4	26,5	23,3	19,1	3,33	61
500 kg NPK/ha		85	21,7	32,5	25,1	31,7	5,33	112

than with surface application. In one case, a higher phosphorus content coincided with a higher rate of slurry. In two cases, the injection of slurry decreased the calcium content of plants compared to that by surface application. However, while increasing rates of slurry lowered Ca content in one case, they raised it in another case.

The level of slurry applied during the first year influenced K, Ca and Mg contents in grass in the second year. At Ruukki, the contents were (g/kg):

	1st grass yield K	1st grass yield Ca	1st grass yield Mg	2nd grass yield K	2nd grass yield Mg
30 m³/ha	20,3	2,23	1,27	26,4	2,69
60 m³/ha	21,7	2,14	1,23	27,5	2,51
90 m³/ha	24,6	2,05	1,15	28,8	2,44
HSD (P = 0,05)	2,0	0,13	0,09	2,4	0,14

Table 11. Nitrogen uptake, the content of N and K in yields, and lodgment in 1982 for plots with a barley grain crop. Results with significant differences are presented only.

Rate of slurry m³/ha	Method of application	Maaninka N, g/kg	Ruukki N uptake, kg/ha	Ruukki N, g/kg	Ruukki K, g/kg	Ruukki Lodge, %
30 ,,	surface injection	17,3 15,8 } 16,5	49 55 } 52	15,5 14,7 } 15,1	5,26 5,61 } 5,44	5 18 } 11
60 ,,	surface injection	16,2 16,7 } 16,5	58 61 } 60	16,0 15,6 } 15,8	5,37 5,65 } 5,51	8 31 } 19
90 ,,	surface injection	17,6 18,6 } 18,1	77 73 } 75	18,3 19,3 } 18,8	5,91 5,96 } 5,94	41 63 } 52
x̄ surface application		17,0	62	16,6	5,51	18
x̄ injection		17,0	63	16,5	5,74	37
Tukey's HSD (P = 0,05) for means:						
amount of slurry		1,4	16	1,8	0,46	32
method of appl.		0,9	8	1,2	0,20	14
Unfertilized		17,3	42	15,6	5,29	9
500 kg NPK/ha		18,4	72	17,6	5,90	71

In addition, injected slurry produced grass with a K content of 22,9 g/kg in the first cut, but by surface application the K content was 21,5 g/kg (HSD P = 0,05 = 1,2).

In the second year (1983) at Maaninka, the residual effect of injection was seen in a higher Ca content in the first grass yield (3,06 g/kg) compared to that by surface application (2,93 g/kg, HSD P = 0,05 = 0,08).

Barley lodgment and density of grass

Significant differences were found in barley lodgment at Ruukki (Table 11). Lodgment was greater by an increasing rate of slurry, and it was greater with injected slurry than with surface applied slurry. However, lodgment was greatest in plots with artificial fertilizer. At Maaninka, the results were similar to those at Ruukki, but not statistically significant.

The density of grass was assessed several times. There were significant differences between treatments in both autumn 1982 and spring 1983 (Table 12). Grass was denser in plots without a nurse crop or with a barley green forage crop in 1982 than in plots with a barley grain crop. Injection diminished grass density compared to surface application. The rate of slurry had no significant effect on grass density, nor were significant interactions found.

Winter damage was assessed by comparing the grass densities in autumn 1982 and in spring 1983. No differences between treatments were found at Maaninka, but at Ruukki winter damage was clearly greater for plots with a barley grain crop in 1982 than for the other plots. Injection seemed to have a slightly negative effect, too.

Apparent recovery of nitrogen

The apparent recovery of nitrogen was achieved by calculating the amount of extra nitrogen in the yields (compared to unfertilized) of the amount of nitrogen added in slurry or fertilizer. For the barley grain yield, it was calculated on the basis of nitrogen in the grain yield only. In the first year the apparent recovery of nitrogen was clearly higher at Ruukki than at Maaninka, but the reverse was true in the second year. At best, the apparent recovery of total nitrogen in slurry was 75 % (Ruukki, 30 m^3/ha slurry injected).

In Table 13, the apparent recovery of nitrogen is presented as an average for the experiments at Ruukki and Maaninka, combining both experimental years. The apparent recovery of nitrogen was highest in plots without a nurse crop, and lowest in plots with a barley grain crop in 1982. The lowest rate of slurry had the best effect, except in those plots with a barley grain crop in 1982. In those plots, the

Table 12. Effect of different nurse crops and different methods of slurry application on the density of grass.

Treatment in 1982	Density of grass, %			
	Ruukki 8.9.1982	Ruukki 20.5.1983	Maaninka 5.10.1982	Maaninka 13.5.1983
No nurse crop	92	95	91	88
Barley green forage crop	93	94	86	86
Barley grain crop	79	73	81	79
Tukey's HSD (P = 0,05)	7	9	7	7
Surface application	89	89	87	85
Injection	86	85	85	83
Tukey's HSD (P = 0,05)	1	2	1	1

Table 13. Apparent recovery of total nitrogen in slurry and artificial fertilizer. Averages for the experiments at Ruukki and at Maaninka, recoveries in 1982 and 1983 combined.

Rate of slurry m^3/ha	Method of application	Apparent recovery of nitrogen, %			
		Nurse crop in 1982			
		No nurse crop	Barley green forage crop	Barley grain grop	$\bar{x}$
30	surface	46 } 51	38 } 47	−22 } −16	21 } 27
”	injection	55	56	−10	34
60	surface	35 } 37	19 } 25	− 7 } − 6	16 } 19
”	injection	39	30	− 5	21
90	surface	34 } 38	24 } 28	4 } 4	21 } 23
”	injection	42	31	4	26
$\bar{x}$ surface application		38 } 42	27 } 33	− 8 } − 6	19 } 23
$\bar{x}$ injection		45	39	− 4	27
Artificial fertilizer		95	67	10	57

Table 14. Effectiveness of slurry total nitrogen compared to nitrogen in artificial fertilizer, calculated on the basis of apparent recovery of nitrogen.

Rate of slurry m^3/ha	Method of application	Effectiveness of slurry nitrogen, %		
		Nurse crop in 1982		
		No nurse crop	Barley green forage crop	Barley grain grop
30	surface	48 } 53	57 } 71	—
”	injection	58	84	—
60	surface	37 } 39	28 } 37	—
”	injection	41	45	—
90	surface	36 } 40	36 } 41	40 } 40
”	injection	44	46	40
$\bar{x}$ surface application		40 } 44	40 } 49	—
$\bar{x}$ injection		48	58	

recovery of nitrogen often was negative, i.e. the amount of nitrogen in yields was smaller than that in unfertilized plots.

The effectiveness of nitrogen in slurry was compared to that in artificial fertilizer on the basis of the apparent recovery of nitrogen. In plots with a barley green forage crop in 1982, 49 % of the total nitrogen in slurry was as effective as the nitrogen in artificial fertilizer (Table 14). In plots without a nurse crop in 1982, the effectiveness of slurry total nitrogen was 44 % on average. The effectiveness of nitrogen in slurry could not be calculated for the plots with a barley grain crop in 1982, as the apparent recovery of nitrogen from the two lowest rates of slurry was negative. Since the proportion of soluble nitrogen in total nitrogen in slurry was 61 %, the effectiveness of soluble nitrogen in slurry averaged 72 % for plots without a nurse crop in 1982, and 80 % for plots with a barley green forage crop in 1982.

Injection vs. surface application

In the first year, slurry injection often increased yields compared to surface application but the residual effect of injection was generally negative (Table 15). The combined results indicate that injection was superior to surface

Table 15. Yield increase by injection of slurry compared to surface application. For 1982, averages for the three nurse crops are shown.

Rate of slurry m^3/ha	Yield increase by injection, kg of dry matter/ha								
	Ruukki			Maaninka			$\bar{x}$		
	1982	1983	Total	1982	1983	Total	1982	1983	Total
30	640	− 80	560	280	10	290	460	− 40	430
60	640	−100	540	180	−80	110	410	− 90	320
90	−220	−570	−780	170	0	160	−30	−290	−310
$\bar{x}$	350	−250	110	210	−20	190	280	−140	150

application with 30 m^3/ha and 60 m^3/ha of slurry, but surface application was better when 90 m^3/ha of slurry was applied. On average, injection increased the dry matter yield by 150 kg/ha. At Maaninka, yield increases by injection were similar for plots with different kinds of crops in 1982, but at Ruukki, injection was by far the most effective in plots with a barley green forage crop in 1982. On an average, apparent recovery of nitrogen was 8 % higher by the injection method.

DISCUSSION

In the first year, slurry had a significantly higher effect on the yields at Ruukki compared to Maaninka. This is partly due to the fact that the nutrient content of slurry used in Ruukki was significantly higher. At Ruukki, slurry increased yields more than control NPK-fertilizer, but at Maaninka, slurry was less effective than the same NPK-fertilizer. Another reason for the difference in yields is that the soil at Maaninka was more fertile than that at Ruukki. Unfertilized control plots also produced much higher yields at Maaninka than at Ruukki.

Slurry treatments in 1982 had no significant effect on dry matter yields in 1983, nor on yields in 1984. Nor were differences found between the residual effect of slurry and artificial fertilizer. From the literature, no conclusions can be made on the residual effect of slurry compared to artificial fertilizer. In some studies, the effect of slurry has been clearly higher than that of artificial fertilizer, but in other studies, no differences have been found (LAINE 1967, 1970, HOVDE 1972, RINNE 1977, HAKKOLA 1980).

The nurse crop had a clear residual effect on grass yields at Ruukki. The highest yields were cut from plots without a nurse crop in 1982, and the lowest yields from plots with a barley grain crop in 1982. This corresponds well to earlier results in Finland (HAKKOLA 1978, 1984). The barley grain crop is the poorest alternative because it is harvested too late in the summer. Grass is not able to grow strong enough to manage through the winter, or becomes too scanty because of overshadowing by the grain crop. In this experiment, where barley was lodged, the winter damage was greatest and the density of grass poorest in plots with a barley grain crop in 1982. The effect of a nurse crop was clearly seen in the apparent recovery of nitrogen, as well.

In addition to the effect of different nurse crops, the density of grass was affected by the method of slurry application. Grass was less dense in plots with injected slurry than in plots with surface applied slurry. This is explained by the better effect by injection, which produced luxuriant vegetation in 1982. Again, overshadowing damage to the grass resulted.

The effect of treatments on nitrogen uptake was similar to that on dry matter yields. As the increasing rate of slurry and injection raised the nitrogen content in plants, too, the differences in nitrogen uptake were greater and statistically more significant than the differences between dry matter yields. Nitrogen uptake and the nitrogen content of plants can be regarded as valuable means for assessing the quality of different treatments, especially when forage crops are produced.

An increasing rate of slurry raised the nitrogen and potassium content of yields, and, in one case, also the phosphorus content. This is in agreement with the literature (HERRIOTT et al. 1965, NAESS and MYHR 1976, HÅLAND 1984). The content of potassium in grass was sometimes over 3 % per dry matter, which is regarded as the safety limit. However, potassium content exceeded 3 % in many grass samples fertilized with artificial fertilizer, too. An increasing rate of slurry often decreased the contents of calcium and magnesium in grass. This also is in agreement with the literature (NAESS and MYHR 1976, HÅLAND 1984, REID et al. 1984).

In the most effective treatments, 84 % of the total nitrogen in slurry was as effective as the nitrogen in artificial fertilizer. On an average, the effectiveness of nitrogen in slurry was less than 50 %. In the literature, values between 35 % and 85 % have been reported (HERRIOTT et al. 1963, 1965, STEWART 1965, SLUIJSMANS and KOLENBRANDER 1977, SCHECHTNER et al. 1980). The best result was achieved by the lowest rate of injected slurry, as was also expected.

Injection often increased yields in the first year compared to surface application, but reduced yields in the second year. The advantageous effect in the first year was due to the improved effect of slurry nitrogen, as volatilization of ammonia was prevented. Often between 25—50 % of nitrogen is lost by volatilization from surface applied slurry, and yield increases by injection can be as high as 30—40 % (KORKMAN 1971a, 1971b, HOFF et al. 1981, BEAUCHAMP et al. 1982, KEMPPAINEN 1985). The negative effect of injection in the second year, in turn, is explained by its disadvantageous effect on the density of grass.

The results show that cow slurry is a good fertilizer for establishing grass swards. However, certain caution should be exercised. The nutrient content of slurry should be known as exactly as possible to avoid excessive fertilization. Overly high amounts of nutrients in slurry may cause damage to grass, especially when using a barley grain crop as a nurse crop. By injection the recovery of slurry nitrogen is more effective compared to that by surface application.

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SELOSTUS

Naudan lietelanta nurmen peruslannoitteena

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Maatalouden tutkimuskeskus

Naudan lietelannan käyttöä nurmen peruslannoitteena tutkittiin kahdessa kenttäkokeessa, joista toinen oli Maatalouden tutkimuskeskuksen Pohjois-Pohjanmaan tutkimusasemalla Ruukissa ja toinen Pohjois-Savon tutkimusasemalla Maaningalla. Koetekijöinä olivat suojakasvi, lietemäärä sekä lannan levitystapa.

