EFFECT OF ORGANIC ACID TREATMENT ON PRESERVATION, FERMENTATION AND NUTRITIVE VALUE OF UNPROTECTED FORAGES AND HIGH MOISTURE EAR CORN

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This is to certify that the

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ABSTRACT

EFFECT OF ORGANIC ACID TREATMENT ON PRESERVATION, FERMENTATION AND NUTRITIVE VALUE OF UNPROTECTED FORAGES AND HIGH MOISTURE EAR CORN

By

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Experiments were conducted to determine the preservative effect of organic acids on forages left under minimal protection conditions. The acids were: formic, propionic and acetic. Acids were used at different levels and combinations.

Part I consisted of 4 trials and was designed to determine which acid level or combination of acids is most effective in retarding spoilage of rye forage. Also, the influence of acid treatment on fermentation characteristics and acceptability of treated forages by the animals was examined. In trial I, three treatments were used: control, 1% formic and 1% AP (60 Acetic: 40 Propionic). The temperature of the control was higher 4 hours after treatment 28.3 C, compared to 21.9 and 25.5 C on the AP and formic acid treatments, respectively. The control temperature peaked by the third week (54 C) and corresponded to a peak in the pH on this treatment. At 3, 9, and 14 days after storage, mold was detected

on control, AP and formic treatments, respectively. The DM recovery was higher on the acid treatments than the control. Temperature changes were highly correlated +0.98 with amount of molded DM. Formic acid treatment had the lowest pH values and control the highest. Changes in pH were directly correlated with temperature (+0.98) and with the amount of molded DM (+0.92). Organic acid production was lower on formic than AP. The control treatment had the highest concentration of butyric acid. After removal of molded layer, lactic acid levels were comparable to that of good silages. Temperature and VFA concentrations were negatively correlated -0.46. Also, VFA concentrations were negatively correlated with molded DM, -0.61. Changes in protein content were not different ($P > .05$). Also, differences in NPN content after the first week of storage were not significant ($P > .05$). Cows consumed 7.9, 7.4 and 9.6 kg of DM/day on control, formic and AP, respectively. In trial II, spoilage was first detected on the control followed by the low levels of acids (0.25%). However, a mixture of 1:1 of F:AP at 1.0 and 1.5% resulted in highest recovery of DM. The changes in pH were directly related to those of temperature +0.76. Temperature was negatively correlated with the time of mold detection, -0.93. Animals consumed forage treated at the high acid level (1.5%). In trial III, the effect of moderate compaction on acid treatment was tested. A delay in temperature rises was observed for all acid treatments compared to control which spoiled first. Temperature, pH and VFA relationships were similar to those observed with previous studies. Propionic acid treatment resulted in the least spoilage followed by the 1% mixture of P+F. Changes in ADF (Acid Detergent Fiber) and ADF-N were not different among treatments ($P > .05$). In trial 4, rye was treated with 0.4% formic acid and ensiled in conventional upright silos. Milk production and persistency and milk composition were not different ($P > .05$) on formic rye, control rye and alfalfa haylage. Although forage intakes were not significantly different ($P > .05$) slightly higher consumption was observed on the formic treated rye compared to control (8.3 vs 7.6 kg of DM daily).

In part II corn forage (38% DM) was treated with different acid treatments and left uncompacted. In trial I, the control molded first and had the highest temperatures. The second treatment to spoil was acetic acid. The propionic acid treatment maintained the lowest temperature throughout the 6 weeks of storage and the AP and propionic acid forages had the least amount of molded DM. Temperature was negatively correlated (-0.81) with the time of mold detection and positively related +0.40 to amount of molded DM. Formic acid treatment had the lowest pH value. The pH was negatively correlated (-0.61) to time of mold detection. Total organic acid production of unspoiled silage was higher on control, formic and propionic than other treatments. Crude protein and NPN contents were not different among treatments ($P > .05$). AP and propionic acid treatments had the lowest temperatures during the short acceptability trial suggesting that propionic acid depressed after-fermentation. In trial II, 51 different acid levels and combinations were used. The first treatment to spoil was the control and the last to spoil were those to which 1.5, 1.0 and 1.25% propionic acid were added. Formic plus propionic was more effective in delaying spoilage than formic alone or formic plus acetic. Earlier detection of mold occurred as the proportion of acetic acid added to forages increased. Temperature and time of mold detection were negatively correlated (-0.54).

Part III was conducted to study the effectiveness of organic acids as peripheral preservatives. In trial I, more DM molded on the control (64%) and least on the AP treatment, 23.8%. Addition of propionic to formic decreased the amount of molded DM by 38% compared to formic alone. Preserved material was fed to lactating cows and intakes of 9.5, 9.4, 8.3, and 9.0 kg of DM were observed for AP+F, AP, formic, and control, respectively. When high DM (50%) corn silage was used, the highest amount of spoilage (90%) was on the control and the least on propionic acid, 9.7%. Formic acid was a better preservative than AP or acetic acid on high DM material. In trial II, acids were sprinkled on top of horizontal silos and more DM molded on the control (34 kg/sq m) while propionic acid treatment had the least amount (22.4 kg/sq m). AP treatment delayed further spoilage when applied on material that had been placed in the silo several days earlier and was partially spoiled. Acid treatments had lower pH values than controls. Changes in pH were directly related to the amount of molded DM (+0.66). Lactic acid concentrations were higher in the upper layers while acetic acid levels were higher in the lower levels. Crude protein and NPN content were not affected by the different acid treatments.

Part IV was conducted to determine the effect of organic acid treatment on urea-treated HMEC (High Moisture Ear Corn). In trial 1, formic acid alone depressed lactic acid production. However, lactic acid concentrations were not affected by acid treatment in presence of urea. Pro-Sil and control treatments had higher pH than acid treatments. Highest intake were observed on urea-formic acid treated HMEC but differences among treatments were not significant ($P > .05$). Also, milk production and persistency and milk composition did not differ ($P > .05$) between treatments. In trial II, pH values were lower on treatments without NPN addition. Formic acid depressed lactic acid production. Milk production and persistency and HMEC intake was higher on the acetic than other acid treatment even though differences were not significant ($P > .05$). Untreated and Pro-Sil treated HMEC had the highest temperatures during the study.

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INTRODUCTION

Roughages play a predominant role in dairy cattle rations, primarily because they are recognized as the most economical sources of energy. In areas where hay curing is difficult and losses are high, silage offers a method to overcome these problems. The processes which convert fresh forages to silage can, at best, preserve only what is already there.

The voluntary intake and the nutritive contribution a forage makes towards meeting the animal needs is related to certain factors of management, composition of the forage, the efficiency with which the animal uses the ingested nutrients and the environment. The farmer must consider the various aspects of production, harvesting, storage and feeding which may influence the value of his silage.

In developing countries the farmers usually operate on small scale and therefore good storage facilities are not used in order to reduce the cost of operation thus resulting in more feed loss. While in the developed countries, where farming is a large scale business, the farmer uses the best available storage facilities but still has peripheral losses in upright and bunker silos. In addition, some farmers desire to make more silage than their facilities hold. This material is often left under minimally protected conditions resulting in tremendous spoilage.

The objectives of these studies were to examine the possibilities of preserving silages with organic acids with minimal storage protection and to determine which level and combination of these acids are most effective; also, to determine the acceptability of such silages by the ruminant animal.

REVIEW OF LITERATURE

Many factors influence the nutritive value and the degree of preservation of stored forages and grains. Some of the factors that are of great importance in making good quality silages are:

1. The state of maturity and moisture level of the plant at ensiling time.

2. The effect of oxidation and temperature on silage preservation.

3. Silage additives.

In this review, information and publications related to these factors will be discussed.

Stage of Maturity and Moisture Level Of The Plant At Ensiling Time

Corn Silage

The maturity of the plant at harvesting is one of the major factors that influences the production of good quality silages, Noller et al. (1963) found that milk stage had a slightly higher dry matter (DM) digestibility (72%) compared to the very early dent (70%) and late dent (69%) stages. They also observed that the voluntary intake by heifers was 20-30% higher for the two more mature stages. Byers and Ormiston (1964) found that the DM yields of silage/acre was 6.97 tons for the control (31.5% DM) and 6.21 tons for the mature (54.9% DM). The DM consumption and digestibility were 16.1 vs 16.6 kg and 62.7 vs 56.7% for the control and mature silages, respectively. Similar results were obtained by Bryant et al. (1965) who found that milk production and persistency, DM digestibility and consumption were higher for the mature corn harvested at the hard dough stage (31.8% DM) than for the corn harvested at milk stage (21.7% DM).

Results obtained by Huber et al. (1965) indicated no significant differences in milk composition, body weight gains, efficiency of milk production or total digestible nutrient (TDN) content of silages harvested at soft (25.4% DM), medium (30.3% DM), and hard dough stages (33.3% DM); while milk yields and DM intakes increased significantly with DM content of the silage.

When corn was harvested at late stage (58-63% DM), Gordon et al. (1968) found that the DM yields were 19-27% less than that harvested at early stage (26-30% DM), and that the digestibility of DM and acid detergent fiber (ADF) were lower in the mature silage, In addition, they observed that early silage had more VFA and lactic acid and that the late silage had a tendency to heat when fed in hot weather.

