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The effect of ADD-H preservative (ammonium propionate) on the quality and feedingvalue of baled hay

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Abstract. The effect of ADD-H at 3 or 4 rates of application on the quality and feeding value of baled hay at 3 dey matter levels (65.0–69.9, 70.0–74.9 and 75.0–79.9 %) was studied on Hankkija's farm in Kangasala and at DM 78–82 % on the Koivisto farm in Hausjärvi. The field experiments were performed in 1979 and the testing of the hay completed by the following spring.

The field experiments were affected by uneven drying of the hay, uneven rewetting due to rainfall after cutting, loss of ADD-H during application, uneven distribution of ADD-H in the bales, and other factors.

At DM 65.0–69.9 % ADD-H gave only a slight improvement in hay quality; at the highest application rate the sugar content was the highest and the crude fibre content the lowest. At the other DM levels ADD-H restricted the generation of heat during storage; the sugar content was higher, and the mould count lower, in the treated hay than in the untreated hay. The beneficial effect of ADD-H on the feeding value of baled hay was small; further study on this aspect is required.

Introduction

In 1979–1980 the Valio Laboratory and the Regional Institute of Occupational Health, Kuopio (RIOH), with the cooperation of the firm Hankkija, studied the preservation of and growth of moulds in baled hay treated with ammonium propionate (ADD-H). The field experiments were performed on Hankkija's Nikkilä experimental farm in Kangasala and on the Koivisto farm in Hausjärvi. The RIOH study will be published separately.

Field work

ADD-H (BP Chemicals Ltd., UK) was obtained from Hankkija, Helsinki. Machinery: (i) cutting: Nurmi-Combi (Nikkilä farm) and Esa GCH 170 (Koivisto farm) drum mowers. (ii) tedding: Ylö (Nikkilä) and Rysky (Koivisto) tedder-windrowers. (iii) addition of preservative and baling: BP applicators (BP Chemicals Ltd., UK) fitted into Massey-Ferguson balers were used on both farms.

Hay DM (dry matter) was determined in the field by drying 30–40 g samples in a Radarange microwave oven (Amana Refrigeration Inc., Amana, Iowa, U.S.A.)

Table 1. Effect of ADD-H on the composition and feeding value of baled hay (Nikkilä farm). $\bar{x}$ is the mean and s the standard deviation. The significance levels are NS not significant, o $P < 0.1$, x $P < 0.05$, xx $P < 0.01$, xxx $P < 0.001$. The C (Kuopio) section gives the data for those bales sampled by the Regional Institute of Occupational Health, Kuopio.

	ADD-H dose rate	pH value		Dry matter %		Ash % DM		Sugars % DM		Crude fiber % DM		Crude protein % DM		Feed units/ kg/DM		Rainfall mm	Number of samples
	kg/t	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
	0	7.1	0.3	80.2	5.8	7.6	0.4	2.9	1.6	35.8	1.4	11.0	0.7	0.38	0.03	0.9	9
Trial A	7.8	7.2	0.4	79.9	6.0	7.4	0.3	3.9	3.6	36.3	1.1	11.3	0.6	0.37	0.03	0.4	9
DM 65–69.9 %	12.2	6.8	0.4	80.7	4.1	7.8	0.2	6.5	2.5	33.6	1.3	10.9	1.2	0.43	0.04	0.9	9
	14.5	6.7	0.5	79.6	3.5	7.7	0.4	7.1	5.2	34.2	2.1	11.0	0.9	0.40	0.03	0.9	9
Significance level		NS		NS		o		x		xx		NS		xx			
Trial B	0	6.5	0.3	83.4	3.0	6.5	0.2	6.9	2.7	34.3	1.5	9.3	1.1	0.43	0.02	3.8	9
70–74.9 %	9.1	6.6	0.4	80.6	1.9	7.1	0.7	8.3	2.7	34.1	1.2	9.3	0.6	0.42	0.02	3.8	9
	16.7	6.1	0.3	79.4	1.6	7.4	0.5	10.9	1.8	31.7	1.5	9.5	0.7	0.47	0.05	3.8	9
Significance level		NS		xx		xx		xx		xx		NS		xx			
	0	6.7	0.4	83.7	3.3	7.3	0.4	5.1	1.8	34.1	1.7	12.0	0.8	0.43	0.03	3.8	9
Trial C	7.9	6.7	0.2	80.6	4.8	7.0	0.2	5.5	2.1	34.1	1.3	12.2	1.1	0.41	0.03	3.8	9
75–79.9 %	8.2	6.4	0.2	81.9	1.5	7.0	0.3	8.6	1.6	33.2	1.3	11.1	0.8	0.44	0.03	3.8	9
	13.5	6.5	0.4	79.9	1.5	7.3	0.4	9.2	1.3	34.1	1.2	9.6	0.8	0.41	0.02	3.8	9
Significance level		NS		o		x		xxx		NS		xx		NS			
	0	6.7	0.3	84.6	1.6	7.0	0.5	4.7	1.9	34.6	1.8	10.7	0.7	0.43	0.03	3.8	7
C	7.9	6.7	0.5	81.8	3.1	6.6	0.9	7.7	2.2	33.4	1.9	10.8	1.3	0.44	0.04	3.8	8
(Kuopio)	8.2	6.5	0.3	81.8	1.9	6.9	0.8	7.3	1.5	34.0	1.2	10.7	1.0	0.42	0.01	3.8	8
75–79.9 %	13.5	6.6	0.4	80.7	1.5	6.6	1.2	8.5	2.0	33.7	1.1	10.6	1.2	0.42	0.01	3.8	8
Significance level		NS		x		NS		xx		NS		NS		NS			