Nurmen perustamisvuonna sekä kasvava lietemäärä että lietteen sijoitus kohottivat satoa, kasvien typenottoa sekä kasvuston typpi- ja kaliumpitoisuutta. Yhdessä tapauksessa kasvava lietemäärä kohotti myös kasvuston fosforipitoisuutta. Lietteen sijoitus pienensi satojen kalsiumpitoisuutta pintalevitykseen verrattuna. Sekä kasvava lietemäärä että lietteen sijoitus lisäsivät suojaviljan lakoa.

Suurin vaikutus ensimmäisen nurmivuoden satoon oli perustamisvuoden suojakasvilla. Tuleentuneena korjattu ohra oli selvästi muita suojakasvivaihtoehtoja huonompi. Nurmi talvehti ohraruuduissa keskimääräistä huonommin, ja se oli näissä ruuduissa myös harvempi kuin muilla ruuduilla. Myös lietelannan sijoitus näytti heikentävän nurmen tiheyttä. Satojen kaliumpitoisuus oli ensimmäisenä nurmivuonna usein sitä suurempi ja kalsium- sekä magnesiumpitoisuus sitä pienempi, mitä enemmän lietettä oli levitetty.

Toisen nurmivuoden satoihin koekäsittelyillä ei enää ollut vaikutusta.

Lietelannan typen tehokkuus laskettiin vertaamalla sen näennäistä hyväksikäyttöä väkilannoitteen typen hyväksikäyttöön. Väkilannoitteen veroisesti vaikutti ilman suojakasvia perustetuissa ruuduissa keskimäärin 44 % lannan kokonaistypestä ja 72 % sen liukoisesta typestä. Vihantaohraruuduissa lietteen typen tehokkuus oli vastaavasti 49 % (kokonaistyppi) ja 80 % (liukoinen typpi). Ohraruuduissa typen hyväksikäyttö oli hyvin pientä.

Sijoitus kohotti kahden vuoden kuiva-ainesatoja pintalevitykseen verrattuna keskimäärin 150 kg/ha. Vaikutus oli suurin pienimmällä lietemäärällä, ja se tuli kokonaisuudessaan esiin perustamisvuoden sadoissa. Sijoitus kohotti lietelannan kokonaistypen näennäistä hyväksikäyttöä keskimäärin 8 %-yksikköä.

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INFLUENCE OF CHOICE FEEDING ON THE PERFORMANCE OF GROWING PULLETS AND LAYING HENS

TUOMO KIISKINEN

KIISKINEN, T. 1987. **Influence of choice feeding on the performance of growing pullets and laying hens.** Ann. Agric. Fenn. 26: 131—144. (Agric. Res. Centre., Dept. Anim. Husb., SF-31600 Jokioinen, Finland.)

Ability to self-regulate nutrient intake by growing pullets (4—20 weeks) and the laying hens (24—72 weeks) was studied in two experiments. In the first experiment pullets of three Finnish hybrids were offered either a complete diet or a choice diet (a protein concentrate + an energy diet). The components of the choice diet were fed from separate troughs situated on opposite sides of the cage. In the second experiment laying hens were fed according to four regimes: 1) complete diet; 2) choice between a low calcium diet and limestone grit; 3) choice between an energy-protein diet and a calcium diet; 4) choice between a protein concentrate, whole grain and limestone grit. All diets were offered as pellets and the choice diets either from lengthwise or crosswise divided troughs.

Growth patterns of the pullets on the complete and self-selection diets were different but in final body weight no significant differences could be ascertained. There were differences between strains ($P<0,001$) and in the responses of strains to the dietary treatments ($P<0,01$). Choice-fed pullets consumed less feed and significantly less ($P<0,05$) energy (ME) than birds fed the complete diet. This method seemed to cause excessive protein intake by pullets without any effect on subsequent production.

The three choice diets (Expt. 2) caused at least the same production level as that by the complete diet. Hens on diet 4 tended to produce more and larger-sized eggs than hens on the other regimes. Feed intake and feed conversion ratio were lowest ($P<0,05$) on the two calcium self-selection regimes (2 and 3). On diet 2 hens consumed less ($P<0,05$) protein than hens on the other diets. Birds on diet 4 consumed excessive levels of protein and calcium due to the overeating of protein concentrate. No significant differences between the treatments were found in weight gain, egg quality or plumage condition. Mortality among hens fed diet 4 was significantly ($P<0,05$) lower than that among hens fed the complete diet.

Between the trough designs no significant differences were ascertained in the most important production traits.

These results confirm the ability of domestic fowl to select diet but that differences in the palatability of alternative diets can change the eating behaviour of birds in such a way, which is not in agreement with their nutritional requirements.

Index words: choice feeding, pullet, laying hen, egg production, protein intake, calcium intake, shell quality.

Choice feeding (self-selection) of poultry generally means that the bird has the possibility to choose simultaneously from two or three components (split-diets) and compose its feed ration according to individual requirements. Complete diets are predominant today because of prevalent cage models and systems. However, these diets are formulated to meet the requirements of an average animal and ignores individual variations in dietary requirements.

Several studies suggest that growing pullets and laying hens are generally able to select a nutritionally adequate diet from two diets of different protein and energy concentrations (HOLCOMBE et al. 1976, KAUFMAN et al. 1978, SUMMERS and LEESON 1978, LEESON and SUMMERS 1981, CHAH and MORAN 1985). Apparently, hens are capable of regulating protein as well as caloric intake but according to CHERRY et al. (1983) these abilities are acquired in the same temporal framework.

The third nutritional factor of practical importance in regulation of feed intake is calcium. This especially concerns laying hens, because of the key position calcium occupies in the layer's diet. There is evidence that hens increase their feed consumption to maintain an optimal calcium intake if the diet is marginally low in calcium (DAMRON and HARM 1980). When given the opportunity, hens are able to selectively consume calcium to meet maintenance and production requirements. This appears as an increased calcium intake before the first oviposition and is connected with calcium storage in the medullary bone (MAYER et al. 1970, CLASSEN and SCOTT 1982). During the laying period hens show diurnal variation in calcium intake related to ovulation and shell calcification (HUGHES 1972, MONGIN and SAUVEUR 1974, NYS et al. 1976, CLASSEN and SCOTT 1982, CHAH and MORAN 1985). CHAH and MORAN (1985) conclude that in the choice situation, hens consume nutrients parallel to their needs and this in turn improves shell and albumen quality.

From the economic point of view, choice feeding also offers the possibility to use whole grain thus saving grinding and mixing costs. The results of several studies present that growing pullets can balance their intake of a mash (15—22 % protein) and whole grain quite well in the choice situation (FULLER 1958, BAILEY et al. 1959, BERG 1959, FULLER 1962, COWAN et al. 1978, COWAN and MICHIE 1979). This ability is also maintained if a high-protein concentrate has been used as a supplement to whole grain (FULLER 1962, COWAN et al. 1978, SUMMERS and LEESON 1978). On the contrary, POUTIAINEN (1972) found a negative effect on the performance of pullets if the protein content of the concentrate exceeded 40 %.

Several variations on choice feeding for layers have been used especially in trials. Regimes based chiefly on calcium self-selection have yielded similar production levels, lower feed, protein and energy intake and better shell quality than by the complete diet (LEESON and SUMMERS 1978, 1979, CLASSEN and SCOTT 1982). PETERSEN (1976) and COWAN and MICHIE (1979) found no response in egg production but higher consumption of feed, protein and energy when a choice was offered between a mash (21—24 % protein) and whole grain. TAUSON and ELWINGER (1986) have tested choice and semi-choice feeding with a concentrate (27 % protein, 13 % calcium) and whole grain in flat chain feeders. They present that these methods may be practically applicable.

KARUNAJEEWA (1978) reported more efficient feed conversion, larger eggs, lower protein, energy and calcium intake when a choice between a concentrate, whole grain and shell grit was compared with an all-mash diet. ELWINGER (1982) presented results which were slightly inferior to the complete diet but he calculated a lower cost and a higher margin for the selection diet (a protein concentrate, whole or ground grain and oystershells). In some trials a pelleted concentrate has been mixed with whole grain (LAGERVALL 1984) or with whole grain and oystershells (BLAIR et al 1973). The former semi-choice feeding resulted in lower production and a poorer feed conversion ratio. However, by the latter the same production level, larger eggs and higher conversion of feed and dietary protein to eggs were obtained than by all-mash-feeding.

Although most of self-selection studies suggest that domestic birds can compose their ration from various feeds or feed components and balance it according to their actual needs, various factors can alter the selection behaviour. HUGHES (1984) emphasizes the important role of palatability which is influenced by composition, form, texture and flavour of diets. In addition level of learning and the previous experience of the birds (CLASSEN and SCOTT 1982, SCOTT and BALNAVE 1986), trough position and design (BRAY 1978, HOPKINS 1978), color of feed (SUMMERS and LEESON 1985), environmental temperature (SCOTT and BALNAVE 1986), or possibly social factors can affect eating behaviour.

The objective of the present study was to evaluate self-selection by growing pullets of three hybrids in "through-cages" offering the split diets in separate troughs on the opposite sides of cages, and then compare different split-diets with a complete diet in the feeding of laying hens.

MATERIAL AND METHODS

Experiment 1. At 28 days of age a total of 1080 chickens of three Finnish layer hybrids were individually weighed and assigned to 72 rearing cages in three-tier batteries. The cages ("through"-cages 1,0 × 1,0 m) had a feed trough along each free side and a nipple waterline half-way between the feed troughs. Housing conditions are described in a previous paper (KIISKINEN 1983). Two feeding treatments, a complete grower diet (15 % protein, 10,70 MJ ME/kg) or the choice between a protein concentrate (43 % protein, 9,65 MJ ME/kg) and energy feed (10,5 % protein, 10,90 MJ ME/kg) were arranged for each hybrid according to the 2 × 3 factorial design. Supplementary protein of the complete diet and the protein concentrate was derived from soybean meal. All diets (Table 1) were fed *ad libitum* as meal, and the split-diets from the separate troughs.

Individual body weights and feed intakes for replicates of six cages (90 birds) were measured at 4-week intervals until 20 weeks of age. Mortality of the birds and their performance during the subsequent laying period were recorded. Six replicates of 30 hens could be allocated for each rearing group. The ME values of the diets were determined using total excreta collection. The chickens were 5 weeks old and six birds, two from each hybrid, were allotted for each diet.

Experiment 2. This trial consisted of four treatment groups of 240 White Leghorn hens (Strain SK 51). The experiment started when the pullets were 22 weeks old and it lasted for 48 weeks. The hens were raised in conventional three-tier battery cages (4 hens/cage) using the two lowest tiers. Nine hours of light (10 lux) per day was provided at the start of the experiment then gradually increased to 16 hours. A room temperature of 17 °C was maintained. For choice feeding the troughs were divided into two compartments, two

Table 1. Composition of grower diets in Expt. 1 (%).

		Complete diet	Choice feeding diet Protein contentrate	Energy feed
Soybean meal	%	12,5	95,5	—
Barley	,,	45,5	—	53
Oats	,,	37,3	—	42,3
Rapeseed oil	,,	0,5	0,5	0,5
Dicalc.phosphate	,,	1,9	1,5	2,0
Limestone	,,	0,9	0,75	0,85
Sodium chloride	,,	0,35	0,35	0,35
DL-methionine	,,	0,05	0,40	—
Vitamins+minerals[1]	,,	1,0	1,0	1,0
ME (MJ/kg) calc.		10,70	9,65	10,90
,, determ.		10,35	9,80	10,36
Crude protein calc.		15,0	43,0	10,5
,, ,, anal.		14,0	43,4	9,5
Methionine calc.		0,30	1,05	0,19
,, anal.		0,28	1,00	0,16
Lysine calc.		0,72	2,66	0,42
anal.		0,67	2,56	0,35
Calcium calc.		0,92	0,92	0,90
,, anal.		0,95	0,86	0,90
Phosphorus anal.		0,71	0,76	0,67
,, avail.calc.		0,45	0,46	0,44

[1] Supplies per kilogram of diet: 15000 IU vitamin A, 1700 IU vitamin D_3, 20 mg vitamin E, 1 mg vitamin K, 3 mg riboflavin, 1,5 mg pyridoxine, 18 mg niacin, 10 ug B_{12}, 0,3 mg folic acid, 500 mg choline chloride, 20 mg Fe, 45 mg Zn, 50 mg Mn, 4 mg Cu, 0,5 mg I, 0,1 mg Se.

thirds of them lengthwise and one third crosswise. The crosswise separation was chiefly arranged to check the intake of the split-diets. Six replicate groups of 40 hens were assigned to one of the following feeding regimes: 1) complete diet, 15 % protein, 10,50 MJ ME/kg, 3,2 % calcium (Table 2); 2) choice between a low-calcium (0,9 %) diet and limestone grit (38 % calcium); 3) choice between an energy-protein diet (17,5 % protein, 11,15 MJ ME/kg, 0,5 % calcium) and a calcium diet (7,2 % protein, 7,70 MJ ME/kg, 12 % calcium); 4) choice between a protein concentrate (37 % protein, 2,4 calcium), whole grain (barley : oat 80 : 20) and limestone grit. Limestone grit and the calcium diet were offered in the outer part of the troughs divided lengthwise except in diet 4 consisting of limestone grit together with whole grain in the inner part of the trough. In this experiment the supplementary protein of the diets was also derived from soybean meal.