In contrast to most of the previous reports, Perry et al. (1968) said that the corn plant if stored in gas-tight silos, may be harvested at a much later stage than at hard dough which has been recommended by other workers. They also reported that the digestibility of the product (75-73%) remained quite constant regardless of the harvest date, even though the stalks and leaves had been exposed to a relatively long period of weathering following maturity. The acceptability of the silage remained about the same in one experiment but declined in the second. In comparison, Coppock (1969) reported that corn harvested for silage over a broad range in maturity exhibited little change in DM digestibility but an increase in DM intake occurred through the range of 25-35% DM. McCullough (1971) found that corn crop was least affected by maturity and grasses and legumes the most affected because in corn 50% or more of the total nutrients in the silage were in the ear. The date of harvest had no significant effect on the percent crude protein or ether extract according to Caldwell and Perry (1971) but found that these were positively correlated with crude fiber, nitrogen free extract (NFE) and ash. They also observed that a maximum yield/hectare occurred at the time when plant contained 33% DM.

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Lopez et al. (1970) reported greater pH values for corn silages with low (25%) or high (52%) DM than with medium (30%) DM when the corn was harvested at the different stages of maturity and treated with urea or soybean meal and ensiled in small plastic silos stored under controlled temperatures. A significant decline in lactic acid concentration was observed with advance in maturity and that total organic acid concentration declined from 11.94% of DM in low DM samples to 3.14% of DM in high DM silage. They also observed a higher VFA concentration with lower nitrogen supplementation.

Sorghum Silage

Nehring and Laube (1958) found little effect of maturity at harvest on digestibility or sorghum harvested between flower and milk stage. A decline in the digestibility of crude fiber, NFE, and protein with maturation of Tracy sorghum from the milk to the mature stages was reported by Helm and Leighton (1960) who found that the highest TDN (65%) was at the soft dough stage. Mississippi studies (Browning and Lusk, 1965) revealed no significant differences in DM or energy digestibility for Tracy sorghum harvested from the late flowering to the ripe seed stage.

The deterioration in quality of forage sorghums with advancing maturity may be explained, in part, by results of Thurman et al. (1960), who found that increased yields with advancing maturity were man

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manifested mainly in higher yields of stalks. They also observed that the percent of heads, blades and sheaths decreased with yield.

When Atlas sorghum silages were harvested at milk (21% DM), soft dough (24% DM), hard dough (26.5% DM) and mature stages (28.2% DM) and compared as roughages for lactating cows, Owen (1962) found that consumption of DM increased and FCM/lb. of DM intake decreased with advancing maturity. He also observed that the consumption of silage (as fed), milk fat percent and body weight changes were not significantly affected by maturity at harvest. Because the differences found in quality of the silage DM favoring early-cut silage appear insufficient to compensate for the usual yield advantage of harvesting sorghum after reaching maturity, he recommended to harvest sorghum when acreage yields are near maximum. This is usually at the hard seed stage.

Rye Silage

When Italian rye grass was wilted and ensiled at 34 and 47% DM or ensiled as fresh grass 15.9% DM, McDonald et al. (1968) found that the DM losses from wilted silages were low and ranged from 6.7-10.4%. The researchers observed that the residual amounts of sugars in the wilted silages were directly related to the degree of wilting and that little fermentation occurred in material of 47% DM.

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Barley Silage

Polan et al. (1968) harvested barley at three stages of maturity (bloom, milk and dough) and found that DM content increased ($P < .05$) with stages of growth, but DM yields increased significantly between bloom and milk stage only. The dough stage was lower in crude fiber and higher in NFE than milk or bloom, but there was little change in protein content. The barley ensiled at these 3 stages was fed as the sole source of roughage to lactating cows. Milk production was similar for the 3 treatments. Silage DM intake was least ($P < .01$) for bloom silage and resulted in lowest ($P < .05$) body weight gains. In digestibility trials DM and NFE were least ($P < .05$) digestible for the dough silage. Crude fiber digestibility was highest ($P < .01$) at bloom. Cows fed milk stage silages exhibited lowest rumen acetate and highest propionate.

Wheat Silage

McCullough and Sisk (1967) fed wheat silages harvested at early heading, milk and dough stages to dairy heifers as the only feed and found that intake of the early cut silage was superior to the late cut. Crude protein was highest and crude fiber, cellulose and NFE were lowest for the early cut silage. They added that the superiority of early cut silage was retained when 20, 35, and 50% of the silage DM was replaced with a grain mixture.

Oat Silage

Martz et al. (1959) compared oat silages harvested at boot (21% DM), early milk (23.5% DM) and soft dough (29.9% DM) as a source of roughage for lactating cows to supply about 86-88% of the total forage DM intake. Dry matter intake of the soft dough was highest but the TDN intake was highest at boot. Milk production was correlated with TDN intake of the silages. The authors concluded that the optimum stage to ensile oats was at the boot stage or soon thereafter.

Alfalfa Silage

When the moisture level of alfalfa haylage was reduced from 53 to 35% Owen and Senel (1963) observed a decrease in propionic and butyric acids from 1.7 and 1.3%, respectively, to unmeasurably small amounts. Acetic acid levels averaged about the same (1.6%) while lactic acid was reduced to 1.8% or just one half the level in the haylage of higher moisture content. They concluded that the lower acid content and higher pH of low moisture haylage was an indication of a decrease in the amount of fermentation.

Gordon _et al_. (1965) ensiled alfalfa from 39 to 65% DM and found that high DM levels resulted in less fermentation. They also observed higher DM intakes with increasing levels of DM but this response was less consistent above 50%. They did not find marked differences in milk production or DM digestibility and concluded that for storage in conventional silos, more than 50% DM was neither desirable nor harmful.

Gordon (1968) showed that protein digestibilities were substantially reduced in haylages ensiled at high DM levels (55%) regardless of the type of storage used.

Roffler _et al_. (1967) reported that Alfalfa-Brome forage preserved as hay was lower in protein, ether extract, and ash than that preserved as low moisture silage or wilted silage. Ammoniacal nitrogen constituted a greater proportion of the total nitrogen in wilted than in low-moisture silage.

Sutton and Vetter (1968) found that the DM and nitrogen digestibilities of Alfalfa hay (92% DM) were significantly higher than that of alfalfa haylage (60% DM) and silage (28% DM) and that the digestibility of silage nitrogen was significantly higher than that of haylage.

The Effect of Temperature and Oxidation On Silage Quality

Oxidation occurs for a short period just after ensiling in well packed or gas-tight silos. Temperatures rise slowly to a peak, are constant for some time and then drop to a level corresponding to ambient temperatures. The degree of oxidation and the amount of heat produced are closely correlated. Thus, temperature rises are often a good indication of the degree of spoilage that occurred in the silage. According to Barnett and Duncan (1954) poor quality silages are high in VFA content and low in lactic acid. To prevent the formation of butyric acid they recommended compressing the mass to make it more air-tight.

Wieringa et al. (1961) reported that temperature was of great importance in influencing the different kinds of micro-organisms which dominate the fermentation and is associated with the amount of proteolysis and subsequent ammonia production. They also stated that the presence of oxygen resulted in a faster loss of soluble sugars because respiration in silages continues for a longer time. They added that at temperatures above 40 C, oxygen was responsible for the fixation of protein into undigestible compounds and that under farm conditions the highest percent of butyric acid and NH_3 were found in silages with a maximum temperature of 40-50 C. Their recommendation was that temperature of the silages must be kept below 30 C to prevent putrefaction and/or fixation of indigestible protein.

Langston _et al_. (1962) showed that aerated silages had high temperatures and pH values with increased butyric acid and NH_3-N; whereas, lactic acid concentrations were depressed. They also observed that total acids were higher in sealed than aerated silages which suggested to them that some of the substrate initially present was destroyed as a result of aeration. Therefore, high levels of sugars did not insure silage of superior quality unless the forage was properly packed to exclude air.

Zimmer and Gordon (1964) used laboratory silos (jars) which were sealed continuously for 38 days or sealed with the exception of aeration on the first, second, third, and sixth day. They reported that oxygen consumption was greatest for unwilted-chopped silage during the first and second days of aeration. Grinding the material improved total preservation and reduced CO_2 and DM losses. Improvement of fermentation was indicated by lesser amounts of NH_3 and butyric acid and greater amounts of lactic acid. A correlation coefficient of +0.71 was observed between CO_2 production and DM losses, so they concluded that aeration resulted in poor preservation of the silage.

Honig (1969) conducted gas balance tests with silages. He found that DM losses increased linearly with the amount of added air, and observed losses as high as 2% of DM per month of storage. He also reported that the digestibility of nutrients as well as the quality and stability of silages decreased with increased air. He recommended air tightness of silos because of its economical importance in preventing DM losses.

With insulated silos Federson (1971) found that oxidation was accompanied by a large rise in temperature and high DM losses in high moisture silages. Temperature increases in the silos without oxygen present were negligible. He observed that the pH closely paralleled the added oxygen supply. These data agree with those of Honig (1969); that the loss in DM rose almost linearly with an increased oxygen supply.

Pierson et al. (1971) reported that digestible protein was lost when haylage heated during the ensiling process. They reasoned that heating caused the protein to react with other materials in the plant to make part of the protein indigestible by animals.