for 2 min (DM 70 %) to 9 min (DM 30 %). In calibration tests such DM figures agreed closely with laboratory results (80°C 24 h).

The hay field on the Nikkilä farm was on a slight slope, down to level ground where the stand was denser and thicker-stemmed. The grass was mainly cocksfoot, almost in full flower, and was cut on 25 June 1979, beginning at 2 p.m. Conditions at this time were: grass DM 35 %, air temperature 27°C, relative humidity 30 % and cloud cover about 40 %, increasing during the afternoon. The hay was tedded during the evening, at which stage its DM was 45–52 %. 0.4 mm drizzle fell during the night and by the following morning the hay dry matter had fallen to 40–45 %. Towards noon the DM reached 63–72 %, but drying was slow in the unexposed hay on the level ground.

Baling was begun on 26 June at 1 p.m., starting with trial A, 7.8 kg ADD-H/t (Table 1). Rain (0.5 mm) interrupted baling and reduced the hay DM to 45 %. The DM had risen to 64–69.5 % by 6 p.m. and baling for the remainder of trial A was completed the same evening. The 0 kg ADD-H/t bales were the last and the twine and bales were slack. All trial A bales were transported to storage on the 26th. The morning of the 27th was cloudy (100 % cover); the relative humidity was 76 % at 8 a.m., 75 % at 2 p.m. and 55 % at 8 p.m. Light rain fell at noon. Trials B and C (Table 1) were baled and stored during the afternoon and evening.

The number of bales per treatment averaged 27; bale weight was 15–20 kg. For storage the bales were placed in a 3×3×3 stack. A temperature sensor was placed in the central bale of each stack (no readings were obtained for the 7.8 kg ADD-H/t bales of trial A).

Timothy and orchard grass were the main species in the hay field on the Koivisto farm. Part of the grass was cut on 23 June 1979 and was dried and baled in completely dry weather; this hay was denoted dry-weather hay (Table 2). The rest of the grass, for treatments A-D (Table 2), was cut on 25 June. Treatments A and B were baled on 2 July, after a total of 17 mm rain; hay DM at baling was 78 %. Treatments C and D were baled on 9 July, after 70 mm rain; DM averaged 82 %. The number of bales per treatment was 25–30, each weighing 20–25 kg.

Table 2. Effect of ADD-H on the composition and feeding value of baled hay (Koivisto farm). Abbreviations as in Table 1.