All diets excluding whole grain were pelleted (4 mm) and fed *ad libitum.*

Egg production and the intake of each diet of the replicate groups was recorded for a period of 28 days. All birds were weighed three times (at 29, 45 and 70 weeks) during the experiment. Sixty eggs from each treatment were collected at ages 27, 45 and 68 weeks for measurements of egg quality. Albumen quality (Haugh unit) was determined with an Ames HU micrometer, specific weight using NaCl solutions and shell strength with a Wazau compression force meter. At the end of the experiment, the condition of plumage in the breast, back, wings, feet and tail was evaluated from 40 birds per each dietary treatment on a scale from 1 to 4 (1 = bare or nearly bare, 4 = good or complete plumage). The ME values of the diets were determined by total ecxreta collection. Six hens aged 59 weeks were used per diet.

Table 2. Composition of layer diets in Expt. 2 (%).

	Feeding regime 1	2	3		4	
	Complete diet	Diet with low Ca content	Energy-protein diet	Calcium diet	Protein concen-trate	Whole grain
Soybean meal	17	18,5	23	—	83	—
Barley	51	53,5	60	10	—	80
Oats	20	22	11	56	—	20
Rapeseed oil	2	2	3	1	—	
Limestone	7	0,9	—	30	—	
Dicalc. phosp.	1,6	1,69	1,57	1,6	8,5	
Sodium chloride	0,35	0,35	0,35	0,35	2,05	
DL-methionine	0,05	0,06	0,08	0,05	0,45	
Vitamins+minerals[1]	1,0	1,0	1,0	1,0	6,0	
ME(MJ/kg) calc.	10,50	11,15	11,53	7,70	8,65	11,45
” determ.	10,48	10,93	10,94	7,52	8,89	11,32
Crude protein calc.	15,0	16,1	17,5	7,2	37,0	10,5
” ” anal.	14,5	15,3	16,6	6,8	35,2	10,4
Methionin calc.	0,32	0,34	0,38	0,17	1,0	0,18
” anal.	0,30	0,31	0,34	0,16	0,90	0,17
Lysin calc.	0,78	0,85	0,94	0,30	2,3	0,42
” anal.	0,73	0,75	0,86	0,27	2,25	0,38
Calcium calc.	3,2	0,9	0,53	12,0	2,4	0,06
” anal.	2,82	0,82	0,53	10,5	2,42	0,09
Phosphorus anal.	0,65	0,66	0,67	0,54	1,96	0,36
” avail.calc.	0,40	0,42	0,41	0,35	1,67	0,12

[1] Same supplies per kilogram of diet as in Experiment 1, and in the concentrate six times more.

Chemical and statistical analysis. Proximate feed analysis was done for each lot of the diets according to the standard methods used by the Department of Animal Husbandry of the Agricultural Research Centre. Due to the mixing of the dietary components in the lengthwise divided troughs, the crude protein and calcium content of the scraps of each component were analysed at the end of each period to calculate the real intake of the ingredients and components. Amino acids were determined with a gas chromatograph (Hewlet Packard 1570) for a common sample from each diet. Calcium was analysed with an atomic absorption spectrophotometer (Perkin-Elmer 2380) and phosphorus with a photometer after colour reaction with ammonium vanadate.

Data were statistically analysed by a generalized multivariate analysis of variance and covariance program (MANOVA, Expt. 1) and one way analysis of variance (Expt. 2). The comparisons between treatments were performed using Tukey's test or the t-test (STEEL & TORRIE 1960).

RESULTS

Experiment 1. The complete diet and the energy feed of the choice diet contained according to the determinations less crude protein and metabolizable energy than calculated (Table 1). Apparently this can be attributed to the low quality of the grain used. The pullets consumed around 21 % protein concentrate (17,3—24,0 %) of the total feed intake, with the lightest strain (nr 1) consuming the most (Table 3).

Birds offered the split-diet grew during the first phase (4—12 weeks) significantly ($P<0,001$) faster than those fed the complete diet (Table 4). During the second phase (12—20 weeks) the situation was converse and therefore the difference in total weight gain was not significant. Significant differences were ascertained between hybrids, and interaction between diets and hybrids.

Feed intake between the dietary treatments did not differ significantly although each hybrid consumed less of the choice diet than of the complete diet (Table 5). The choice-fed birds consumed more protein than those fed the

Table 3. Average consumption of the dietary components in choice feeding (% of total intake).

Experiment 1

Hybrid[1)]	1	2	3	Average
Protein concentrate	24,0	21,2	17,3	20,8
Energy feed	76,0	78,8	82,7	79,2

Experiment 2

Feeding regime 2		3		4	
Low calcium diet	93,5	Energy-protein diet	79,6	Protein conc.	31,0
Limestone grit	6,5	Calcium diet	20,4	Whole grain.	61,5
				Limestone grit	7,5

1) Hybrid 1 = Långstedt
Hybrid 2 = LSK
Hybrid 3 = Aliperhe

Table 4. Body weight gain and mortality of White Leghorn pullets (Expt. 1).

Diet	Hybrid	Weight gain (g) Age (weeks) 4—12	12—20	4—20	Mortality % 4—20
Complete	1	705	407	1112	0,65
”	2	749	472	1221	0,55
”	3	768	420	1188	0,00
Average		741	431	1172	0,40
Choice	1	722	392	1114	0,00
”	2	842	434	1276	0,55
”	3	805	343	1148	0,55
Average		793	389	1182	0,37
Standard error of mean		3,5	3,9	4,3	0,164
Source of variation		Probabilities of significance			
Diet (D)		0,001	0,001	NS	NS
Hybrid (H)		0,001	0,001	0,001	NS
D × H		0,001	0,003	0,001	NS

NS = non significant

Table 5. Feed and nutrient intake of pullets (4—20 weeks) in Experiment 1.

Diet	Hybrid	Age (weeks) 4—12			12—20			4—20		
		Feed (kg/bird)	Prot. (g/bird)	Energy (MJ ME/bird)	Feed (kg/bird)	Prot. (g/bird)	Energy (MJ ME/bird)	Feed (kg/bird)	Prot. (g/bird)	Energy (MJ ME/bird)
Complete	1	3,29	447	34,04	4,07	563	42,10	7,36	1009	76,14
”	2	3,65	495	37,71	4,53	627	46,90	8,18	1121	84,61
”	3	3,73	506	38,60	4,60	635	47,55	8,33	1141	86,15
Average		3,56	482	36,78	4,40	608	45,52	7,95	1090	82,30
Choice	1	3,20	544	32,64	3,95	698	40,41	7,15	1242	73,05
”	2	3,66	632	37,39	4,42	693	45,29	8,08	1325	82,67
”	3	3,43	539	35,16	3,78	547	38,86	7,22	1085	74,02
Average		3,43	572	35,06	4,05	646	41,52	7,48	1217	76,58
Standard error of mean		0,063	17,4	0,675	0,096	21,5	1,018	0,151	34,2	1,620
Source of variation		———————Probabilities of significance———————								
Diet		NS	0,0087	0,046	NS	NS	NS	NS	NS	0,046
Hybrid		0,031	NS	0,006	NS	NS	NS	0,039	NS	0,048

Table 6. Performance of birds during the subsequent laying period (Expt. 1).

Rearing diet	Hybrid	Egg laying %	Egg weight g	Egg output g/hen/day	Feed intake g/hen/day	Feed intake kg/kg eggs	Weight gain %	Mortality %
Complete	1	73,6	59,5	43,5	114	2,65	38,3	5,6
”	2	78,2	60,6	47,2	120	2,57	33,8	4,4
”	3	72,8	60,6	43,8	117	2,71	36,2	6,7
Average		74,9	60,2	44,9	117	2,64	36,0	5,6
Choice	1	71,1	59,1	41,7	112	2,71	33,1	5,6
”	2	78,8	61,7	48,4	128	2,53	33,4	3,5
”	3	73,0	60,5	43,9	118	2,71	40,8	5,0
Average		74,4	60,5	44,8	117	2,65	35,9	4,7
Standard error of mean		0,59	0,18	0,39	0,6	0,017	0,54	0,58
		——————Probabilities of significance——————						
Diet		NS	NS	NS	NS	NS	NS	NS
Hybrid		0,001	0,001	0,001	0,001	0,001	NS	NS
D×H		NS	NS	NS	NS	NS	NS	NS

complete diet, but the difference was significant (P<0,01) only during the first phase. This was due to the smaller protein intake of one hybrid (nr 3) on the choice diet than on the complete diet during the second phase and the whole rearing period.

The choice-fed birds consumed less (P<0,05) metabolizable energy than those fed the complete diet. Significant differences between strains were found in feed and ME intake during the first phase (P<0,01) and the whole rearing period (P<0,05). No differences in mortality were ascertained between dietary treatments or hybrids.

Feeding during the rearing period did not affect production nor feed intake during the subsequent laying period (Table 6). Significant differences (P<0,001) were found between the

Table 7. Performance of laying hens in Experiment 2.

Diets Feeding regime nr.	Complete 1	Choice-diets 2	 3	 4	Probab. of signif.	Troughs length-wise	 cross-wise	Probab. of signif.
Egg production								
% (hen-day)	76,2	77,4	75,9	78,3	NS	76,3	78,6	0,021
egg output								
g/hen/day	47,7[ab]	48,2[ab]	47,7[a]	49,8[b]	0,032	48,2	49,1	NS
kg/housed hen	14,01[a]	14,38[ab]	14,22[ab]	14,97[b]	0,024	14,35	14,80	NS
Egg weight g	62,6[ab]	62,3[a]	62,8[ab]	63,6[b]	0,012	63,2	62,5	NS
Feed intake								
g/hen/day	137[ab]	130[a]	132[a]	145[b]	0,001	135	136	NS
kg/kg eggs	2,92[b]	2,71[a]	2,79[a]	2,93[b]	0,001	2,83	2,78	NS
Protein intake								
g/hen/day	19,3[b]	18,3[a]	19,3[b]	24,9[c]	0,001	20,5	21,3	NS
g/kg eggs	422[b]	393[a]	419[b]	519[c]	0,001	442	447	NS
ME intake								
MJ/hen/day	1,44	1,34	1,36	1,41	—	—	—	—
MJ/kg eggs	30,7	27,9	28,8	28,5	—	—	—	—
Calcium intake								
g/hen/day	4,06[c]	3,88[b]	3,38[a]	4,95[d]	0,001	3,98	4,26	NS
Final body								
weight kg	2,00	2,00	2,03	2,05	NS	2,03	2,00	NS
Weight gain %	24,8	26,8	25,0	26,2	NS	26,9	24,3	0,026
Mortality %	13,8[a]	12,5[ab]	11,3[ab]	8,3[b]	0,038	11,3	9,6	NS

[a—d]Means with a different superscript letter within a row are significantly different ($P<0,05$). If no letters are used differences are non-significant.

hybrids in every production trait.

Experiment 2. The average relative consumptions of the split-diets are presented in Table 3. Rate of production was not significantly affected, if hens were given an opportunity to regulate chiefly their calcium intake (Diets 2 and 3, Table 7, Fig. 1). Hens given a choice between the protein concentrate, whole grain and limestone grit (Diet 4) tended to lay more and bigger eggs (Fig. 2) than hens on the other diets. In some cases the differences were significant ($P<0,05$). As a result of lower mortality ($P<0,05$) hens on diet 4 produced nearly one kilogram eggs per housed hen more than birds on the complete diet ($P<0,05$). In regard to the trough design, no significant differences were found in production on the egg mass basis, but laying percentage was higher ($P<0,05$) when the trough was divided crosswise as opposed to lengthwise.

Hens fed diet 4 consumed more feed than those on the other diets, and compared with diets 2 and 3 the difference was significant ($P<0,05$). Birds offered the calcium self-selection diets (2 and 3) utilized feed more efficiently ($P<0,05$) than the others. Protein intake was lowest ($P<0,05$) when hens had a choice between the mash and limestone grit and clearly highest ($P<0,05$) when choosing between the protein concentrate whole grain and limestone grit (Table 7, Fig. 3). Choice-fed hens consumed less energy per kilogram eggs than hens fed the complete diet. Significant differences between the diets were found in calcium intake ($P<0,001$). Hens fed diet 4 comsumed the most Ca and those on diet 3 the least (Table 7, Fig. 4). Trough design did not affect significantly feed, protein or calcium intake.

Choice feeding did not affect final body weight or relative weight gain of the hens. If the trough was divided croswise, birds grew relatively less ($P<0,05$) than when divided lengthwise. Significant differences were not ascertained in egg quality traits or plumage condition between the treatments (Table 8).