Van Soest (1965) showed that exposing feed samples to high temperatures caused an increase in the apparent lignin content when analyzed by the sulfuric acid method. The analysis of this artifact lignin fraction showed that it contained a high percent of nitrogen. He suggested that the nitrogen content of the ligno-cellulose fraction might estimate the amount of compositional change due to heat damage.

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Thomas and Hillman (1972) reported that excessive heating during the curing process of haylage, baled hay or stacked hay caused carmelization to occur between plant proteins, sugar and water resulting in product which was insoluble and indigestible. They concluded that the carmelization effect was small but measurable at 46 C, greater at 51.7 C, and protein digestibility was markedly reduced at 57 C.

Silage Additives

At the present time there are many additives that could be used on silages in order to increase their protein content or to change the pattern of fermentation. This review will cover the influence of organic acids, and their effect on the fermentation pattern, preservation of silage and the performance of the animal.

Addition of Acids to Ruminants

When 400 Cal. of acetic acid, propionic or n-butyric or 800 Cal. as n-butyric were administered to sheep with positive energy balance, Armstrong and Blaxter (1957) found that the acid administration did not interfere with the normal process of rumen fermentation or impose non-physiological conditions upon the animals. They added

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that the energy retained when the acids were given was partly stored as protein, but mainly as fat.

After the administration of 0.5-1.5 kg sodium acetate per day to cows on fat depressing diets an appreciable improvement in milk fat percentage was reported by Balch and Rowland (1959) while the administration of 414 g sodium propionate under the same conditions did not restore the fat percent. They also observed that on normal diets the administration of 500 g sodium acetate did not affect the milk fat content. With continuous infusion techniques Rook and Balch (1961) found that acetic acid caused an increase in milk yield, and yields of fat, lactose and protein and a specific increase in fat percentage. The infusion of propionic acid and butyric acid had no effect on yield of milk, but propionic acid specifically decreased the yield and percentage of fat and increased the yields and percent of protein, SNF; as where butyric acid infusion increased the yield and percent of fat. In addition to the previous study Rook et al. (1965) reported similar findings with other infusions, but when acids were given in combination, effects on fat content were additive. They also observed that formic acid infusions were without significant effect on milk yield and composition.

Montgomery and Baumgardt (1963) reported that lactic acid was converted to butyric acid in the rumen when 700 kg cows on an all-hay diet were infused over a 4 hour period with 340 g lactic acid which had been diluted to four liters with water. In another study, Montgomery et al. (1963) found a significant decrease in hay consumption with acetic acid infusion while the infusion of propionic, butyric and lactic acids caused a moderate decrease in voluntary hay intake. Because no change in cellulose digestion occurred they concluded that the acids had little effect on rumen micro-organisms.

Ulyatt (1965) found that feed intake decreased significantly in sheep given acetic acid at a dose rate of 200 Cal. on low and high planes of nutrition, but the decrease was more pronounced on the low plane. An increase in intake was observed with 200 Cal. of propionic acid on both planes of nutrition but 300 Cal. propionic depressed intake at the low level of nutrition.

Vercoe and Blaxter (1965) infused formic acid into sheep on dried grass diets at a constant rate for 17 days and found that methane (CH_4) and CO_2 production increased but there was no significant change in O_2 consumption. Rapid infusions of sodium formate resulted in smaller increases in CH_4 production with a depression in O_2 consumption and CO_2 production. They concluded that rapid infusion of formic acid depressed overall metabolism, probably by interference with micro-organisms other than those concerned with methanogenesis.

Simkins et al. (1965) reported that when VFA mixtures (60 acetic, 20 propionic, 20 butyric) were infused into cows on pelleted al

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alfalfa hay diet to meet 15% of the estimated digestible energy requirement, consumption of pelleted ration decreased significantly. A significant decrease in hay consumption was also observed when propionic and butyric acids were infused. They concluded that VFA's can act as satiety signal compounds in affecting food intake.

McCullough (1971) reported an improvement in milk production and butterfat percent when acetic acid was infused into the rumen. This finding led him to conclude that rumen fermentation may be a limiting factor for milk production in certain cows.

VFA and Lactic Acid Addition to Rations

Bentley et al. (1956) reported that the addition of sodium salts of acetic, propionic and lactic acids to corn-cerelose-urea-hay or corn-hay rations produced significant increases in gains of lambs fed to about 45 kg body weight. The apparent feed replacement values were calculated at 1 kg of the acid salt for 3-10 kg of feed.

In their first study Senel and Owen (1966) reported a significant increase in DM intake when lactate and acetate were added to a basal ration in a 3 to 1 ratio at 11.8% of the DM. The basal ration consisted of 67% sorghum silage, with the remaining 33% a mixture of beet pulp and soybean oil meal. In a second study (1967), no change in voluntary intake was observed with 2% acetic or 1% butyric acids added singly or in combination; but intake was reduced when the acid levels were doubled. They concluded that depression in DM consumption and lower rates of gain which often result from feeding silage rations compared to hay are due to a factor(s) other than the acetate and lactate contributed by the silages.

Formic Acid Treatment of Silages

Waldo et al. (1966) reported that when unwilted orchard-grass silage preserved with 0.5% formic acid was fed to heifers as the sole ration, daily gains were higher (851 vs 744 g) than on hay. Heifers on hay ate more dry matter, but digestibility of the silage was higher at either restricted or ad libitum feeding. A 17% improvement in the apparent digestible energy resulted from formic acid treatment. When unwilted alfalfa was treated with 0.5% formic acid significantly higher daily gains were observed by Waldo et al. (1968) in heifers fed acid treated silage compared to controls. In another study Waldo et al. (1966) found that animals fed unwilted silages treated with formic acid consumed more digestible energy, gained more weight and used the digestible energy more efficiently on a net or gross basis. The formic acid silages were lower in pH, butyric and acetic acids, ammoniacal nitrogen, and higher in lactic acid. In a study

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using sorghum and alfalfa silages Waldo et al. (1969) recovered less DM for the untreated silage compared to the formic acid silage. They also observed that the treated silage contained less cellulose than the untreated silage and that the animals consuming control alfalfa silage required 1.4 times as much digestible energy/unit gain as those fed the acid treated silage. In another study comparing formic to control silages, Waldo et al. (1971) reported that digestible energy intake above maintenance per unit gain was less and that gain per metric ton of DM was higher for treated silages (122 vs 80 kg). A better recovery of energy from the silo was also observed for treated compared to control silages (91.9 vs 85.6%).

Derbyshire and Gordon (1969, 1970) and Derbyshire et al. (1971) found that alfalfa orchardgrass wilted and treated with 1.17% formic acid, or orchardgrass silages treated with 1.1% formic acid on a DM basis had significantly lower ADF, lignin, cellulose, pH values, NH_3-N as percent of total nitrogen. Also the treated silages had lower acetic and lactic acids than untreated silages. They suggested that direct acidification by the formic acid inhibited many of the biochemical changes noted in untreated silages. Silage treatment had no significant effect on average milk production, percent butterfat and percent SNF even though milk yields for cows receiving treated silages were slightly higher. Heifers gained more weight on the formic acid treated silages. In another experiment

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wilted silage was treated with 0.8% formic acid and direct cut silage with 0.5% resulting in a marked improvement in DM recovery of the wilted forage and increased DM digestibility of both silages treated with acid. A slight depression in percent of butterfat was observed for the formic treatment. Addition of formic acid to wilted forage improved feed efficiencies 34% in growing heifers. Because of the compounding effect of concentrate feeding and body energy changes a similar increase in efficiency was not demonstrated with milking cows.

In fermentation studies with lucerne, Carpintero et al. (1969) used formic acid at 0.85% and found that this level was sufficient to achieve an immediate pH fall to 4.2. The formic acid inhibited both lactic acid and clostridial activities. They also observed that water soluble carbohydrates (WSC) were preserved and suggested a beneficial effect on ruminants.

Wilkins and Wilson (1969) added formic acid at the rate of one half gallon per ton to grass silage and found that the pH dropped immediately to about 4.4 with little change during the first 6-12 days in the silo. Lactic acid in the treated silage was low; but for crops high in WSC, such as rye grass, these workers suggested that the lactic acid content would be comparable to untreated silages. However, Huber (1970) showed a greater depression in lactic acid content of corn silage, which is usually high in WSC, due to formic acid treatment than has usually been reported for other crops. No change in the digestibility of the silage was observed but mean intakes were higher for the formic silages (Wilkins and Wilson, 1969).

Castle and Watson (1970) harvested Timothy and perennial rye grasses at about 17-20% DM for treatment with 1/2 gallon/ton of formic acid. The silages were vacuum packed and temperatures were recorded. They found that formic acid treatments had about 7-15 C lower temperature rises than the control and that the maximum temperature recorded occurred about one week after the silos had been filled. Lactic acid was higher and butyric lower in treated silages indicating that formic acid improved the type of silage fermentation. Acid treatment increased digestibility and DM intakes (11-12%). In another study (Castle and Watson, 1970), unwilted or wilted herbage was treated with formic acid. Digestibility and total soluble sugar content of the wilted herbage which was treated were lower than for the unwilted-treated or the unwilted-control silages. Treatment resulted in increased DM intakes and decreased milk production. The significant increases observed in the SNF and protein contents of milk were related to higher energy intakes on treated silages. The authors concluded that wilting of silages did not have the same beneficial effects as did formic acid treatment.