Treatment	ADD-H dose rate	pH value		Dry matter %		Ash % DM		Sugars % DM		Crude fiber % DM		Crude protein % DM		Feed units/ kg DM		Rainfall mm	Number of samples
	kg/t	x̄	s	x̄	s	x̄	s	x̄	s	x̄	s	x̄	s	x̄	s		
A	6.4	6.6	0.3	84.4	2.3	5.0	0.4	5.0	1.4	36.4	1.8	11.1	0.8	0.41	0.03	17	8
B	20.4	6.5	0.3	82.9	2.1	4.9	0.3	6.3	2.0	35.2	1.2	12.0	1.5	0.42	0.03	17	8
C	0	6.5	0.3	85.2	1.3	4.8	0.8	1.9	0.8	38.7	1.1	10.4	1.2	0.37	0.01	70	8
D	12.0	6.6	0.3	83.9	1.9	4.9	0.9	2.3	0.4	38.2	0.8	11.0	0.6	0.37	0.01	70	8
Significance level				o		NS		xxx		xxx		x		xxx			
Dry-weather hay		6.4	0.2	84.1	2.0	7.2	0.7	11.8	3.8	30.5	1.0	13.6	1.9	0.54	0.03	0	9

Laboratory analyses

A single sample was taken from the central bale of each stack in early July and thereafter monthly. The Nikkilä and Koivisto farm samples for RIOH consisted of one whole bale monthly; the bales from the Nikkilä farm too were sampled for analysis in the Valio Laboratory and the data area given in the C (Kuopio) section of Tables 1 and 3.

Microbial counts and chemical analyses were made by standard methods: propionic acid by high-performance liquid chromatography (after extraction from hay by steam distillation), DM (80°C 24 h), ash (600° overninght), N with a Kjel-Foss analyzer (Foss-Electric, Denmark), sugar (SOMOGYI, 1945), crude fibre (modified Weende method) and *in vitro* digestibility (MENCKE et al. 1979).

Results and Discussion

Preservative. The ADD-H used on both farms was found to contain 72.8 w/w % propionic acid and 7.1 w/w % ammonia. Recovery tests showed that some 75 % of the ADD-H was lost during application, presumably into the soil surface and as aerosol to the air.

Bale temperature (Figures 1–5) showed a rise during the first few days of storage. The maximum start temperature was 27° (trial B, air temperature 16°), rising to 35° two weeks later. The addition of ADD-H restricted the generation of heat.

pH value (Tables 1 and 2). Treatment with ADD-H did not change the pH value of the hay. The pH values in trial A were elevated.

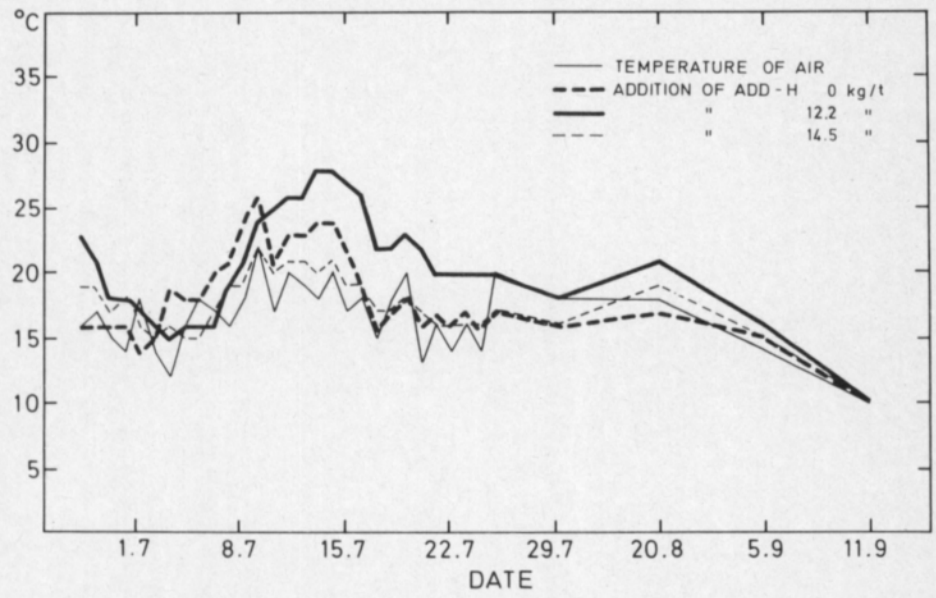

Figure 1. Temperature changes in baled ADD-H -treated hay during storage, Trial A (dry matter 65–69.9 %) Nikkilä farm.