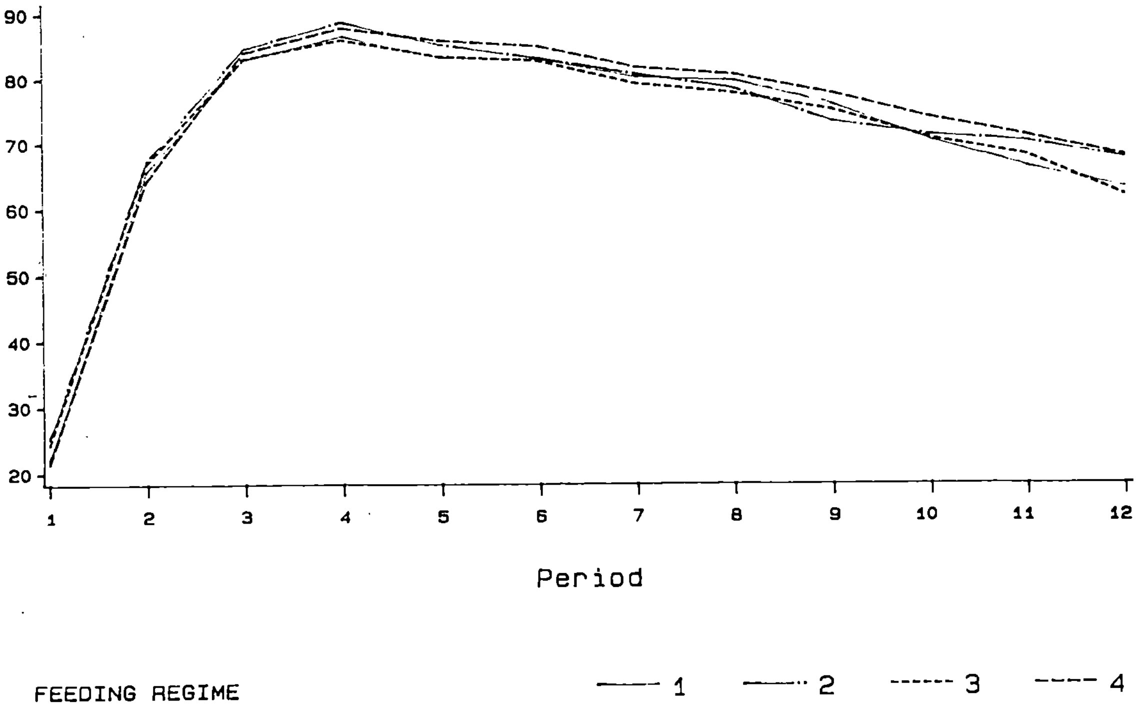

Fig. 1. Percentage egg production (Expt. 2).

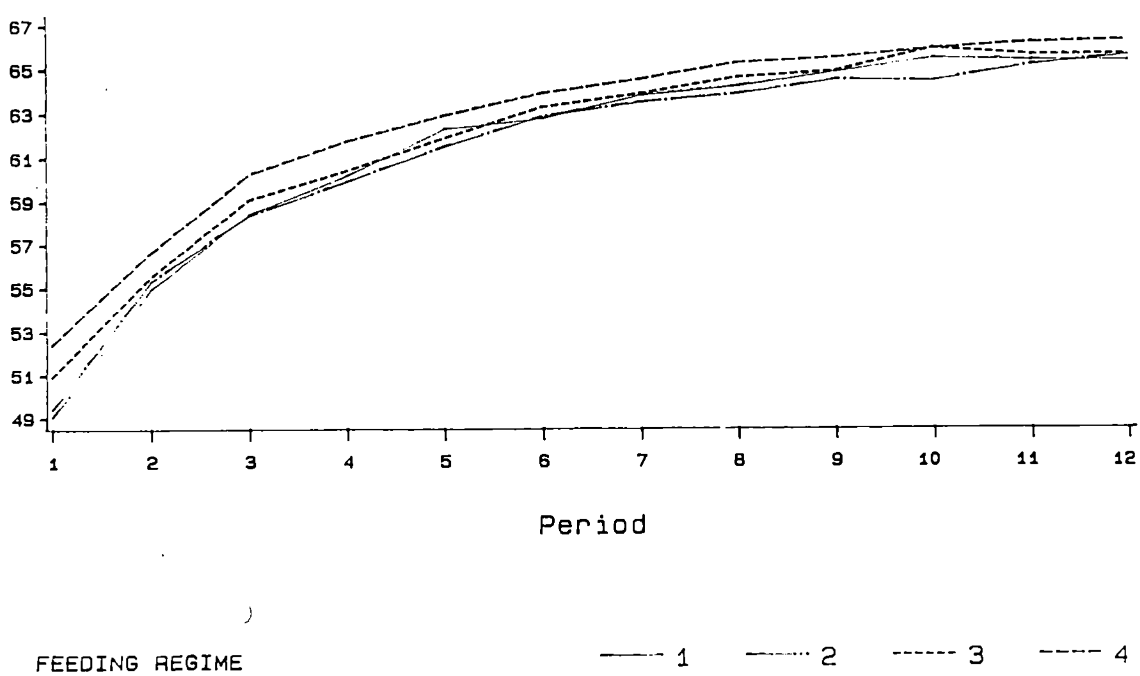

Fig. 2. Egg weight g (Expt. 2).

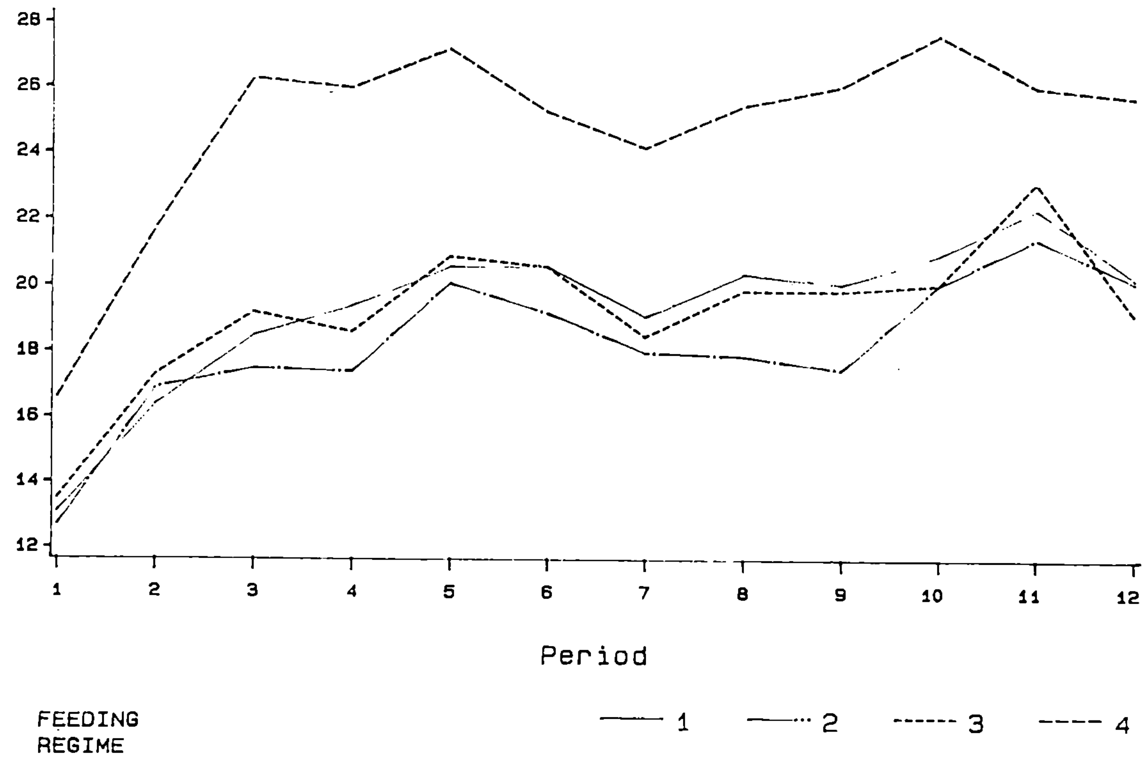

Fig. 3. Protein intake g/hen/day (Expt. 2).

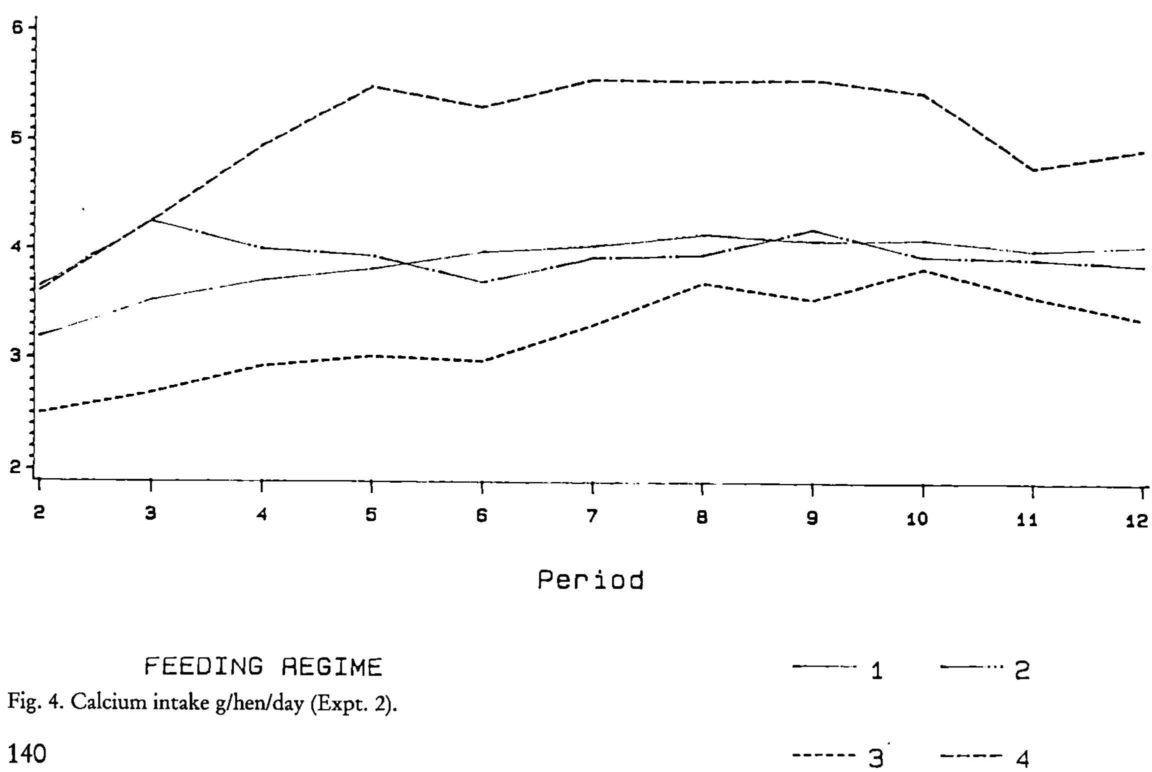

Fig. 4. Calcium intake g/hen/day (Expt. 2).

Table 8. Egg quality and condition of plumage in Experiment 2.

Diets	Complete	Choice-diets			Probab.	Troughs		Probab.
Feeding regime nr.	1	2	3	4	of signif.	length-wise	cross-wise	of signif.
27 weeks								
Haugh unit	93,1	94,1	93,1	92,5	NS	93,1	93,3	NS
Spec.weight	1,0919	1,0911	1,0896	1,0911	NS	1,0900	1,0916	NS
Shell strength	3,39	3,28	3,33	3,32	NS	3,24	3,42	NS
45 weeks								
Haugh unit	83,8	83,9	85,8	87,5	NS	84,3	85,4	NS
Spec.weight	1,0815	1,0819	1,0806	1,0816	NS	1,0810	1,0820	NS
Shell strength	2,80	2,85	2,81	2,88	NS	2,82	2,89	NS
68 weeks								
Haugh unit	78,7	78,1	77,8	77,1	NS	77,7	77,5	NS
Spec.weight	1,0780	1,0800	1,0791	1,0791	NS	1,0792	1,0797	NS
Shell strength	2,56	2,70	2,63	2,74	NS	2,68	2,70	NS
Plumage score (total points)	12,0	11,6	12,5	12,7	NS	—	—	—

DISCUSSION

The growth patterns of the feeding groups in Experiment 1 were not similar, reflecting partly the protein intake of birds. Apparently the increased growth rate of the choice-fed birds during the first phase was due to their higher protein intake compared with the control birds, but during the latter phase, only one strain decreased its protein consumption in the self-selection feeding compared with the all-mash feeding (Tables 4 and 5). The results do not agree with the results of SUMMERS and LEESON (1978) who used similar types of diets for growing pullets. In their study, the choice-fed pullets grew more slowly and consumed less protein than control birds during the age period between 4—11 weeks. In the later phase pullets consumed more protein on the self-selection diet, which according to the authors was caused by the development of sexual organs at the age of 16—20 weeks. The calculated daily protein intakes in Experiment 1 were 9,4 and 10,9 g/bird for the complete diet-fed and the choice-fed pullets, respectively. Each value presents excessive protein consumption, if compared with the requirement of the White Leghorn chicken, which is at most 7,8 g/day (SCOTT et al. 1976). The results of this experiment showed that by this method the pullet could not very well balance its protein intake. It is probable that the protein concentrate based on soybean meal was more palatable than the energy diet composed chiefly of barley and oats. The influence of the distance between the alternative diets is also an incalculable factor. Differences between strains in response to choice feeding are worth noting. Despite the savings in feed and energy intake, and taking into account the final result during the subsequent laying period (Table 6), this method does not appear beneficial.