Fisher et al. (1971) found that milk yields were significantly higher on silages made from direct cut sorghum-sudangrass treated with 0.5% formic acid as compared to wilted silages without formic acid. The acid-treated silage had lower fiber and energy digestibility but efficiency of energy utilization for milk production plus body gain was greater ($P < .05$).

Henderson and McDonald (1971) studied the effect of formic acid on the fermentation of grass of low DM content (11.8-17.3% DM) and found that the acid prevented oxidation of WSC in a short period (4 hrs), thereby preserving more sugar for fermentation. Formic treatment also had an inhibitory effect on proteolytic clostridia; therefore less proteolysis occurred. They concluded that formic acid treatment of low DM silages decreased the formation of lactic acid and volatile nitrogen when used at high levels (0.34% and higher), but increased the production of ethanol and restricted the breakdown of lactic acid to butyric acid.

Taylor and Philips (1970) reported that total aerobic counts in silage treated with formic acid (1/2 gallon/ton) were lower than those in the untreated silages and a similar trend was observed with lactobacillus counts. They also found that the anaerobic proteolytic count was depressed markedly by the addition of formic acid, but the anaerobic lactate fermenters and the thermophilic counts were higher in the acid treated than in the control silage. They concluded that the addition of formic acid to silages provided suitable conditions for the growth of desirable organisms and the suppressed undesirable ones which resulted in an improvement in the silage quality.

Saue and Breirem (1969) reported an 80-90% DM recovery in grass treated with formic acid (0.33 liters/100 kg). At 30 hours after ensiling higher temperatures (64 vs 30 C) and sugar losses (68 vs 13%) were observed on the control silage compared to formic acid silage. They also observed that formic treatment limited respiration (3.2 vs 6.4 g of CO_2/100 g DM), decreased undesirable fermentation caused by Coli-Aerogenes, and depressed breakdown of protein as suggested by low NH_3 levels. They concluded that the preservative effect of formic acid was directly related to its hydrogen ion concentration, and that it is less bactericidal for lactic acid fermenters than for undesirable organisms. In another study the same two authors found that feeding formic acid silage increased milk yields above those in cows fed hay as the only roughage. Because no differences in efficiency of energy utilization were observed when comparing hay and silage in the rations they reasoned that milk stimulation was due to a chemical rather than an energy effect.

High Moisture Corn

Under current conditions feeding high moisture corn (HMC) is probably one of the most economical and efficient ways of using grain in cattle rations. High moisture corn can be harvested as soon as the kernel reaches physiological maturity. Therefore harvesting can commence 2-3 weeks earlier than usual without the expense of artificially drying. In addition, early harvest may permit greater utilization of corn stalks. Another major benefit of HMC is a reduction in harvesting losses. Handling operations are also decreased; since once the product is in storage, no further processing is needed before feeding.

Feeding Value of HMC

The results of two trials by Beeson and Perry (1958) indicated that fattening beef cattle utilized high moisture ground ear corn (32% moisture) from 10-15% more efficiently than regular ground ear corn when grains were adjusted to the same moisture.

Iowa researchers (Burroughs, 1971) also found that when corn was harvested and stored at 24-30% moisture, the feeding value of the grain DM was increased by 4-9% above that of artificially dried corn. No differences were observed in DM intake between steers on HMC and those on grain ration. Zogg et al. (1961) examined the nutritive value of HMC fed with various silages and found that the efficiency of utilization of the DM of the HMC increased as the moisture content of the corn increased from 22 to 32%. In contrast, Bridson (1972) compared dry corn with HMC in rations with low roughage levels (10% or less of diet DM) and found that dry grain was better for rate of gain. However, HMC resulted in superior animal performance when fed with high roughage levels (20% or more of diet DM).

In trials to evaluate HMC as the primary source of concentrate energy for dairy cows, McCaffree and Merril (1968) found that high moisture (HM) shelled corn resulted in significantly lower forage DM intake, milk fat percent and total DM intake and significantly higher milk production than HM ear corn. No differences were observed in TDN or grain DM intakes. Barrington and Jorgenson (1971) found that milk production and feed efficiency were similar for HMC and dry corn, but milk fat tests were lowest in the group fed HMC. In contrast, Johnson and Otterby (1971) reported that milk fat depression was not a problem in rations containing 33% HMC and that rations containing corn silage and HMC appeared to support lactation.

Chemical Changes in HMC

Schmutz *et al*. (1962) related nutritive value of HMC ensiled at 24, 32 and 45% moisture to chemical and bacteriological changes.

Lactobacilli and Anaerobes were 10^9/ml after 10 days and yeast were ten times higher for the drier corn at 60 days. Acetic acid was highest at 45% moisture. Weight gains increased with lactic acid concentration of HMC which was directly related to moisture content.

When dry cracked corn was reconstituted to 20, 25 and 30% moisture and ensiled in quart jars, Sprague and Breniman (1969) observed little fermentation at 20% moisture. There were high pH values and low concentrations of lactic acid and soluble protein. At moisture contents of 25 and 30% the pH was lower than at 20% with more lactic acid and soluble proteins present. They concluded that the minimum moisture content to prevent mold in HMC was 30-35%.

Non-Protein Nitrogen and HMC

Schmutz et al. (1962) found that 50% of the urea added to HMC was degraded to ammonia by 20 days and 80% within 60 days.

Dutton and Otterby (1971) found that HMC which was supplemented with urea or diammonium phosphate and placed in sealed evacuated bags for 45-60 days had higher pH values, higher NH_3 levels and greater nitrogen losses than control or soybean meal-treated HMC. The HMC treated with urea was highest in acetic and lowest in propionic acid, with low concentrations of lactic acid and ethanol.

Acid Treated Grains

Grains absorb liquids as a natural phenomenon necessary before germination can take place. Acid is absorbed in a similar way by combining with the grain embryo to prevent growth.

Drysdale (1970) estimated losses (not spoilage) caused by the production of CO_2 during fermentation in sealed storage to be as high as 5% and found that the loss in value of the feed was almost equivalent to the cost of adding propionic acid to grain which would incur essentially no CO_2 loss. In addition, the acid-preserved grain was found to keep for a year or more under open storage conditions.

Jones (1970) did not detect heating or mold growth at seven days in samples treated with mixtures of VFA's (14:83:01, 40:40:20; 70 acetic:20 propionic:10 butyric) and placed in unsealed plastic bags, while the controls molded (185,000-62,000 colonies/g) and had an off-odor. A pH of 4.4 or less was found effective in inhibiting mold formation. For 72% DM ear corn this required a 1% level of acid addition. When HMC (66.7% DM) preserved with 1.5% propionic acid was fed to dairy cows and heifers at 4.5 kg/animal daily, Jones _et al_. (1970) found that FCM, persistency of milk production, milk fat and protein percent and rate of gain were not significantly different than for animals fed untreated HMC. Slightly higher gains were noted for treated corn even though maximum daily intake of the acid approximated only 68 g/day. In another report Jones (1971) found that either propionic acid or mixtures of acetic and propionic acid effectively preserved corn grain ranging in moisture content from 28 to 33%. But, HM ground ear corn, at moisture levels within this range heated within several weeks and molded even though it was treated with 1.2% propionic acid.

Marion et al. (1972) found that steers fed HM grain treated with 0, 4, and 6% acetic or propionic acid gained well at the lower levels of acid addition. Gains were higher than controls ($P < .05$) at 4% and lower ($P < .05$) at 6% added acid. In another study, propionic acid was added at 2% to dry grain or to grain reconstituted to 30% moisture and stored for 14 days in open barrels and compared in feeding trials with same untreated grain kept in air tight plastic bags. No significant differences in daily gain, feed intake or feed/kg gain were observed. Treated grain did not heat or mold while the untreated grain did.

Bridson (1972) reported that Purdue University researchers found 6% more rapid gains in steers full fed HMC treated with acetic and propionic acids (60:40 ratio) at the 1.5% level compared to dry corn. Feed efficiencies favored the acid treated corn. In comparison, Wilson and Long (1972) found a 5% increase in feed efficiency of steers fed HMC treated with 1.6% acetic and propionic acids (60:40) compared to steers fed dry untreated corn. They did not observe significant differences in the digestibility of the corn but reported that more protein was digested and retained by lambs fed the acid treated corn.

The amount of propionic acid required for preservation was found by Miller (1971) to be directly proportional to the moisture content of the grain. When propionic acid treated grain was fed to yearling steers there was no evidence of lower palatability and no adjustment period was required for feeding the treated corn. For HMC with 25% moisture, Miller (1971) suggested adding 1% propionic acid but 1.25% was needed for material with 30% moisture.

When pigs were fed HMC (76% DM) treated with 1.5% propionic acid which was stored in bins open to air, Young et al. (1970) found that the animals gained at a similar rate and had a feed efficiency equal or better than pigs fed dry corn (90% DM). No problems of mold or heating were reported for the acid treated grain.