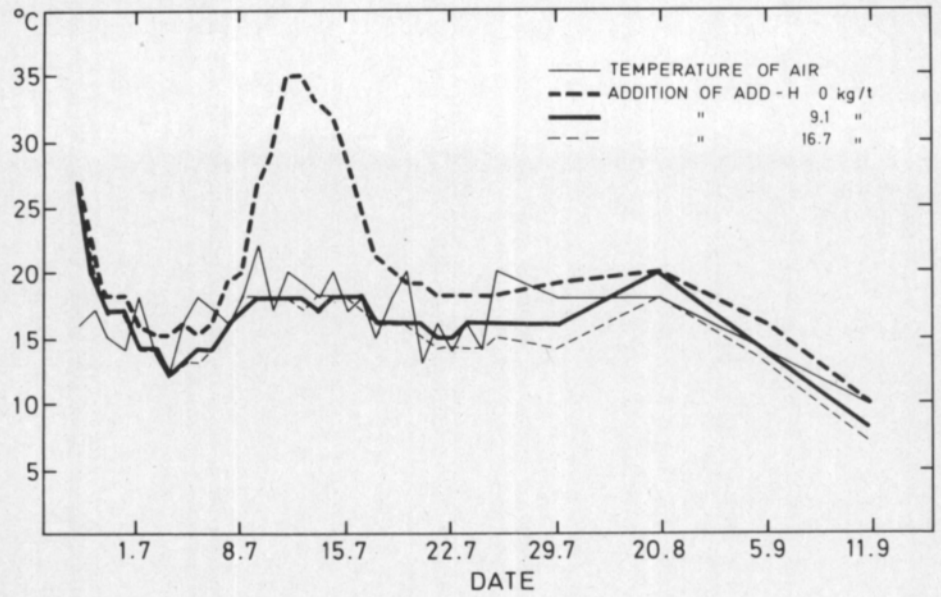

Figure 2. Temperature changes in baled ADD-H -treated hay during storage, Trial B (dry matter 70—74.9 %) Nikkilä farm.

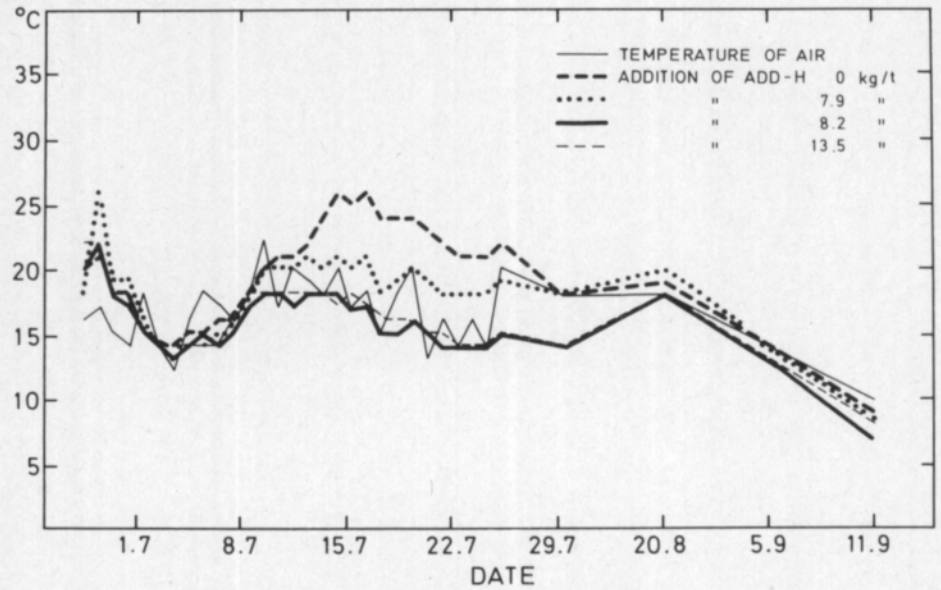

Figure 3. Temperature changes in baled ADD-H -treated hay during storage, Trial C (dry matter 75—79.9 %) Nikkilä farm.