Each choice-diet in Experiment 2 caused at least the same production level as that by the complete diet (Table 7, Fig. 1). The results of the feeding regimes 2 and 3 are in agreement with some previous reports based chiefly on calcium self-selection (LEESON and SUMMERS 1978, 1979, CLASSEN and SCOTT 1982). Whether the improved egg production on diet 4 was genuine or coincidental is difficult to explain. In any case differences in percentage laying were not numerically large enough to reach significance ($P<0,05$) on six replicates.

Larger eggs and lower mortality of hens fed diet 4 increased its superiority on the egg mass basis compared with the other regimes. The differences in egg weight, which appeared at the start of the experiment and lasted during the whole laying period (Fig. 2), may have been due to the relatively high protein (amino acid) supply of group 4 during that phase (Fig. 3). SHARPE and MORRIS (1965) have reported a significant linear response of protein level on egg weight for the first 8 weeks after the start of laying. In the present study, hens on diet 4 consumed around 16,5 g and hens on the other diets 13 g protein during the first period. On average, hens fed diet 4 overconsumed protein, the daily intake being 25 g (Table 7, Fig. 2). This exceeds markedly the recommendation of 17 g (SCOTT et al. 1976) and is uneconomical.

Although the birds fed choice diet 4(concentrate+whole grain+limestone grit) consumed feed in abundance their feed efficiency was not inferior to the birds on the complete diet and their energy efficiency was even better. Overeating of the concentrate was apparently caused by the different palatability of the components. It was not wise to pellet the concentrate, because in that form it was apparently more acceptable than whole barley and oats.

In spite of that, the concentrate contained 2,4 % calcium, that hens consumed the usual level of limestone grit (7,5 %). The calcium intake of this group was excessive and was maintained mostly at a level of 5 g or more per day (Table 7, Fig. 4). Homeostatic control did not work in this case. On the contrary, hens having a choice between the energy-protein diet and the calcium diet (regime 3) consumed, at least during the first third of the laying period, less calcium than the recommended values of 3,1—3,4 g for a daily egg output of 45—50 g (SALO et al. 1982). However, no significant differences between the treatments were found in shell quality (Table 8).

The results of Experiment 2 suggest that choice feeding provides as good a production level as that by the complete diet. Self-selection improves feed and energy efficiency if there is a balance between the requirements of the birds and palatability of the alternative diets.

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SELOSTUS

Poikasten ja munivien kanojen vapaavalintaisen ruokinnan vaikutukset tuotantoon

TUOMO KIISKINEN

Maatalouden tutkimuskeskus

Kahdessa ruokintakokeessa verrattiin vapaavalintaista ruokintaa täysrehuruokintaan kasvavilla poikasilla (4—20 vk) ja munivilla kanoilla (24—72 vk). Ensimmäisessä kokeessa käytettiin kolmea kotimaista kanajalostetta (Långstedt, LSK, Aliperhe), joille tarjottiin joko täysrehua tai häkin vastakkaisilla puolilla olevista kaukaloista valkuaistiivistettä (43 %) ja energiarehua (ohra+kaura). Seosten lisävalkuaisena oli soijajauho ja kaikissa rehuissa pyrittiin samoihin kivennäis- ja vitamiinipitoisuuksiin. Rehut syötettiin jauhona. Toisessa kokeessa munivilla kanoilla verrattiin täysrehuruokintaa (1) kolmeen vapaavalintaiseen ruokintaan: 2) vapaasti valittavana joko täysrehu, jossa alhainen kalsiumpitoisuus tai kanakalkki, 3) vapaa valinta kohtalaisesti energiaa (ME) ja valkuaista mutta vähän kalsiumia (0,9 %) sisältävän rehun sekä vähän energiaa ja valkuaista mutta paljon kalsiumia (12 %) sisältävän rehun välillä; 4) valinta valkuaistiivisteen (37 %), kokojyväviljan (ohra+kaura) ja kanakalkin välillä. Rehuseosten, jotka syötettiin rakeisina, lisävalkuainen tuli soijajauhosta. Kaukalot jaettiin kahteen osaan sekä pitkittäin että poikittain.

Poikasten loppupainoissa ei ollut merkitsevää eroa ruokintaryhmien välillä, mutta alkuvaiheessa vapaavalintaisella ruokinnalla olleet eläimet kasvoivat merkitsevästi nopeammin ja kuluttivat enemmän valkuaista kuin täysrehua saaneet poikaset. Kokeen loppuvaiheessa puolestaan täysrehuryhmän poikasten kasvu oli suurempi kuin vapaavalintaryhmän. Vapaavalinnalla poikaset kuluttivat vähemmän rehua ja energiaa kuin täysrehulla, mutta eivät ilmeisesti pystyneet säätelemään valkuaisen kulutustaan. Kasvatuskauden vapaavalinta-menetelmä ei vaikuttanut munantuotantokauden tulokseen.

Munivilla kanoilla rehun vapaa valinta tuotti ainakin yhtä hyvän tuloksen kuin täysrehu. Ryhmän 4 kanat munivat jossakin määrin paremmin ja sen munat olivat suurempia kuin muissa ryhmissä. Tämän ryhmän suuri munanpaino perustui ilmeisesti verrattain runsaaseen valkuaisen kulutukseen jo muninnan alkuvaiheessa. Kokonaisuudessaan ryhmä 4 kulutti tarpeettoman paljon valkuaista ja kalsiumia ilmeisesti valkuaistiivisteen ja kanakalkin ohran ja kauran jyviä paremman maittavuuden ansiosta. Paras rehuhyötysuhde oli ryhmillä 2 ja 3, ryhmän 2 kuluttaessa valkuaista vähemmän kuin muut ryhmät. Munanlaadussa ja höyhenyksessä ei todettu merkitseviä eroja.

Tulokset vahvistavat käsitystä, että siipikarja pystyy valikoimaan itse rehunsa tarpeidensa mukaisesti. Edellytyksenä on, että vaihtoehtoisten rehujen maittavuuserot eivät vaikuta eläinten syömiskäyttäytymiseen tavalla, joka ei ole sopusoinnussa eläimen tarpeiden kanssa.

ANNALES AGRICULTURAE FENNIAE, VOL. 26: 145—149 (1987)
Seria ANIMALIA DOMESTICA N. 79 — Sarja KOTIELÄIMET n:o 79

COMPARISON OF FEED ADDITIVES AVOTAN AND ALBAC IN BROILER DIETS

TUOMO KIISKINEN

KIISKINEN, T. 1987. **Comparison of feed additives Avotan and Albac in broiler diets.** Ann. Agric. Fenn. 26: 145—149 (Agric. Res. Centre, Dept. Anim. Husb. SF-31600 Jokioinen, Finland.)

Feed antibiotics Avotan (avoparcin) and Albac (zinc bacitracin) were evaluated in an experiment involving 3600 broiler chicks. Avotan was used in two dietary concentrations 10 and 20 ppm and Albac at three levels 15, 50 and 100 ppm. On average (combined sexes) the supplementations increased growth rate by around 1 %. The differences between the treatments were not significant. The greatest response to the additives was obtained at the level of 20 ppm Avotan among male broilers which reached a 3—4 % higher final body weight than the male birds of the other treatment groups ($P<0,05$). Significant interaction was not found between the additions and sexes. Feed efficiency was improved significantly ($P<0,05$) as a result of both the Avotan and the Albac supplementations (15 and 50 ppm). This improvement was from 2 to 4 %. Significant differences between the treatments were not ascertained in mortality or leg lesions. Compared with the control group mortality in all additive groups was slightly lower. According to the results of this study the optimum levels of Avotan and Albac seem to be 10 and 15—50 ppm, respectively.

Index words: feed antibiotics, avoparcin, zinc bacitracin, broiler chick, growth, feed efficiency.

INTRODUCTION

Albac is the registered trade name for the Norwegian zinc bacitracin which as well as Avotan (avoparcin) has been used as a growth promoter in poultry diets. Albac has not been tested or used in broiler diets in Finland because its most effective concentration is apparently higher than 20 ppm, which is the highest content prescribed by the Finnish feed law.

According to some workers (KIRCHGESSNER and SPOERL 1977, FOSTER 1978, ROSEN 1980) additions of zinc bacitracin up to 100 ppm have resulted in further improvement in growth rate and feed efficiency of broilers compared with lower levels. Avoparcin (avoparcin lauryl sulphate) is a newer antibiotic than zinc bacitracin. It has been tested at a level of 5—50 ppm (ROTH-MAIER and KIRCHGESSNER 1976, SPOERL and KIRCHGESSNER 1978, KIRCHGESSNER and ROTH 1982, PENSACK et al. 1982). The optimum dietary concentration seems to be 10 ppm (5—15 ppm). No interactions between dietary crude protein content and these feed additives has been ascertained

(FOSTER and STEVENSON 1983). The results concerning interactions between avoparcin and anticoccidial compounds are contradictory (LEESON et al. 1980, FAIRLEY et al. 1985).

This study was conducted to compare Avotan and Albac as growth promoters in broiler production. The object was also to study the concentration in which these additives should be used in broiler diets.

MATERIAL AND METHODS

Commercial, day-old, sexed broiler chicks (Pilch) were distributed into 30 floor pens (6 m^2) each pen containing 60 males and 60 females. The average initial weight was 36 g. Housing conditions were maintained at the standard levels used by the broiler house of the Agricultural Research Centre (KIISKINEN 1983). The chicks were fed and watered *ad libitum.* Wood shaving was used as litter.

The basic composition of the experimental diets was similar to the commercial broiler feeds manufactured by Oy Vehnä Ab. The starter which was used up to 2,5 weeks of age contained according to the declaration: fish meal 8, soybean meal 23,5, grain 60, fat mixture 4 %, minerals and vitamins. The finisher from 2,5 to 6 weeks contained fish meal 6, soybean meal 21,5, grain 64, fat mixture 4,5 %, minerals and vitamins. The declared protein and ME content of the starter and the finisher were 22, 12,5 and 20 %, 12,5 MJ/kg respectively.

The dietary treatments:

Group 1	Basic feed, no growth promoters			
" 2	" "	+ 10 ppm	AVOTAN	(produced by Cyanamid)
" 3	" "	+ 20 "	"	
" 4	" "	+ 15 "	ALBAC	(" by A/S Aporthekernes Lab.)
" 5	" "	+ 50 "	"	
" 6	" "	+ 100 "	"	

According to the analyses the diets contained on average (% ± SD):

	starters	finishers
dry matter	88,6±0,41	88,7±0,50
crude protein	20,9±0,16	20,2±0,19
ether extract (crude fat)	6,8±0,15	6,7±0,51
crude fibre	3,8±0,11	3,5±0,16
ash	5,5±0,16	5,5±0,34

Five replicate pens were assigned to each dietary treatment. The birds of each pen were further divided into six replicate groups of 20 birds each marked with wing marks of different colours.

The total weight and mortality of each replicate (20 birds) was recorded at the ages of one, 19 and 40 days. Feed intake was measured for each pen between the weighings. The incidence of non-classified leg lesions was also recorded. Unfortunately the slaughter weight of the birds could not be measured because of a food industry strike. Quality of litter (wetness) was observed in the broiler house.

Data concerning growth rate were subjected to analysis of variance (MANOVA), which allowed for the testing of the effects of dietary treatment and sex, and for the interaction between them. Data of feed consumption, mortality and leg lesions were analyzed by one way analysis of variance. Tukey's test (STEEL and TORRIE 1960) was applied to the means of the dietary treatments.

RESULTS AND DISCUSSION

Addition of Avotan or Albac to the rations did not generally (combined sexes) increase weight gain significantly (Table 1). The average response to Avotan was 1,5 % and that to Albac 0,5 %. The highest level of Avotan (20 ppm) produced the highest final body weight of male broilers. (P<0,05). The improvement in growth compared with the other groups was from 3 to 4 %. Among females the lowest final body weight was obtained at a level of 100 ppm Albac, which differed significantly (P<0,05) from that of Group 2 (10 ppm Avotan). A significant difference (P<0,001) in the growth rate between sexes was ascertained. No significant interaction was found between the dietary treatments and sexes (Table 1).

As regards feed intake, during the last phase (18—43 days) birds of the growth promoter groups consumed slightly less feed than the control group (Table 2). The difference between the control group (Group 1) and Group 2 (10 ppm Avotan) was significant (P<0,05). Feed efficiency during the first phase (1—17 days) was best in the Albac groups, the levels of 15 and 100 ppm differing significantly (P<0,05) from the control. During the second phase all growth promoter supplementations excluding 100 ppm of Albac produced significant (P<0,05) improvement in feed efficiency compared with the control group. Feed utilization during the whole growing period was improved from 3 to 4 % as a result of Avotan supplementations (P<0,05) and on two lowest levels of Albac (15 and 50 ppm) 2—3 % (P<0,05). No differences between the groups were ascertained in mortality and leg lesions.

Table 1. Growth rate of broiler chickens receiving different dietary levels of two additives.