Otterby and Murphy (1971) studied the effectiveness of different acids in preventing hydrolysis of urea (at 1%) added to HMC (68% DM) placed in polyethylene bags which were then evacuated and sealed. They found that DM and nitrogen losses were minimal during fermentation. The lactic acid concentrations were lowest on treatments made with 1% urea plus 1% acetic acid, 1% acetic acid, and 1% propionic acid. Largest amounts of lactic acid were reported for the control and the 1% urea treatment.

It seems that after reviewing most of the available literature on organic acid treatment of silages little is known at the present time about the relative effects of the different acids (formic, acetic and propionic) as silage preservatives. The literature on these acids deals mainly with their influence on feed intake and animal performance with minor information relating their effects on silage recovery. Therefore, a main objective of this thesis was to supply information on the preservative role of these organic acids under different conditions and at different levels and combinations.

PART I

EFFECT OF ORGANIC ACID TREATMENT ON UNPROTECTED RYE FORAGE

INTRODUCTION

Better animal performance as measured by intake, feed efficiency, and gain in body weight has resulted from feeding formic acid treated silages (Waldo et al., 1966, 1968; Derbyshire and Gordon, 1971; Castle and Watson, 1970). However, little is known at the present time about the relative effectiveness of different organic acids (formic, acetic, and propionic) as silage preservatives. Also, no data are available on the effects of these acids as silage preservatives under minimally protected conditions.

The objectives of Part I were to determine which acid or combination of acids was the most effective preservative of material stored under complete aerobic conditions with minimal protection. Also, changes in fermentation and animal performance due to acid treatment were determined.

MATERIALS AND METHODS

Trial I

Four trials were conducted to evaluate the preservative effect of organic acids on unprotected rye forage. In trial I, chopped rye forage harvested at the boot stage was wilted to about 27% DM then transferred into temporary silos (3x1.5m). The silos used were snow fences lined with polyethylene. They held about 3 ton portions of fresh rye forage. The treatments were control; 1% acetic and propionic acids (AP) (60:40 ratio), and 1% formic (F) acid. The acids were diluted 1:1 with water and added at a constant rate to the forage as it went up the hay elevator into the silos.

Forage samples were taken immediately before and after treatment and then 3 times weekly. The samples were kept frozen at -5 C until analyzed for DM, total nitrogen and NPN according to AOAC (1960). Silage extracts were prepared by homogenizing a 25 gram aliquot of the sample in a Servall Omni-Mixer with 100 ml of distilled water for 1 minute and straining through two layers of cheesecloth. About 20 ml aliquot of the extract was used for determining pH by using a Beckman pH-meter. The remainder of the extract was deproteinized using 1 ml of 50% sulfosalicylic acid (SSA) and 9 ml of extract. The sample was then centrifuged at 18,000 rpm for 10 minutes and stored in a refrigerator for later analysis. The VFA content of the silage was determined by injecting samples of the deproteinized silage fluid described above into a Packard gas chromatograph. Formic acid was determined by following same procedure used for VFA but with some modifications made through the use of Packard Detector Power Supply. Colorimetric procedures of Barker and Summerson (1941) were used to determine lactic acid content of the deproteinized sample.

Temperature of forages was recorded twice daily by using five thermometers located at different positions in the silos. In addition, spoilage was recorded when first observed. At the end of 4 weeks, all spoiled material was removed, weighed and sampled for DM determination. The preserved forage was fed in a short acceptability trial to four lactating cows per treatment. Cows used, averaged 18 kg of milk/day and weighed about 550 Kg. The trial was for 1 week during which rye forage served as the only roughage. A concentrate mixture was fed at 1 Kg to 3 Kg milk daily. Forage was sampled for analysis three times during the feeding trial. Feed intakes were recorded daily for each animal.

Trial II

In trial II, rye from the same harvest used in trial I was placed loose in open 220 liter drums. Portions of about 35 Kg were treated with varying amounts of the acids (Table 1) diluted in water (1:5). Acid was sprinkled on the rye forage which was mixed by rolling on polyethylene plastic sheets. The treated material was then transferred into the drums and left unpacked. Forages were sampled as in the previous trial. Also, temperature was recorded twice daily and spoilage was monitored. After 3 weeks the drums were emptied and the unspoiled material was sampled. In two treatments (4 and 7) rye was well-preserved so it was fed to young calves to test acceptability.

Trial III

In trial III, rye forage was cut at late boot and wilted in the field to about 35% DM. It was then chopped and ensiled in 220 liter drums as described above. The acids used were propionic (P), formic (F), and a mixture of 1:1 (P:F) (Table 2). The acids were diluted 1:1 with water, sprinkled on the rye and mixed as in the previous trial. Two drums were used per treatment. For each acid treatment silage in 2 drums was left loose and two others were packed.

In the unpacked drums, 18 Kg occupied the same volume as 36 Kg in packed drums. At the end of every week the packed drums were emptied, aerated and repacked. Samples were taken before and after treatment and at weekly intervals for analysis as described in the two previous trials. In addition, the samples were analyzed for ADF and ADF-N after the method of Van Soest (1967). Temperatures were recorded for the first 3 days after ensiling and then every other day thereafter for the first 2 weeks. Days after harvest when mold first appeared was also recorded.

Trial IV

In trial IV, 21 lactating cows, averaging more than 18 Kg of milk/day were assigned in a randomized block design to three silage treatments. The treatments were control rye silage, rye silage treated with 0.4% formic acid, and alfalfa haylage. Rye silages were of the same cut as used in trials I and II, but ensiled in conventional upright silos. In addition to silages, which were fed ad libitum as the only forages, a concentrate mixture was fed at 1 Kg per 3 Kg milk. The feeding trial was for 7 weeks, the first 2 weeks were used as a standardization period. During the experimental period, silages were sampled 3 times weekly, composited and frozen for later analysis. Daily silage intake, milk production and persistency, and biweekly milk composition were determined.

RESULTS AND DISCUSSION

Trial I

Forage Temperatures and DM Preservation

Temperatures of the untreated forage were higher a few hours after filling than those treated with the AP or formic acid (Table 3 and Figure 1). The control rye increased in temperature until the third week and peaked at 53.9 C; while a peak of less than 40 C was observed during the second week for the acid treated forages. The temperature of the acid treated rye plateaued between the second and third week.

Spoilage was first observed on the control treatment at 3 days. This corresponded to an average temperature of about 50 C. The time when spoilage was first observed on the control forage agrees with the findings of Zimmer and Gordon (1964) who reported that O_2 consumption was highest during the first and second days of aeration. Also, this finding is in agreement with the observations of Honig (1969) and Federson (1971) who reported that oxidation was accompanied by a large rise in temperature and high DM losses.

The temperatures of the formic acid treatment were slightly higher than the AP for the first 10 days; after which they were slightly lower. Spoilage was observed on the AP before the formic acid treated forages (9 vs 14 days) which corresponded to temperatures of 37.5 C and 39 C, respectively. These observations indicate that acid treatment (1% on a wet basis) delayed oxidation or limited respiration even under completely aerobic conditions. This decrease in respiration could be attributed to the inhibition of the aerobic micro-organisms by the acids. Weise and Daniel (1970), reported that formic and propionic acids had strong bacteriocidal effects. Thus, the delay in spoilage, the lower heat production and decrease in DM losses could have been due to a decreased number of aerobic organisms resulting from acid treatment. The amount of CO_2 produced was not measured but it was probably higher for the control than the acid treatments. Zimmer and Gordon (1964) reported a correlation coefficient of +0.71 between amounts of DM loss and CO_2 produced.

More DM was preserved on the AP than the formic acid treatment (83 vs 78%), and both acids resulted in higher DM recoveries than the control (57%); which might be related to the higher temperatures observed on control silage in the early stages of storage and to the earlier detection of spoilage. When the average 4 week temperature was correlated with amount of DM spoiled at the end of the study a correlation coefficient of +0.98 was obtained. This correlation is higher than that obtained by Zimmer and Gordon (1964) for DM and CO_2 produced. The higher DM recoveries on acid treated forage are in agreement with Waldo et al. (1969) who added formic acid to conventional silos. However, the amount recovered was somewhat lower than the 80-90% reported by Saue and Breirem (1969). This could be due to the lower DM content and anaerobic storage conditions of their silages; while our forages were unprotected. Also, these findings are in agreement with those of Gordon and Goering (1972) who observed less mold on 55% DM chopped forage ensiled in snow fences and treated with AP (2.1%) than on untreated forage.

Lower counts and less activity of micro-organisms on acid treatment probably resulted in more fermentable carbohydrates which escaped fermentation. This is in general agreement with Taylor and Philips (1970) who found lower aerobic counts after formic acid treatment compared to control treatments; and with Saue and Breirem (1969) who observed higher sugar losses on the control than formic acid treated silages; and to Henderson and McDonald (1971) who found that formic acid prevented the oxidation of WSC for four hours after ensiling, thus preserving sugar for subsequent fermentation.