Dry matter contents (Tables 1 and 2) rose during storage. Mean DM's on the Nikkilä farm, where the bales were stored at ground level and relatively close to a lake, were lower than on the Koivisto farm, where storage was on the first floor and at a greater distance from a lake, resulting apparently in a lower relative humidity.

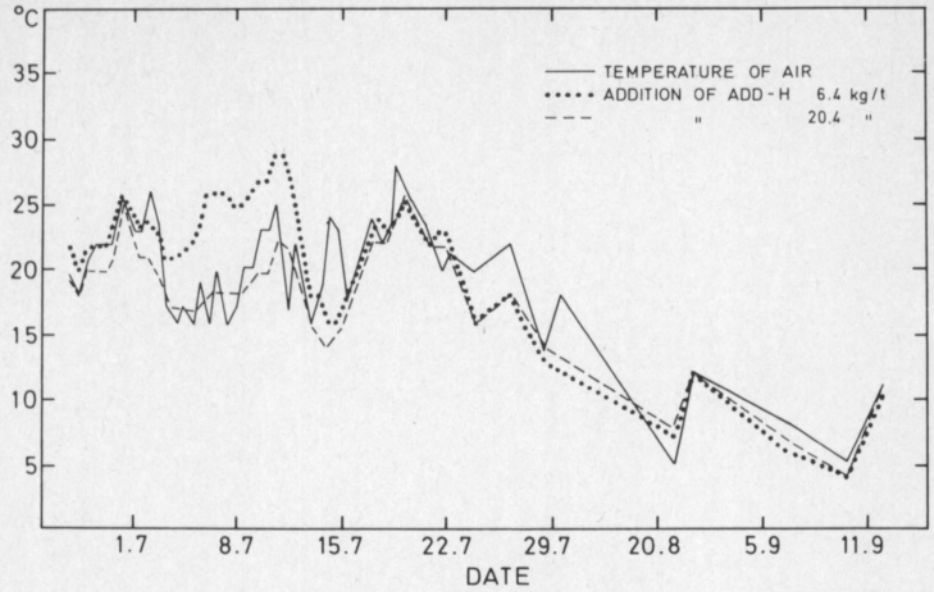

Figure 4. Temperature changes in baled ADD-H -treated hay during storage, Treatments A and B (dry matter 78—82 %) Koivisto farm.

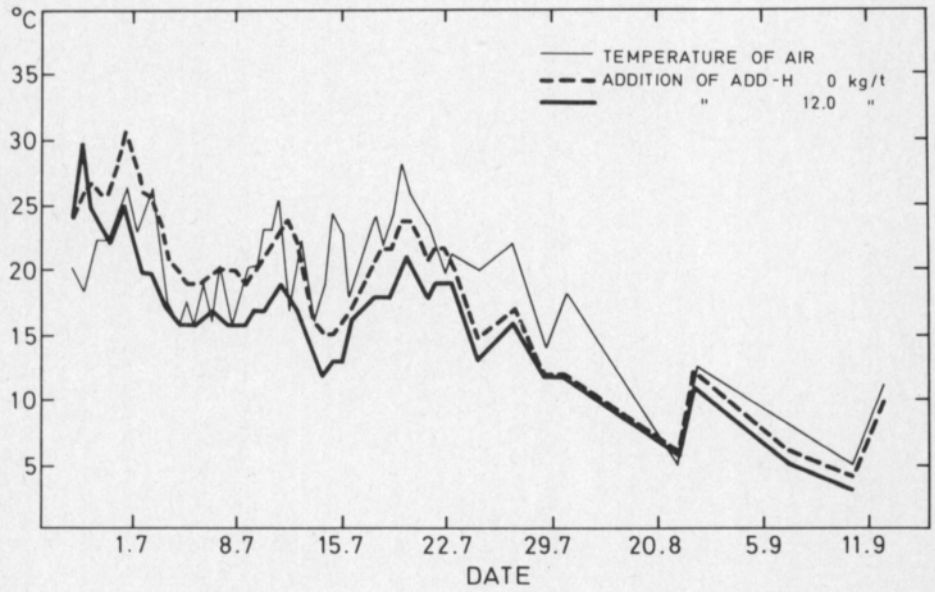

Figure 5. Temperature changes in baled ADD-H -treated hay during storage, Treatmets C and D (dry matter 78—82 %) Koivisto farm.