Group nr.	Additive ppm	Body weight 17 days males g	Body weight 17 days females g	Final body weight 43 days males g	Final body weight 43 days females g	Final body weight combined sexes g	Final body weight combined sexes Relative
1	Control	472[ab]	419	1936[a]	1622[ab]	1779	100
2	Avotan 10	482[a]	425	1947[a]	1662[a]	1804	101
3	" 20	475[a]	415	2009[b]	1610[ab]	1810	102
4	Albac 15	475[a]	425	1964[ab]	1629[ab]	1797	101
5	" 50	464[b]	419	1943[a]	1628[ab]	1786	100
6	" 100	481[a]	424	1948[a]	1596[b]	1772	100

Probability of significance

Source of variation	17 days	43 days
Treatment (T)	0,02	0,45
Sex (S)	0,001	0,001
T × S	0,44	0,13

a—b Means with a different superscript letter within a vertical column are significantly different (P<0,05). If no letters are used the differences are non-significant.

Table 2. Feed consumption, mortality and leg lesions of broilers fed different levels of two additives.

Group nr	Additive ppm	Feed intake g/day 1—17	Feed intake g/day 18—43	Feed conversion ratio kg/kg 1—17	Feed conversion ratio kg/kg 18—43	Feed conversion ratio kg/kg 1—43	Rel.	Mortality %	Leg lesions %
1	Control	31,5	94,4[a]	1,35[a]	1,87[a]	1,75[a]	100	8,0	1,1
2	Avotan 10	32,0	91,4[b]	1,33[ab]	1,78[b]	1,67[b]	96	5,6	1,3
3	″ 20	31,5	92,5[ab]	1,35[a]	1,80[bc]	1,69[b]	97	7,1	1,1
4	Albac 15	31,6	93,5[ab]	1,32[b]	1,84[c]	1,71[bc]	98	4,7	0,9
5	″ 50	30,8	92,3[ab]	1,32[ab]	1,81[bc]	1,69[b]	97	6,1	1,1
6	″ 100	31,5	94,1[ab]	1,31[b]	1,87[a]	1,74[ac]	100	5,3	2,0

[a—c] see Table 1.

(Table 2). However, mortality in all additive groups was lower than that in the control group. In visual observation no differences were found in wetness of litter.

The response of broiler chickens to Avotan and Albac in the present study was lower than the response of 2—6 % obtained with avoparcin (ROTHMAIER and KIRCHGESSNER 1976, SPOERL and KIRCHGESSNER 1978, LEESON et al. 1980, KIRCHGESSNER and ROTH 1982, PENSACK et al. 1982, FOSTER and STEVENSON 1983, FAIRLEY et al. 1985) and 2—5 % obtained with zinc bacitracin in previous studies (FOSTER 1972, 1978, KIRCHGESSNER and SPOERL 1977, FOSTER and STEVENSON 1983). However, the improvement in feed efficiency was in agreement with most of the above mentioned reports.

In conclusion, both Avotan and Albac supplementations are beneficial to broiler production, especially to feed utilization. The response of broiler chickens to these growth promoters is apparently higher in the practical conditions of larger units than under experimental conditions. The optimum dietary level of Avotan seems to be 10 ppm and that of Albac from 15 to 50 ppm.

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SELOSTUS

Kahden kasvunedistäjän (Avotan, Albac) vertailu broilereiden rehussa

TUOMO KIISKINEN

Maatalouden tutkimuskeskus

Avotan (avoparsiini) ja Albac (sinkkibasitrasiini) ovat rehuantibiootteja, joita käytetään parantamaan tuotantoa ja rehun hyväksikäyttöä. Avotan on meilläkin yleisesti käytetty kasvunedistäjä, mutta Albacia ei meillä ole otettu käyttöön broilerrehuissa, koska sen optimiteho saavutetaan ilmeisesti suuremmalla pitoisuudella kuin meillä sallittu 20 mg/kg. Tässä kokeessa, jossa oli yhteensä 3600 broileria verrattiin näitä kahta kasvunedistäjää lisäämällä Avotania 10 ja 20 mg ja Albacia 15, 50 ja 100 mg rehukiloa kohden.

Rehuantibioottilisäykset eivät keskimäärin vaikuttaneet merkitsevästi broilerien kasvuun. Ainoastaan 20 mg Avotania rehukilossa lisäsi merkitsevästi 3—4 % kukkopoikasten kasvua muihin ryhmiin verrattuna. Merkittävää yhdysvaikutusta kasvunedistäjälisäysten ja sukupuolen välillä ei kuitenkaan todettu. Rehun hyväksikäyttö parani merkittävästi 2—4 % kaikissa rehuantibioottiryhmissä lukuunottamatta 100 mg:n Albac-lisäystä. Kuolleisuudessa ei todettu merkitseviä eroja, vaikkakin se oli kaikissa rehuantibioottiryhmissä hieman vertailuryhmää pienempi. Tämän kokeen tulosten mukaan Avotanin optimipitoisuus on 10 mg/kg ja Albacin 15—50 mg/kg.

ANNALES AGRICULTURAE FENNIAE, VOL. 26: 151—156 (1987)
Seria ANIMALIA DOMESTICA N. 80 — Sarja KOTIELÄIMET n:o 80

EFFICACY OF SACOX (SALINOMYCIN) AND ELANCOBAN (MONENSIN) FOR THE CONTROL OF COCCIDIOSIS IN BROILER CHICKENS

TUOMO KIISKINEN and PER ANDERSSON

KIISKINEN, T. and ANDERSSON, P. 1987. **Efficacy of Sacox (salinomycin) and Elancoban (monensin) for the control of coccidiosis in broiler chickens.** Ann. Agric. Fenn. 26: 151—156. (Agric. Res. Centre, Dept. Anim. Husb., SF-31600 Jokioinen, Finland.)

The anticoccidial drugs salinomycin (Sacox) and monensin (Elancoban) were fed with avoparcin (10 ppm) to 650 broiler chickens (1—40 days) each. The dietary levels of salinomycin and monensin were 60 and 100 ppm, respectively. Coccidial exposure was arranged by mixing contaminated litter among the litter of the experimental pens.

The anticoccidials did not significantly affect the growth rate of the birds but the carcass weight of the anticoccidial groups was 4—5 % heavier ($P<0,05$) than that of the control group. Feed consumption decreased and feed efficiency improved 5—6 % ($P<0,05$) as a result of the anticoccidial supplementation. No significant differences between the anticoccidials were ascertained in growth rate or feed consumption. Mortality or incidence of leg problems was not significantly affected by anticoccidial supplementation. Litter moisture content near the water cup was higher ($P<0,05$) in the Sacox groups than in the others.

According to the patological and parasitological investigation each anticoccidial was effective against coccidiosis and seems to provide sufficient but not complete protection against infection. The few *Eimeria* infections formed in the anticoccidial groups were mild.

Index words: anticoccidials, salinomycin, monensin, broiler chick.

INTRODUCTION

Ionophorous anticoccidials, of which monensin is the first one on the market, form lipid-soluble complexes with polar cations (K^+, Na^+, Ca^{++} and Mg^{++}). The effect of these drugs is based on their selective transport of cations through cell-membranes. In addition to monensin (Elancoban), maduramicin ammonium (Cygro) has been registered and tested in Finland (KIISKINEN and ANDERSSON 1986).

Salinomycin which is a fermentation product of *Strectomyces albus,* also belongs to the polyether ionophorous anticoccidials. It has been marketed in the EEC and in the USA.

Results based on lesion scores, mortality and weight gain show that salinomycin at 60 ppm is comparable or superior to monensin at 100 ppm (DANFORTH et al. 1977, MIGAKI et al. 1979, CHAPPEL and BABCOCK 1979, McDOUGALD 1981, KOS and WITTNER 1983, BADSTUE and JOHANSEN 1984, WHEELHOUSE et al. 1985). Some trials suggest that salinomycin is not quite as effective against cecal coccidiosis as maduramicin ammonium (EDGAR and FITZ-COY 1985, BADSTUE and JOHANSEN 1986).

Salinomycin has been found beneficial to diets low in sulphur amino acids or protein content (WHEELHOUSE et al. 1985, HAMMANT 1985). However, the literature on the interactions between ionophorous drugs and amino acids or protein is not uniform (BRAUNIUS 1985). FAIRLEY et al. (1985) showed that salinomycin and lasalocid had a greater interaction with avoparcin for body weight gain than monensin and narasin.

In some conditions ionophorous anticoccidials may depress growth performance of broiler chickens, and this depression induced by monensin (CERVANTES et al. 1982) and monensin or salinomycin (STAPPERS and VAHL 1983) has been diminished by supplementation of potassium carbonate. The toxic dietary level of salinomycin for chickens is 100 ppm and the optimal level is 60 ppm (DANFORTH et al. 1977). Turkeys are less tolerant than chickens with toxic effects of salinomycin appearing, at the level of 20—30 ppm (STUART 1983, BLAIR et al. 1985). Therefore, salinomycin is not recommended for turkeys.

The purpose of the present work was to compare the effects of salinomycin (Sacox) upon broiler performance with monensin (Elancoban) using coccidial exposure with *Eimeria*-contaminated litter.

MATERIAL AND METHODS

This experiment was conducted according to the plan which the authors used in their study with Cygro (KIISKINEN and ANDERSSON 1986). The present study employed the following treatments:

1. Basic feed, Avotan 10 ppm
2. " " " " Sacox 60 ppm
3. " " " " Elancoban 100 ppm

The feed mixtures (starters, finishers) were manufactured by the same company (Keskusosuusliike Hankkija) as in the previous trial. Likewise, in this experiment contaminated litter derived from a private farm was distributed among the litter of the experimental pens to produce natural infection with *Eimeria*. The same measurements and investigations as in the earlier study were performed.

RESULTS AND DISCUSSION

According to the proximate analysis the differences in the crude protein between the starters and finishers were relatively small (Table 1). The slightly higher protein content of the anticoccidial finisher diets compared with the control diet hardly affected the growth rate of birds in that phase.

The growth rate of chicks of each sex during the first 11 days was very uniform in the groups (Table 2). The differences in the final body weights were not significant although the cocks of the Sacox group were 25—30 g (2 %) heavier than those of the other groups. However, carcass weight of the anticoccidial groups was on an average 40 g (4—5 %) higher ($P<0,05$) than that of the control group. Daily feed

Table 1. Proximate analysis of the experimental diets.

	Dry matter	Crude protein	Ether extrat	Crude fibre	Ash
Starters	%	%	%	%	%
Control	92,3	23,4	5,7	3,7	4,9
Sacox	92,2	23,5	6,0	3,8	4,7
Elancoban	92,2	23,4	5,8	3,6	4,8
Finishers					
Control	90,6	21,1	6,6	3,5	5,1
Sacox	90,7	22,3	6,7	4,0	5,9
Elancoban	90,8	22,2	7,2	3,6	4,8

Table 2. Performance of broilers fed anticoccidials.

	Control	Sacox	Elancoban	SE[1)]
Avotan ppm	10	10	10	
Anticoccidial ppm	—	60	100	
Live weight:				
Male chicks				
N	287	270	306	
11 days g	267	268	266	0,7
40 days g	1687	1716	1692	5,8
Relative	100	102	100	
Female chicks				
N	352	361	333	
11 days g	242	239	240	0,7
40 days g	1397	1386	1389	5,1
Relative	100	99	99	
Carcass weight:				
Males + Females g	952^a	1000^b	989^b	7,4
Relative	100	105	104	
Mortality 5—6 weeks %	4,4	6,9	5,7	0,48
Leg lesions %	6,0	5,4	5,8	0,59
Feed intake:				
g/day 1—11 days	25,1	24,8	24,2	0,24
g/day 12—40 days	$88,1^a$	$83,7^b$	$82,7^b$	0,75
kg/kg weight gain 1—40 days	$1,90^a$	$1,83^b$	$1,81^b$	0,014
Relative	100	96	95	
kg/kg carcass weight	$2,95^a$	$2,70^b$	$2,72^b$	0,039
Relative	100	92	92	
Litter dry matter				
near water cup %	$41,2^a$	$34,1^b$	$41,6^a$	0,73
further from water cup %	66,2	64,8	67,1	1,17

a—b $P<0,05$ Values with a different superscript letter are significantly different. If no letters are used the differences are non-significant.

[1)]SE = Standard error of mean.

consumption of the anticoccidial groups was approximately 5 grams lower ($P<0,05$) during the period of 12—40 days. As a result of this the feed conversion ratio of the anticoccidial groups was significantly ($P<0,05$) lower than that of the control group. The saving on feed was 80—100 g per kilogram weight gain or 4—5 % and calculated per kilogram carcass weight 230—250 g (8 %).

As regards improvement in feed efficiency the results agree with the earlier studies which have been based on exposure to used litter, seeder birds or coccidia cultures (CHAPPEL and BABCOCK 1979, MIGAKI et al. 1979, BADSTUE and JOHANSEN 1984, 1986). When no coccidial exposure has been used salinomycin or monensin supplementation of diets with normal protein levels has not significantly affected the feed conversion ratio (WHEELHOUSE et al. 1985), but slight growth depression has been found in the anticoccidial groups (VAHL 1983, WHEELHOUSE et al. 1985). Apparently in the present study the exposure to *Eimeria* was not sufficiently strong to result in improvement of growth in consequence of anticoccidial supplementation.

Dry matter content of the litter in the Sacox pens was lower ($P<0,05$) than that in the other pens (Table 2). This may have been due to the increased water consumption of the Sacox group compared with the other groups. In some studies the use of ionophorous anticoccidials has increased water consumption and litter moisture (WARD and BREWER 1981, WHEELHOUSE et al. 1985).