Characteristics of Fermentation on Acid Treatment

Changes in pH

The change in pH values during the experimental period are given in Table 4 and Figure 2. The control treatment had a pH of 6.4 at the beginning of the study which then increased to 6.5 by the end of the first week. The pH of the control reached its peak (7) by the third week. This peak in pH was parallel to the peak in temperature observed on this treatment during the same period. The pH values for the acid-treated rye were lower than the control. The lowest pH values were obtained by formic acid treatment due to a stronger acid effect of formic compared to propionic or acetic acids (AP treatment). The pH values were positively correlated (+0.98) to the temperatures observed for the different treatments. Also, a high correlation coefficient (+0.92) was obtained between pH and degree of spoilage. These findings agree with those of Waldo _et al_. (1968), Derbyshire and Gordon (1969) and Carpintero _et al_. (1969). The pH values observed on the formic acid treatment during the first two weeks agree well with those reported by Wilkins and Wilson (1969) who found little change in pH during the first 6-12 days after ensiling. Our data shows that unprotected forage treated with formic acid maintains a low, stable pH for 1-2 weeks. Decreases in pH were also obtained for the AP treatment but changes between the first two weeks were larger than for formic acid treatment (0.15 vs 0.02). The low pH values on the acid treatments suggest that fermentation was delayed due to a decrease in viable micro-organisms.

Organic Acids

The VFA concentrations for the different treatments are given in Table 5. Acetic acid in control forage increased during the first week to about 0.55% on a DM basis, and continued to increase by the second week. However, this increase was lower than that observed on the AP treatment even after correcting for the amount of acetic acid added. This indicates that the AP treatment influenced fermentation by offering a more appropriate medium for acetic acid-forming bacteria. The acetic acid production on the formic acid treatment was lower than that of the control for the first week but then increased over the control and remained lower than that of the AP treatment. The low acetic acid concentrations on the formic acid treatment might be explained by the inhibitory effect of the formic acid on the bacteria during the first week of storage.

A trend similar to that shown for acetic was observed for the propionic acid concentrations; which increased during the first week on control forage to about 0.35% and then decreased until the end of the study. The AP treatment had more propionic acid than the control and that observed at 1 week was approximately double the original level. This apparent increase may have been due to distribution or sampling error. Even though some production of propionic acid occurs, it is doubtful that this would be sufficient to account for the large change observed in the forage. However, propionic acid addition (from AP) may have stimulated bacteria to produce more propionate. The amount of propionate detected decreased with time and at the end of the 4-week period only 63% of the initial level was present.

Since the rye forages were stored under aerobic conditions, considerable production of butyric acid was expected, particularly in untreated forages. In general, the control forage exhibited higher concentrations of butyric acid than acid treatments, which was in agreement with the observation of Irvin et al. (1956) who reported that in poor quality silages, butyric acid was present after 5-8 days. The AP treatment had the lowest concentrations of butyric acid. In other studies formic acid has decreased butyric and acetic acid levels in regular silage (Waldo et al., 1968; Derbyshire and Gordon, 1970; Castle and Watson, 1970).

Lactic acid was not detected during the first week after harvest (Table 6). Irvin et al. (1956) found that in silages of poor quality the lactic acid increased in the first 5 days and then decreased but in good quality silages lactic acid concentrations increased during the first 8-12 days.

After 10 days, lactic acid was detected in the control and in the formic treatments (0.75 vs 0.50%) but not on the AP treatment. By the third week less than 1% (on a DM basis) lactic acid was present in all treatments. The low amount of lactic acid detected after 2-3 weeks could be related to the difficulty in getting a representative sample because of mold in the top layers. After the removal of spoiled layers, higher concentrations of lactic acid were present in the well-fermented material. The data suggests that lactic acid was either not produced or disappeared in forage sampled near the periphery of the mass; whereas much higher concentrations of lactic acid were detected in material after spoilage was removed. In contrast, the place and time of sampling the forage seemed to have less effect on concentrations of the other acids present.

These results are somewhat different from those reported by Emery *et al*. (1965) who observed that lactic acid concentrations achieved a maximum within 5 days after ensiling; and to those of Allen *et al*. (1937) who found that lactic acid concentrations in grass silages were highest during the fifth to eighth day of fermentation. Barnett (1954) stated that lactic acid peaks by the third day and Langston *et al*. (1958) reported a peak within 5-8 days after ensiling direct-cut alfalfa and orchard grass silages. The contradicting observations in this study are probably because these forages were stored under aerobic conditions. However, these findings are in agreement with those reported by Wilkins and Wilson (1969) who observed low lactic acid concentrations on formic acid treated silages but were comparable to those of untreated silages after fermentation was complete. For corn silage, Huber (1970) and Huber et al. (1972) found a large decrease in lactic acid concentrations (20% of control) resulted from formic acid treatment of corn silage which was in agreement with the finding of Henderson and McDonald (1971).

Correlations

Total VFA was negatively correlated with pH values, -0.29. This indicates that as the amount of VFA increases the pH values decrease. A negative correlation was also obtained between temperature and total VFA levels (-0.46); indicating that high temperatures depress VFA production and general fermentation. Also a negative correlation was obtained between VFAs and amount of DM loss (-0.61) suggesting that high concentrations of VFA are associated with higher recoveries.

Influence of Acid Treatment on Nitrogen Content of Forages

The crude protein of forages is given in Table 7 and DM in Table 9. A slightly lower value was observed on the AP treatment at the beginning of the experiment which might be attributed to sampling error. However, differences in crude protein were not statistically significant ($P > .05$). A correlation of -0.62 was obtained for average temperature and percent crude protein content in the final sample suggesting that as the temperature increases less protein is preserved.

In addition to the effect of temperature, the acidity seems to play a role in saving the protein. Henderson and McDonald (1971) suggested that formic acid treatment inhibited proteolytic clostridia and therefore less proteolysis occurred. A similar finding was reported by Saue and Breirem (1969).

The percent NPN expressed on DM basis is shown in Table 8. At the beginning of the experiment all treatments had a similar NPN content; however, this increased ($P < .05$) by the first week with the greatest rise occurring on the control treatment. At the end of four weeks and after removal of spoiled forage the NPN was higher on the formic acid than the AP treatment but highest values were still noted for the control even though differences were not significant ($P > .05$).

The lower NPN on the formic acid treatment compared to AP during the first few weeks was probably due to a greater inhibition of proteolysis by formic because of its stronger acidity. A correlation coefficient of +0.82 was obtained between the percent of NPN on the 4th week samples and the four weeks average temperature. The decrease in proteolysis and aerobic counts reported by Taylor and Philips (1970) indicated an advantage of acid treatments for preserving the protein of ensiled material, especially when left under aerobic conditions.

Acceptability of Acid Treated Rye Forage

The preserved material was fed in a short acceptability trial to 12 lactating cows (4 cows/treatment). The feeding trial lasted 1 week during which the rye served as the only forage. Daily forage DM intakes on the control, formic acid and AP treatments averaged 7.9, 7.4 and 9.6 Kg, respectively. The experimental period was too short and the number of cows too few to attach any significance to treatment differences. However, cows accepted the treated rye with no problems and milk production and composition were normal.

The fermentation patterns described in the previous sections are in agreement with those reported in literature for acid-treated silages. Even though insufficient silage was available for a large enough study to detect real differences in animal performance, increased DM intake (Castle and Watson, 1970), better gains in heifers, more digestible energy and improved feed efficiencies (Waldo *et al.*, 1968; Derbyshire and Gordon, 1970) have resulted from acid treatment of silages.

Trial II

The results of this trial are shown in Tables 10 through 19. Results are summarized and presented in a manner similar to those for Trial I.

Effect of Acid Treatment on Forage Temperature and Time of Spoilage

On the day of harvest the control treatment (1), had the highest temperature (30 C), and lowest temperatures (15 C) were observed for the 1.5% (trt 7) and 1.0% (trt 4) acid treatments (Table 10). The average temperatures for the first 4 days after treatment were highest on the control (37.1 C) followed by 0.25% formic acid (37 C) and then 0.25% AP (36.4 C). Treatments 7 and 4 had the lowest temperatures at this time.

Two days after harvest spoilage was noted on the control treatment and at 3 days on 0.25% acid (Table 10). The higher the acid level, the longer spoilage was delayed. On the fourth day after harvest spoilage was detected on the 0.5% AP treatment. Three treatments, 2 (0.5% F), 5 (1% (1F+3AP) and 11 (0.75% AP) spoiled by the fifth day; treatment 10 (0.75% F) on the sixth day, and treatment 6 (1% (3F+1AP) on the ninth day. Some spoilage was detected on treatments 4 and 7 on the 15th and the 18th days, respectively. The last two treatments to spoil maintained the lowest temperatures to the end of second week of storage, but detection of spoilage corresponded to temperature rises similar to those when other treatments spoiled. The correlation coefficient for the average temperature recorded during this study and the days after harvest that spoilage was detected was -0.93.

These observations are in general agreement with those of the first trial and show that acid treatment lowers temperature rises and delays spoilage. Acid treatment may have delayed oxidation by lowering the acrobic bacteria counts in forages (Taylor and Phillips, 1970; Henderson and McDonald, 1971).

When the experimental silos were emptied by the end of the 3rd week all treatments were totally spoiled except 4 and 7 which showed 65 and 90% recoveries, respectively. The data suggest that high levels of acids will preserve unprotected as well as those stored in conventional silos for at least 3 weeks.