ADD-H slowed the rate of drying: lowest DM's were found at the highest rates of ADD-H application.

Ash content (Tables 1 and 2) was not affected by treatment with ADD-H. The higher the rainfall the lower was the ash content, even though the extra tedding

Table 3. Effect of ADD-H on the microbial counts of baled hay (Nikkilä farm). Abbreviations as in Table 1.

	ADD-H dose rate	Total count of bacteria		Acid-producing bacteria		Coliform bacteria		Psychrophilic micro-organisms		Yeasts		Moulds		Clostridium spores MPN		Bacillus spores		Number of samples
	kg/t	10^6/g		10^6/g		10^3/g		10^6/g		10^3/g		10^3/g		10^0/g		10^3/g		
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	
	0	65	46	55	45	35	100	25	66	160	250	660	350	54	66	9.5	21	9
Trial A	7.8	490	350	450	350	0.7	1.6	3	8	1700	3800	12000	16000	32	4.4	5	5	9
65–69.9 %	12.2	740	710	690	730	0.4	0.7	2	5	2400	4500	1700	2000	64	30	10	9	9
	14.5	630	500	560	430	14	30	41	82	24000	70000	2300	3000	57	65	19	35	9
Significance level			x		x		NS		NS		NS		x		NS		NS	
Trial B	0	13	23	3	3	520	1600	3.5	5	1500	4000	3600	4200	33	5	12	12	9
70–74.9 %	9.1	40	41	20	31	120	330	14	19	2500	4500	970	1800	36	13	5	5	9
	16.7	1.5	4	0.1	0.2	38	110	.06	.08	2	3	5	3	62	66	7	6	9
Significance level			x		o		NS		x		NS		x		NS		NS	
	0	29	43	23	39	7.7	21	0.2	0.3	910	1700	2200	2000	38	20	2	2	9
Trial C	7.9	93	130	70	110	160	470	2	3	97	180	1100	1200	39	20	4	3	9
75–79.9 %	8.2	7	17	1	3	0.1	0.1	0.2	0.3	3	3	75	210	33	5	6	4	9
	13.5	9	10	5	10	4.0	7.4	2	5	6	6	11	17	74	64	5	7	9
Significance level			x		o		NS		NS		o		xxx		o		NS	
C	0	7	10	5	7	28	65	1	2	13000	33000	670	820	33	5.2	7	7	6
(Kuopio)	7.9	30	36	19	27	2.5	5.9	1	2	3500	7100	760	1000	31	3.8	2	7	7
75–79.9 %	8.2	28	34	22	31	28	56	0.4	1	3	5	400	650	33	4.9	2	2	7
	13.5	110	240	100	230	30	71	0.1	0.1	130	300	63	1200	37	15	9	12	7
Significance level			NS		NS		NS		NS		NS		NS		NS		NS	

Table 4. Effect of ADD-H on the microbial counts of baled hay (Koivisto farm). Abbrevitations as in Table 1.

Treatment	ADD-H dose rate	Total count of bacteria		Acid-producing bacteria		Coliform bacteria		Psychrophilic micro-organisms		Yeasts		Moulds		Clostridium spores MPN		Bacillus spores		Number of samples
	kg/t	10^6/g		10^6/g		10^6/g		10^6/g		10^6/g		10^6/g		10^3/g		10^6/g		
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	x	s	
A	6.4	110	230	21	29	46	110	98	200	0.5	1.2	1.6	1.2	30	0	1.1	1.1	8
B	20.4	140	320	6	8	21	56	65	170	1.0	2.8	2.1	3.1	33	4.6	0.8	0.5	8
C	0	780	510	220	270	52	90	630	540	7.5	9.1	8.7	11	38	21	1.3	2.7	8
D	12.0	470	580	200	270	29	61	230	340	1.4	1.8	1.2	3.3	31	3.3	0.4	0.5	9
Significance level		x		o		NS		x		x		o		NS		NS		
Dry-weather hay	6.4	6	13	1	2	8.6	25	0.5	0.9	.002	.003	0.2	0.5	31	3.3	1.2	1.9	9