The use of Sacox or Elancoban did not influence mortality or the appearance of leg problems (Table 2). Parasitological investigations showed the appearance of *Eimeria tenella* and at least two morphologically different small intestine coccidia. The results are presented in Table 3. Birds completely free of the *Eimeria* infection were 21 % in the control group, 87 % in the Sacox group and 79 % in the Elancoban group. The infections found in the anticoccidial groups were mild cases. Among the 65 dead birds investigated, seven coccidial infections were found from which two were in the control and Sacox groups each, and three in the Elancoban group. The data presented indicate that Sacox at the level used is at least as effective in coccidiosis control as Elancoban. This is in agreement with the results of some other workers (CHAPPEL and BABCOCK 1979,

Table 3. Anticoccidial activity of Sacox and Elancoban

Cage number	Number of samples	Duodenum			Jejunum			Caecum		
		+++	++	+	+++	++	+	+++	++	+
Control										
1	20	—	2	8	—	—	2	—	—	8
4	20	—	—	—	—	—	2	—	—	1
7	20	—	1	—	—	—	—	9	8	1
10	20	—	2	2	—	—	—	7	6	3
13	20	—	1	—	—	—	2	1	5	8
		—	6	10	—	—	6	17	19	21
Sacox										
3	20	—	—	—	—	—	—	—	—	3
6	20	—	—	—	—	—	—	1	—	3
9	20	—	—	—	—	—	2	—	—	4
12	20	—	—	—	—	—	—	—	—	—
15	20	—	—	—	—	—	—	—	—	—
		—	—	—	—	—	2	1	—	10
Elancoban										
2	20	—	—	—	—	—	—	—	—	—
5	20	—	—	—	—	—	—	—	—	6
8	20	—	—	—	—	—	—	—	1	10
11	19	—	—	—	—	—	—	—	1	2
14	20	—	—	—	—	—	—	—	—	1
		—	—	—	—	—	—	—	2	19

+++ appearance of oocysts and schizonts, macroscopic tissue lesions
++ moderate appearance of oocysts and schizonts without tissue lesions
\+ less than ten oocysts or schizonts

McDOUGALD 1981, BADSTUE and JOHANSEN 1984). These anticoccidials do not give complete but do, however, provide sufficient protection against coccidiosis in field conditions.

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SELOSTUS

Sacoxin ja Elancobanin tehokkuus kokkidiosin ehkäisyssä broilereilla

TUOMO KIISKINEN ja PER ANDERSSON

Maatalouden tutkimuskeskus ja Valtion eläinlääketieteellinen laitos

Sacox (salinomycin) ja Elancoban (monensin) ovat molemmat ionofore- ja kokkidiostaatteja, jotka vaikuttavat kationien (K^+, Na^+, Ca^{++}, Mg^{++}) siirtymiseen solukalvojen läpi. Kokeessa, jossa oli yhteensä 1950 broilerpoikasta verrattiin näiden kahden kokkidiostaatin tehokkuutta. Sacoxia lisättiin 60 mg ja Elancobania 100 mg rehukiloon. Pehkun joukkoon lisättiin *Eimeri*-loisten saastuttamaa pehkua.

Kokkidiostaatin käyttö ei vaikuttanut eläinten kasvuun merkittävästi, mutta se lisäsi teuraspainoa 4—5 %. Rehunkulutus oli kokkidiostaattiryhmissä pienempi ja rehuhyötysuhde 5—6 % parempi. Teuraspainokiloa kohden kokkidiostaattiryhmien broilerit söivät 8 % vähemmän rehua kuin vertailuryhmän broilerit. Rehunkulutukseen nähden kokkidiostaattien vaikutus oli tilastollisesti merkitsevä. Kuolleisuudessa ja jalkavikojen esiintymisessä ei todettu merkitseviä eroja ryhmien välillä. Sacox-ryhmien pehku oli vesikupin läheisyydessä kosteampaa kuin muissa ryhmissä, ilmeisesti ko. ryhmän suuremman vedenkulutuksen vuoksi.

Molemmat kokkidiostaatit antoivat hyvän, joskaan ei täydellisen suojan kokkidioosia vastaan. Täydellisesti *Eimeria*-loisista vapaita eläimiä löydettiin vertailuryhmässä 21 %, Sacox-ryhmässä 87 % ja Elancoban-ryhmässä 79 %.

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Seria ANIMALIA DOMESTICA N. 81 — Sarja KOTIELÄIMET n:o 81

EVALUATION OF POLYOL MIXTURE AS A FEEDSTUFF IN PRACTICAL-TYPE DIETS FOR LACTATING MINKS AND MINK KITS

TUOMO KIISKINEN and JAAKKO MÄKELÄ

KIISKINEN, T. & MÄKELÄ, J. 1987. **Evaluation of polyol mixture as a feedstuff in practical-type diets for lactating minks and mink kits.** Ann. Agric. Fenn. 26: 157—165 (Agric. Res. Centre, Dept. Anim. Husb. SF-31600 Jokioinen, Finland.)

Polyol mixture (PM) or polyol molasses, a by-product of xylitol production, was blended in doses of 1 and 2 % into the ration of lactating minks and their kits during the first two months after birth (Expts. 1 and 2). During the main growth period (July — November, Expt. 3) 1 % PM was included in the ration of the kits and acceptability of the diets containing 0, 1 and 2 % PM was compared using adult males for determining faecal dry matter and polyols (Expt. 4).

During the first 3—6 weeks after parturition supplementations of PM to the diet of lactating minks did not significantly affect the growth rate of kits. At the beginning of July, 1 % PM (Expt. 1) resulted in higher body weights for male minks than by the other diets ($P<0,01$), and the females of each PM group were heavier ($P<0,05$) than those of the control group. In the second experiment no significant difference between the treatments were ascertained. In the later phase of growth (Expt. 3), 1 % PM resulted in a significant reduction of growth of both males ($P<0,001$) and females ($P<0,01$) and in the haemaglobine values of males ($P<0,001$). A possible reason for these differences is discussed. No significant differences were found in fur quality, but the skins of the males of the PM group were shorter than those of the control group ($P<0,05$).

The use of PM did not significantly affect feed consumption (Expt. 3), but if minks were unaccustomed, they seemed to reduce their feed intake as a result of the PM addition (Expt. 4). The polyol mixture did not cause watery faeces or diarrhoea, and on the basis of the small increase of polyols in faeces the authors estimated that around 95 % of the polyols from PM was absorbed.

Index words: polyols, sugar alcohols, mink, growth, feed consumption, haemaglobine values, faecal dry matter.

INTRODUCTION

As a by-product of xylitol production from the xylans of birch trees, a liquid mixture of polyols (sugar alcohols) is produced. This molasses-like product contains rhamnitol, arabinitol, xylitol, mannitol, galactitol, sorbitol and other organic substances such as reducing sugars, short-chain polyols and degradation products. Sugar is occasionally added into the rations during the lactation period of minks in order to provide available energy for milk production and for the growth of young kits. It has been shown that sucrose can be replaced by the polyol mixture (PM) in the diet of piglets (NÄSI and ALAVIUHKOLA 1981) and that PM improved growth when given in the creep feed of piglets (NÄSI and ALAVIUHKOLA 1980). In addition, polyols have been shown to increase lactoperoxidase activity in the milks of cows and sows (KORHONEN et al. 1977, MÄKINEN et al. 1981). This enzyme is known to have antimicrobial effects on intestinal infections in the newborn (REITER 1978). The four experiments described in this paper were designed to study the effects of supplementation of the polyol mixture in practical-type diets for lactating female minks and growing kits.

MATERIAL AND METHODS

Experiment 1 was conducted at a private minkfarm. Three groups of black pregnant female minks were formed at the end of April before parturition. Sixty animals were included in each group.

Dietary treatments:

	PM % in wet feed	PM % in dry matter
Group 1 (control)	0	0
,, 2	1	2
,, 3	2	4

The control diet was the normal feed ration of the farm into which polyol molasses were mixed (Table 1). The polyol mixture used in this experiment had, according to the analyses, the following composition: dry matter 54,9 %, in dry matter (%) rhamnitol 8,7, arabinitol 24,9, xylitol 17,5, mannitol 22,3, qalactitol 7,9, sorbitol 13,0, reducing sugars and other substances 3,7. On average, nearly 300 kits were born per group and their sexual division was around 50:50. The average birthdate of the kits was the same (2.5.) in each group. The kits were weighed at the beginning of June (3.6.) and July (8.7.), or approximately at the ages of one and two months. The first weighing was performed for each sex per litter and the second one individually. Mortality was recorded.

Experiment 2 was started in the middle of April at the experimental farm of the Finnish Fur Breeders Association. The dietary treatments were the same as in experiment 1. Forty-two pregnant topaz females were chosen for each group. On average, 34 females per group gave birth to living kits and the total number of kits was 170. The compositions of the diets are presented in Table 1. The polyol mixture replaced around a corresponding amount of dry matter of the grain mixture in the control diet. The polyol mixture used in this experiment contained 59,8 % dry matter and the dry matter contained rhamnitol 5,3, arabinitol 25,8, xylitol 15,9, mannitol 13,6, galactitol 5,8, sorbitol 11,0 and other substances 22,6 %. Kits were weighed individually at the ages of three and six weeks. Their mothers were weighed simultaneously. In addition, kits were weighed at the end of June. Mortality of the groups was checked.

Experiment 3 was a direct continuation of experiment 2. Forty-two male and female kits were included in group 1 (0 % PM) and group 2 (1 % PM). The kits were chosen from the corresponding groups of experiment 2, the average live weight remaining same. Two kits (one male, one female) were kept in a cage (40 × 60 cm). All kits were weighed individually at 3-week intervals. Feed was given once a day

Table 1. Composition of the feed rations (experiments 1—3).

Ingredients %	Expt. 1 Basic feed	Expt. 2 (Mai — Juni) Group 1	Group 2	Group 3	Expt 3 (Summer/autumn) Group 1	Group 2
Slaughter waste	38	20	20	20	20	20
Fish offal (cod)	8	30	30	30	25/20	25/20
Baltic herring	12	15	15	15	15	15
Fish meal	2	5	5	5	4	4
Soybean meal	—	—	—	—	—/1	—/1
Blood	4	—	—	—	—	—
Grain mix. (cooked)	8	8	7,5	7	10/11	9,5/10,5
Fat	—	1	1	1	0,5	0,5
Polyol mix. (PM)	(1 and 2 %)	—	1	2	—	1
Wheat germ	3	—	—	—	—	—
Brewery yeast	0,5	—	—	—	0,5	0,5
Vitamin premix[1)]	1,5	1,5	1,5	1,5	1,5	1,5
Sodium chloride	—	0,1	0,1	0,1	—	—
Water	23	23	18,9	18,4	23,5/26,5	23/26
Calc. contens:						
ME Mcal(MJ)/kgDM		4,20(17,6)	4,00(16,8)		3,85(16,1)/3,80	
Digestible protein g/Mcal		8,0	10,2		9,1/8,8	
Digest.prot % from ME		36	46		41/40	
" fat "		48	38		40/39	
" carbohydrates "		16	16		19/21	

[1)]STKL vitamin mixture

into the roof net of the cage. Total feed intake per group during the 3-week periods was measured as the difference between the ration given and the feed rests collected daily from the net. In addition, the feed intake of 24 kits (12 males, 12 females) was accurately measured during five days in August by placing a plastic sheet under the cages to collect dropped feed. Faecal dry matter content was also determined. The composition of the diets was changed in September (Table 1). Samples from the feed ration of each group were taken weekly, pooling them into the same sample for each diet and period. Haemoglobine was determined three times: 12.—13.7., 8.—9.9., 3.—4.11. during the experiment from the blood of the male minks. The male kits were pelted in November and the females were preserved for breeding purposes. Body length of the males was measured on the farm, while pelt length was measured and fur quality evaluated in the Finnish Fur Sales Co Ltd, using a score from 1 to 10.

Experiment 4 was performed on adult male minks (topaz) to study the effect of the polyol mixture on acceptability of feed ration and on the moisture and polyol contents of faeces. In this trial the animals were kept in special metallic cages constructed for digestibility studies. The diets of experiment 2 were offered *ad libitum* to three groups of eight animals. The diets were changed between the groups after a 5-day period each group eating each diet. Feed intake was measured individually and dry matter contents of the diets and faeces were determined daily. The content of polyols was determined in faeces from three animals per group during the first period.

Chemical analyses and statistics. The proximate analysis was performed according to the standard methods used by the Department of Animal Husbandry of the Agricultural Research Centre. The sugar alcohol composition of the polyol molasses was determined with a gas chromatograph (Carlo Erba 180) by the laboratory of the Finnish Sugar Co.

The data for each experiment was statistically evaluated using a one-way analysis of variance. The differences between the treatment means were tested by the t-test.

RESULTS

The results of the proximate analysis of the diets are presented in Table 2. The rations in experiment 1 contained on average 37 % crude protein and 27 % fat, which means approximately 32 % protein from the metabolizable energy of those rations. This is below the recommendation of 40—50 % for the lactation period (SALO et al. 1982).