Characteristics of Fermentation on Acid Treatment

Changes in pH

The changes in pH due to the different treatments are given in Table 11. At the beginning of the experiment the pH of the control was the highest (6.2) and it increased during the first week and reached a peak of 8.3 by the third week. This observation was similar to that obtained in the previous trial. The pH values of acid-treated drums were lower than the control. In initial samples formic acid treatments resulted in a lower pH value than acetic and propionic. After 3 weeks treatments 4 and 7 had the lowest pH values. The average temperatures were positively correlated to the pH values (+0.76). This correlation is similar to our observations in the previous trial. A negative correlation of (-0.75) was obtained between pH and days until spoilage was observed. Thus, higher pH values were associated with earlier spoilage.

Volatile Fatty Acid Concentrations

Acetic, propionic, and butyric concentrations for the different treatments are given in Tables 12, 13, and 14, respectively. A general increase in acetic acid was shown for all treatments until the end of the sampling period at 3 weeks. Formic acid-treated forages were lower in acetate than those treated with AP during the early period, but little difference due to treatment was noted at 2 or 3 weeks. Little change in acetic acid of forages occurred after 2 weeks even though they were stored unprotected. The higher value on treatment 3 could be due to sampling error.

Little or no propionic acid was observed in the control and formic acid treated forages. Usually some propionic acid has been reported in silages, but its absence in these samples may reflect the aerobic nature of the fermentation. On AP treatments there was a net loss of propionic acid after the initial samplings were corrected for added acid.

All rye forages used in this study had some butyric acid at 0 days. This level ranged from 0.11-0.56% on DM basis. A decrease in butyrate concentrations were noted thereafter. This decline usually corresponded with spoiling of the forages and highest levels were detected at 3 weeks in samples where least spoilage occurred.

Lactic Acid

Similar to what was observed in the previous trial, lactic acid was not detected before the 10th day after treatment (Table 15). Initially highest concentrations (3.99% on DM basis) were observed in forage treated with 0.25% AP and the control was second. The AP treatments had highest concentrations of lactic acid at 10 days. The low levels in formic treated forages was probably due to a greater inhibition of fermentation than in the control or AP treatments. By the second week the lactic concentrations dropped drastically on the control (0.41%) and were not detected by the third week probably due to the early spoilage observed on this treatment. In general, formic acid addition seemed to have an inhibitory effect on lactic acid concentrations, but this was not true for treatment 10 (0.75% formic). Similar observations were reported by Huber, 1970; Huber *et al*., 1972; and Carpintero *et al*., 1969.

Formic Acid

The formic acid recovery rates were determined for forages treated with this acid (Table 16). Recoveries were highest for treatments 7, 6, and 4 indicating that as the amount of formic increased its recovery also increases. This could be explained by the acid inhibiting micro-organisms which would metabolize it. Lower microbial counts have been shown for formic acid treated silages than for controls.

Effect of Acid Treatment on Nitrogen Content

The DM content of the different treatments is given in Table 17 and the crude protein in Table 18. Formic acid treatment usually resulted in greater decreases in DM content than AP. This increase in moisture might be due to greater condensation on formic acid, but this was not suggested by higher temperature rises.

The eleven treatments had similar crude protein content at the beginning of the study. The differences in crude protein could be related to heat production and time of spoilage. High heat resulted in earlier spoilage and higher DM losses. Hence, nitrogen made a larger percent of DM. Again, there was a trend towards formic and AP treatments to react quite differently with greater increases in crude protein occurring in forages to which formic had been added. A similar pattern was seen for the control treatment which spoiled most rapidly.

With respect to NPN (Table 19), all treatments started with a similar level, but the NPN increased faster on treatments that spoiled during the first week. This increase in NPN could be the result of proteolysis. It was observed that the acids depressed proteolysis when compared to the control. The NPN levels were lower on formic than AP treatments (trt 10 vs 11 and 8 vs 9) which might be due to stronger inhibition of proteolysis by formic acid as suggested by Taylor and Phillips, 1970. However, other comparisons between these acids (2 vs 3) showed the opposite trend. Treatments 4 and 7 maintained a lower percent of NPN due to the inhibition of proteolysis and therefore protein was saved and made available to animals.

Acceptance of Acid Treated Rye Forages

Only two treatments (4 and 7) were preserved in this study. The preserved material was fed to young animals (4 months old) for 2 days. The animals consumed an average of 4.14 kg and 1.8 kg (as fed) on treatments 7 and 4, respectively. Of course, it is dangerous to generalize from very short trials but the animals did accept the 1.5% acid level as long as the material was not spoiled.

Trial III

Results are summarized in Tables 20-32. No acceptability trials were conducted in this study.

Changes in Temperature, DM Recovery and Spoilage

The DM content of the different treatments is given in Table 20. The difference in initial DM can be attributed to very high temperatures during harvest which dried the forage while preparing treatments. The general trend of a lowering of DM observed for most forages might be due to heating and condensation.

The initial temperatures taken 4 hours after placement of forages in drums were higher for packed than unpacked treatments. During the first week this trend was reversed with packed treatments lower than those of the unpacked except for propionic acid additions (Table 21 and Figure 3). The higher initial temperatures on packed treatments suggests the beginning of normal fermentation which never occurred in the unpacked drums exposed to more air. The delay in temperature rises for all acids compared to the controls indicates some inhibition of spoilage for both acids even at 0.5% application, but the marked superiority of propionic over formic in preventing high temperatures was shown during subsequent weeks.

The first treatment to spoil was the unpacked controls (4 days). Also, mold spots were detected on the 4th day on the packed controls and 0.5% formic with and without packing. However, the mold observed on these treatments was not as extensive as that observed on the unpacked controls. This indicates that 0.5% formic acid may have extended some protection, but it was not enough for good preservation under the conditions of this study. Two weeks after the initiation of this study several unpacked treatments were completely spoiled (Table 22). Those unpacked treatments that were not totally spoiled at this time were 1% propionic, 1% mix and 0.5% propionic acid. For those 16.6, 56.3, and 58.8% respectively, of their initial DM was spoiled.

Spoilage was only 3.7% on the 1% packed propionic acid treatment by the end of two weeks and 8.1% after 3 weeks. Forage losses increased probably because of the weekly aerations. High invisible losses of DM (35-39%) were observed on the packed, 0.5% mix, 0.5% formic and the control forages indicating that these low concentrations of acid did not prevent oxidation or gas production. Based on the total DM recovery packed forages were superior to the unpacked. For acid comparisons on packed treatments 1% propionic acid ranked first, followed by the 1% mix, and then 0.5% propionic.

A similar relationship to that obtained in the first two trials was observed between temperature and amount of spoilage. A correlation coefficient of +0.53 was obtained in this trial for these two factors; and higher correlation was obtained between temperature and total DM loss (+0.69). The values obtained in both cases showed that as the temperature of the ensiled material increased, total losses were greater. These observations are in agreement with those of Daniel et al. (1970) who found that propionic acid reduced the frequency and intensity of secondary fermentation and prevented heating and growth of yeast. These researchers agreed with findings of Zimmer and Gordon (1964) who reported a +0.71 correlation between CO_2 production and DM loss and found that about 18 g CO_2/kg DM were produced on the control treatment after five aerations compared to 10 and 4 g on the 0.3 and 1.0% propionic acid. Weise (1970) showed that the presence of air even at the beginning of fermentation had a damaging effect on fermentation and silage quality.

The results of this trial, with respect to the factors discussed, indicate the superiority of propionic acid over formic acid as a preservative for forages stored under aerobic or partially compacted conditions. This observation also applies to mixed treatments which showed that replacement of formic acid with some propionic acid resulted in higher DM recoveries. Moreover, partial compaction also decreased DM losses.

Fermentation Characteristics

Changes in pH

The changes in pH are shown in Table 23 and Figure 4. The pH of the controls were higher than those of acid treatments, as was noted in the first two trials. Lower pH values were again observed on the formic acid treatments compared to propionic. Also, mix treatments had lower pH values than the propionic alone due to the action of formic acid. The pH values of the acid treatments at the beginning of this study were slightly higher than those of similar treatments in Trial II; probably because the higher DM content of forage in this trial. After 1 week of storage the pH of the packed control was similar to that of the 1% proprionic or formic acid suggesting that a somewhat normal fermentation occurred on the packed control. These observations are different from those of Trial II, due to the packing effect which reduced air exposure. The pH values for the two unpacked treatments which were best preserved (1% propionic and 1% mix) did not change after initial readings. The pH of the packed treatments generally decreased by the second week indicating that fermentation and acid production were progressing. As the amount of spoilage started to increase the pH values increased. Between 0 and 3 weeks pH values for formic treatments increased while those for propionic and mix decreased.

At the end of 3 weeks a correlation coefficient of +0.13 was obtained between pH and percent spoilage and a higher coefficient +0.29 between pH and percent invisible DM loss whereas a coefficient of +0.42 was shown between pH and total DM losses. This correlation is lower than the ones in previous trials probably due to decrease in losses due to packing. Also, a correlation of +0.37 was observed for average temperatures and pH values recorded during the three weeks experimental period. These observations indicate that lower pH values and temperature increases are associated with higher DM recovery of exposed forages.