required resulted in more soil contamination. This is seen very clearly in the Kovisto results, the ash content of the test hays being 4.8—5.0 % and that of the dry-weather hay 7.2 %. The highest ash figure in the Nikkilä results, 7.8 %, was in trial A, in which the rainfall was the lowest. According to an unpublished hay quality survey made by the Pellervo Society the whole-country average for the ash content of hay made in Finland in 1979 was 6.2 % of the DM.

Sugar content (Tables 1 and 2). Treatment of hay with ADD-H had a clear sugar-preservation effect; treated hay had a slower respiration rate and sugars were consumed less rapidly during storage. The higher the ADD-H dose rate the higher was the content of sugars (Nikkilä farm) although rain could mask this effect (Koivisto farm).

Crude fibre content appeared to be directly related to amount of rainfall (Table 2).

Crude protein content (Tables 1 and 2) was not affected, in any consistent fashion, by ADD-H treatment; the highest content was found in the dry-weather hay on the Koivisto farm.

Feeding value, in terms of feed units per kg feed DM (Tables 1 and 2). Treatment with ADD-H had a beneficial effect on feeding value of the hay (trials A and B).

Digestibility. The *in vitro* digestibility of ADD-H treated hay was 3—6 % higher than that of the untreated.

Microbial counts (Tables 3 and 4). Within-treatment variation was so large that only few of the between-treatment differences were significant. Further, the slack bales of the untreated hay in trial A dried faster and this affected the microbial counts. Counts were highest in hay of the lowest DM (trial A). ADD-H decreased the mould count, except in trial A. All microbial counts in the dry-weather hay (Koivisto farm) were low. The high coliform counts in the test hay on the Koivisto farm were due probably to its being stored close to the outlet of ventilation ducting from the cowshed; the dry-weather hay was stored further away. Counts of clostridium spores were low in all the test hays. Despite the rain and the heavy tedding the numbers of bacillus spores in the Koivisto test hays were small.

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SELOSTUS

ADD-H:n (ammoniumpropionaatin) vaikutus paalatun heinän laatuun ja ruokinta-arvoihin

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ADD-H:n vaikutusta paalattujen heinien laatuun ja ruokinta-arvoihin tutkittiin Hankkijan Nikkilän koetilalla kolmessa kuiva-aineluokassa: 65–69,9 %, 70–74,9 % ja 75–79,9 %, Koiviston maatilalla yhdessä kuiva-aineluokassa: 78–82 %. Jokaisessa kuiva-aineluokassa käytettiin 3–4 eri säilöntäaineannostusta. Kenttätyöt tehtiin kesällä 1979 ja heinien seurantaa jatkettiin kevääseen 1980.

Kenttäkokeiden tuloksiin liittyy aina monia tekijöitä: heinien epätasainen kuivuminen, erot uudelleen kastumisen määrässä pellolla, annostuksen yhteydessä tapahtuvat säilöntäaineen menetykset ja epätasainen leviäminen heiniin jne.

ADD-H:n vaikutus heinien laatuun oli vähäinen kuiva-aineluokassa 65–69,9 %. Suurimmilla ADD-H:n annostustasoilla heinien sokeripitoisuus oli korkein ja raakakuitupitoisuus vastaavasti pienin. Muissa kuiva-aineluokissa ADD-H:n lisäys heiniin hidasti lämmön muodostusta. Sokeripitoisuudet olivat käsitellyissä heinissä korkeampia kuin käsittelemättömissä. Homeiden kokonaismäärät olivat käsitellyissä heinissä alhaisemmat kuin käsittelemättömissä. ADD-H:n vaikutus paalattujen heinien ruokinta-arvoihin jäi kuitenkin vähäiseksi ja tarvitsisi lisätutkimuksia.