In the first experiment, 1 % PM in the ration increased the growth rate of mink kits during the first month from birth and compared with the other groups, the differences were significant ($P<0,001$) among male kits from litters containing from six to ten kits (Table 3). Two percent PM in the diet did not influence live weight at that age. At the age of two months, male kits of group 2 (1 % PM) showed more rapid growth than males of the other groups ($P<0,001$). The effect seemed to be more prominent in the class of the larger litter size. As regards females, each polyol concentration increased mean live weight at the age of two months ($P<0,05$). The difference between the two OM levels was also significant ($P<0,05$) when litter size exceeded six kits. Mortality was lowest in group 3.

The use of PM in experiment 2 did not significantly affect the early growth of mink kits (Table 4). The six weeks' body weight of males of the polyol groups was about ten grams higher than that of the control group and at the end of June the increase in weight was 23 and 14 g for groups 2 and 3, respectively. Mortality among kits was lowest and weight loss of the mothers during the first six weeks after parturition was highest in group 2 (1 %

Table 2. Proximate analysis of the rations.

	Dry matter %	In dry matter % Crude protein	Ether extract	Crude fibre	Ash
Expt 1					
Control	27,0	38,0	26,3	2,7	6,3
PM 1 %	27,1	36,3	28,1	2,5	6,3
" 2 %	26,5	36,0	27,4	2,5	6,2
Expt 2					
Control	28.7	44,0	20,9	2,3	10,7
PM 1 %	30,1	44,2	23,6	1,9	9,9
" 2 %	32,0	44,8	23,7	1,9	9,7
Expt 3 (July — August)					
Control	27,0	45,5	15,1	2,1	10,0
PM 1 %	28,0	44,6	13,0	2,2	11,8
Expt 3 (Sept. — Nov.)					
Control	30,8	44,0	18,2	2,0	9,0
PM 1 %	30,2	41,8	18,6	2,0	7,7

Table 3. Average weight and mortalility of mink kits in experiment 1.

Group nr	1		2		3	
PM %	0		1		2	
	Males	Females	Males	Females	Males	Females
N	153	161	140	138	138	150
Average litter size	5,9		5,7		6,0	
Body weight g (3.6.)						
Litter size 1—5	205	192	215	190	193	193
Litter size 6—10	193[c]	172	206[d]	189	187[c]	183
Average	197	184	213	190	190	187
Body weight g (8.7.)						
Litter size 1—5	808	635	848	649	796	668
Litter size 6—10	750	599[b]	823	629[a]	725	617[ab]
Average	768[c]	614[a]	835[d]	638[b]	751[c]	636[b]
Mortality % (comb.sexes)	4,8		4,3		1,4	

a—b Corresponding means on a row with different superscripts are significantly different (P<0,05). If no letters are used the differences are non-significant.
c—d As above (P<0,001)

Table 4. Weight gain and mortality of mink kits and weight loss of their mothers in experiment 2.

Group nr	1		2		3	
PM %	0		1		2	
	Males	Females	Males	Females	Males	Females
N	91	89	79	74	95	84
Average litter size	4,7		4,3		4,3	
Body weight g 3 weeks						
litter size 1—5	139	124	132	123	134	118
litter size 6—10	120	106[ab]	120	113[a]	121	103[b]
average	127	114[ab]	127	118[a]	126	109[b]
Body weight g 6 weeks						
litter size 1—5	351[a]	307	369[ab]	312	382[b]	307
litter size 6—10	314	265	302	266	318	264
average	329	284	339	289	341	281
Body weight at the end of June	537	450	560	451	551	436
Mortality %	2,2	3,4	1,3	0	1,1	6,0
Weight loss of lactating females %						
litter size 1—5	16,5		17,9		13,2	
litter size 6—10	18,1[ab]		23,2[a]		17,9[b]	
average	17,2[ab]		19,8[a]		15,4[b]	

a—b See table 3, P<0,05

PM). The difference in the weight loss of mothers was significant between groups 2 and 3 (P<0,05).

Addition of 1 % PM into the ration significantly decreased the growth rate of males (P<0,001) and females (P<0,01) during the period from July to October (Table 5). Mortality was higher (7/3) in the PM group than in the control group. At the beginning of July, haemoglobine values of males in the PM group were higher than in the control group (13,9/13,4; P<0,05) but later the ratio between the Hb values changed contradictorily (17,3/18,9; P<0,001; Table 6). The body lengths of

Table 5. Weight gain and mortality of mink kits in experiment 3.

	N	Dead	Body weight kg 29.6.	21.7.	11.8.	1.9.	22.9.	13.10.
Males								
Group 1 (PM 0 %)	42	2	0,53	1,08	1,53	1,84	2,11	2,29
" 2 (PM 1 %)	42	5	0,56	1,05	1,48	1,76	1,92	2,09
t-value			2,12*	1,27	2,08*	2,13*	3,57***	3,50***
Females								
Group 1	42	1	0,45	0,75	0,94	1,04	1,15	1,25
" 2	42	2	0,45	0,72	0,89	0,98	1,06	1,16
t-value			0,15	2,25*	2,73**	2,73**	4,39***	3,36**

* The difference between the treatments is significant ($P<0,05$)
** " " " " " " " ($P<0,01$)
*** " " " " " " " ($P<0,001$)

Table 6. Haemoglobine values (g/l±SD) of male kits in experiment 3 (N).

Date	12.7.	8.9.	2.11.
Group 1	134±8,5(41)	178± 9,6(40)	189±11,0(40)
" 2	139±1,6(41)	176±16,8(38)	174±24,6(37)
t-value	2,16*	0,70	3,75***

*** $P<0,001$

the males were similar for each group at the end of the experiment, but the pelts of the PM group were nearly 2 cm shorter ($P<0,05$) than those of the control group (Table 7). No differences could be ascertained in fur quality. Daily feed consumption of the polyol group was 10 grams higher than that of the control

Table 7. Size and fur quality of male minks (Experiment 3).

	Body length	Pelt length	Density of guard hair	Density of underfur	Colour of underfur	General appea-rance	Total points
Group 1	43,6	70,5	6,3	5,6	7,7	6,1	25,6
" 2	43,6	68,8	6,8	6,1	7,6	6,6	26,6
t-value	0,11	2,41*	1,03	1,03	0,17	0,92	0,65

* $P<0,05$

Table 8. Feed intake of mink kits in experiment 3.

Group	1		2	
	g/day	gDM/day	g/day	gDM/day
Period 1 (29.6.—21.7.)	250	68	230	64
" 2 (22.7.—11.8.)	265	72	250	70
" 3 (12.8.—1.9.)	285	77	315	88
" 4 (2.9.—22.9.)	230	71	275	83
" 4 (23.9.—13.10.)	250	77	265	80
" 5 (14.10.—2.11.)	200	62	210	63
" 6 (3.11.—25.11.)	200	62	210	63
Average	240	70	250	73
The exact control in August (8.—12.8.)	241	60	221	52
Faecal dry matter % in August	32,0		30,5	

Table 9. Feed intake in the appetite test (Experiment 4).

Dry matter g/animal (±SD)

	Control	PM 1 %	PM 2 %	
N	8	8	8	F. value
Period 1	488±98,7	455±62,9	446±62,9	0,69 NS
Period 2	256±50,5	244±76,3	237±55,3	0,19 NS
Period 3	348±63,0	325±66,3	300±35,1	1,46 NS
F-value	20,2***	33,4***	19,1***	

*** P<0,001

Table 10. Content of dry matter and polyols in feces (Experiment 4).

	Control	PM 1 %	PM 2 %	F-value
Dry matter %	33,1	35,7	37,4	—
Polyols %	1,56±0,06[a]	1,92±0,20[b]	2,27±0,31[c]	16,4***

a—b P<0,05

group (Table 8). At the beginning of the experiment the kits of the PM group consumed less feed than those of the control group. This was confirmed by the exact short-term measurement of feed consumption in August (Table 8).

No significant differences were found in acceptability of the rations, although there was a tendency towards decreased feed consumption due to supplementation of the polyol molasses (Table 9). This appeared during each period. The differences between the periods (P<0,001) were caused by variation in air temperature. Unfortunately, the data from the faecal dry matter determination was lost, but before that, the treatment means had been calculated. In this experiment, dry matter and polyols in feces rose when the content of PM was increased (Table 10). For the polyol content differences were significant (P<0,05). Assuming that eighty percent of the dry matter of the diets was digested, the authors calculated on the basis of the faecal polyol contents that 95 % from polyols was absorbed at each level.

DISCUSSION

Based on the results from experiments 1 and 2 it appears probable that from one to two percent PM given in the ration of lactating females hardly has any beneficial effect on the growth rate of mink kits during the first weeks of life. Later, when the kits begin to eat fast feed the addition of polyols may, in the short-term, positively affect their growth. These results agree with the results of NÄSI and ALAVIUHKOLA (1980) which suggest that the addition of PM to the diet of sows has hardly any effect on the performance of piglets, but when given in the creep feed it increases their rate of growth. In addition the authors found only slight changes in the composition of colostrum and milk from sows receiving polyols. The slight positive response of mink kits to the addition of PM was supported by increased Hb levels in the males fed the diet containing PM (1 %) until the beginning of

July (Expt. 2). However, the results from the main growth period after the beginning of July were not encouraging; the addition of PM (1 %) caused a clearly negative effet on the growth rate of both males and females (Expt. 3). This was also reflected in decreased Hb values of male minks of the PM group, but the animals were hardly anemic as no signs of white underfur were observed. However, the value of 173 g/l represents a marginal value for the appearance of white underfur (PÖLÖNEN 1987).

In general, feed consumption was not remarkably affected by the addition of PM to the ration (Expt. 3). When minks were unaccustomed to the diets the addition of PM seemed to decrease feed consumption (Expt. 4). A possible reason for the negative response to the addition of PM into the ration of the kits during the later phase of growth may have been the decreased supply of available energy in the diet. Polyols are apparently well absorbed from the digestive system of the mink, as shown by the content of polyols in feces (Expt. 4). FÖRSTER (1972) has found that the absorption of polyols is very slow from the small intestine of the rat. It is known that mammals can utilize well some polyols such as xylitol and sorbitol but very weakly for example, arabinitol (TOUSTER 1974) which is mostly excreted in urine (RUTTLOFF and KETZ 1961). Obviously, PM was not as good an energy source as grain (starch) when the digestive capacity of the mink kits had fully developed.

The addition of PM to the diet of mink kits did not cause diarrhoea or watery feces. A relatively high dietary concentration (10 %) of xylitol has caused diarrhoea in rats especially if they have been unaccustomed to it (HOSOYA and IITOYO 1969). A slight increase in the incidence of diarrhoea in piglets (NÄSI and ALAVIUHKOLA 1980) and a slightly lower dry matter content of the faeces of calves (TUORI 1984) has been found in diets containing the polyol mixture.

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SELOSTUS

Sokerialkoholiseoksen (Polyoli) käytön vaikutukset minkkien imetys- ja kasvatuskauden rehuissa

TUOMO KIISKINEN ja JAAKKO MÄKELÄ

Maatalouden tutkimuskeskus ja Suomen Turkiseläinten Kasvattajain Liitto

Polyoliseosta, sokerialkoholeja sisältävää ksylitolin valmistuksen sivutuotetta, lisättiin minkin rehuun 1 ja 2 % imetyskaudella ja varhaisen kasvuvaiheen (touko-kesäkuu) aikana sekä 1 % kasvatuskauden (heinä-marraskuu) rehuun. Lisäksi tutkittiin polyoliseoksen vaikutusta rehun maittavuuteen sekä sonnan kuiva-aine- ja polyolipitoisuuteen.

Polyoliseoksen käyttö imetyskauden rehussa ei vaikuttanut merkitsevästi pentujen kasvuun ensimmäisten 3—6 elinviikon aikana. Ensimmäisessä kokeessa olivat 1 % polyoliseosta rehussaan saaneet urospennut ja molempien polyoliryhmien naaraspennut merkitsevästi painavampia kuin vertailuryhmän pennut. Toisessa kokeessa polyoliryhmien urospennut olivat kesäkuun lopussa hieman painavampia kuin vertailuryhmän, mutta erot eivät olleet merkitseviä.

Yli kahden kuukauden ikäisten pentujen rehussa polyoliseos (1 %) aiheutti selvän ja tilastollisesti merkitsevän kasvun heikkenemisen sekä nahan pituuden lyhenemisen. Mahdollinen syy oli viljan hiilihydraattien (tärkkelys) sokerialkoholeja parempi hyväksikäyttö tässä pentujen ikävaiheessa. Vaikka pentujen hemoglobiiniarvot olivat heinäkuun alussa polyoliryhmällä korkeammat kuin vertailuryhmällä, tilanne oli syksyllä päinvastainen. Turkin laadussa ei ollut merkitseviä eroja.

Polyoliseoksen käyttö (1 %) ei vaikuttanut merkittävästi rehun kulutukseen. Totuttamattomilla eläimillä rehun maittavuus näytti vähenevän polyolilisäysten vaikutuksesta. Polyoliseos ei aiheuttanut vetisiä ulosteita tai ripulia. Sonnan polyolipitoisuuden lisäyksen perusteella tutkimuksen tekijät arvioivat n. 95 % polyoleista imeytyneen minkin ruoansulatuskanavasta.

CONTENTS

SISÄLLYS — CONTENTS

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