Organic Acids

Little or no acetic acid was noted in the initial samples, but levels in all packed forages increased during treatment with highest values generally after 3 weeks (Table 24). Acetate production was greater on formic--than propionic-treated forages. The data suggests that formic acid treatment did not completely inhibit fermentation, but delayed it for at least one week. This could be attributed to lower microbial counts (Taylor and Phillips, 1970).

Little or no propionic acid (Table 25) was detected on control and formic treatments. Propionate levels of forages treated with this acid remained quite constant during the entire period. Recoveries at 21 days ranged from 56 to 84% and were directly related to the amount of acid added. When propionic acid was mixed with formic acid the recoveries of propionic were decreased (56-57%). This might mean that formic acid addition favored certain micro-organisms which metabolized propionic acid (Taylor and Phillips, 1970; Saue and Breirem, 1969).

Butyric acid concentrations were higher than those observed in the first two trials (Table 26). However, these fluctuated from week to week and were lowest at end of the study. It was expected that some butyric acid would be detected because of the aerobic conditions (Henderson and McDonald, 1971; Taylor and Phillips, 1970; and Saue and Breirem, 1969).

Lactic acid concentrations are given in Table 27. Lactic acid was not detected on the initial samples. However, contrary to what was observed in the first two trials substantial lactic acid was detected at one week. This finding could be related to packing which was absent in the first two trials. These observations are in agreement with those of Emery et al. (1965), Allen et al. (1937) and Langston et al. (1958) who observed a peak in lactic acid in the first 5 to 8 days after ensiling. The first week lactic acid concentrations were highest on control and low acid treatments. This means that low levels of acids combined added to packed silage resulted in some fermentation (Taylor and Phillips, 1970). By two weeks, lactic acid appeared on the unpacked propionic and mix treatments. Only two packed treatments, 0.5% propionic acid and 1% mix, decreased in lactic acid concentration by the second week. These treatments might have been affected more by the first aeration than other treatments. This response to aeration could be explained by the inhibition of the lactic acid forming bacteria. The third week lactic acid concentrations were low on the control, 0.5% formic and 0.5% mix, but remained more than 4% on DM basis. The increase in lactic acid on the 0.5% propionic by the third week could be due to less influence of the second aeration on the lactic acid bacteria compared to the first. However, Daniel et al. (1970) reported that propionic acid lowered to about 50% the lactic acid concentrations of grass silage when compared to controls. In general, the lactic acid concentrations of packed acid treatments are in agreement with those reported for well preserved silages. These findings suggest that acid treatments used in this study resulted in a cool fermentation, the type which is needed to obtain good quality silages.

Initial levels of formic acid very closely approximated those added to forages. At 0.5% formic recoveries were negligible for the second and third weeks, but when 1% formic or mix acids were used 41-95% of the added formic was recovered (Table 28). Propionic acid apparently inhibited the metabolism of formic, especially under complete aerobic conditions, perhaps by its influence on microbial action.

Nitrogen, ADF and ADF-N

The nitrogen contents of the different treatments are given in Table 29. Initial nitrogen content was similar on all treatments and averaged 1.5% on DM basis. Little change in total nitrogen was observed indicating little effect of heat in this study.

The percent NPN (Table 30) averaged 0.56% on DM basis at the beginning of the study. An increase in NPN was observed on all treatments by the first week. The highest increase was on the control and 0.5% packed propionic acid treatment. This increase in NPN suggests that proteolysis occurred. Acid treatments inhibited proteolysis when compared to the control. The least proteolysis occurred on the 1% propionic acid as indicated by the lower NPN values. The lower NPN on propionic acid treatments might be explained by the findings of Weise and Daniel (1970) who found that this acid has a strong fungicidal activity and therefore inhibited the growth of mold and fungi even after aeration or fermentation. With the increase in the amount of spoilage by the third week NPN was higher for all treatments, but the 1% propionic acid treatments packed or unpacked maintained the lowest levels.

ADF

The acid detergent fiber procedure provides a method for lignocellulose determination. Van Soest (1965) showed an increase in lignin content when feed samples were exposed to high temperatures. Also, he observed an increase in the nitrogen content of the lignin fraction of these feeds. The ADF method removes the protein and other acid soluble material which would interfere with the lignin determination. The ADF consists of cellulose, lignin, cutin and acid-insoluble ash (mainly silica). The nitrogen content of the ADF is suggested as a sensitive assay for nonenzymic browning which occurs in over heated feeds.

At the beginning of the study the ADF content averaged about 40% of the DM (Table 31). By the first week the ADF content of the control was the highest (42.7%) followed by the 0.5% packed formic acid treatment indicating more oxidation of soluble carbohydrates on these two treatments. The highest temperature and most spoilage were also reported at 4 days for these treatments. At the end of this study control forage had the highest amount of ADF (45.2% on DM basis) followed by the 0.5% acid levels. The 1% acid levels seemed to maintain slightly lower ADF levels probably due to less oxidation of soluble carbohydrates (Henderson and McDonald, 1971). The smaller increases in ADF were also associated with lower DM losses (Table 25).

ADF-N

The ADF-N averaged less than 0.1% on DM basis at the beginning of the study (Table 32). Even though considerable variation was noted, average ADF-N showed little change during the three week experimental period. This could be related to the relatively low temperatures observed for the packed treatments which averaged less than 40 C. Thomas and Hillman (1972) only detected carmelization in forages which reached 46 C, a level that was not attained in this study.

Trial IV

Milk Production, Persistency and Milk Composition as Affected by Formic Acid Treatment of Rye Silage

The average milk production and persistencies on the different silages are given in Table 33. Milk yields were slightly higher during the pretreatment period as compared to the average of five weeks' production on the different silages. However, the pretreatment-treatment differences were not statistically significant ($P > .05$). The persistency of milk production, based on that of pretreatment, was slightly higher on the formic acid-treated rye silage (96.7%) compared to 95.0% and 94% for the alfalfa haylage and control rye silage, respectively.

Milk was sampled bi-weekly and milk composition was determined (Table 33). Differences between treatments in milk solids, proteins and butterfat percentages were not significant ($P > .05$).

Cows were fed the same concentrate mixture at the ratio of 1:3 and silages were fed ad libitum. The DM content of the alfalfa haylage was much higher than the rye silages (Table 34). This could explain the slightly higher intakes of the alfalfa haylage. Also, more DM was consumed on the formic treated rye silage compared to the control but this difference was not significant. The results of this study are in agreement with those of Waldo et al. (1966 and 1968) who observed that heifers consumed more DM on hay than formic acid silage but the digestibility of the silage was higher. They also found that animals fed direct cut silages treated with formic acid consumed more digestible energy and used this energy more efficiently on a net or gross basis than those fed untreated silage. Heifers consuming alfalfa silage required 1.4 times as much digestible energy per unit gain as those fed the formic acid treated silages.

These results also are in strong agreement with Derbyshire and Gordon (1970) who reported that formic acid treatment had no significant effect on average milk production, percent butterfat and percent SNF even though milk yields for cows receiving treated silages were slightly higher. Increases in feed efficiencies have been consistently observed in heifers fed silages treated with formic acid (Waldo et al. 1966, 1968), but this has not been shown in lactating cows (Derbyshire and Gordon, 1971) perhaps due to the compounding effect of the concentrate. Castle and Watson (1970) found that the digestibility and

DM intakes were increased in cows fed formic acid silages. They concluded in another study that because of the increase in DM intake an increase in milk was obtained. However, contrary to the results of our study and the results reported by other researchers, Castle and Watson (1970) reported a significant increase in SNF and protein content of milk for cows fed formic acid silages. Also, Fisher et al. (1971), found significantly higher milk yields when they fed formic acid silages. However, contrary to previous reports they observed lower energy digestibility for the formic silages but higher efficiency of energy utilization.

Effect of Formic Acid Treatment on Nitrogen Content of the Silages

The percent nitrogen, expressed on DM basis, was not statistically significant ($P > .01$) for the three silages used in this study (Table 35). Because of slightly higher milk production on the formic acid treatment the protein of the acid-treated rye was apparently better utilized than that in alfalfa haylage or control rye; similar results from formic treated silages were obtained by Derbyshire and Gordon, 1970; Waldo et al., 1969; Fisher et al., 1971.

The NPN content of the alfalfa haylage was significantly lower ($P < .01$) than that of the rye silages, but no differences due to formic acid treatment was noted. More proteolysis occurred in the rye silages compared to the alfalfa haylage probably due to the lower DM content. Also, the more favorable storage conditions (conventional silos) may have minimized the effect of the low level (0.4% on wet basis) of formic acid used; however, our previous trials indicate that formic acid prevented proteolysis under poor storage conditions.

TABLE 1

EXPERIMENTAL TREATMENTS FOR RYE FORAGE. PART 1, TRIAL II

Drum Number	Acid Treatment	Total Acid Added (%)
1	Control	----
2	Formic acid (F)	0.5
3	Acetic-Propionic (AP)*	0.5
4	1 F : 1 AP	1.0
5	1 F : 3 AP	1.0
6	3 F : 1 AP	1.0
7	1 F : 1 AP	1.5
8	F	0.25
9	AP	0.25
10	F	0.75
11	AP	0.75

*60 acetic : 40 propionic acid.

TABLE 2

EXPERIMENTAL TREATMENTS FOR RYE FORAGE.
PART 1, TRIAL III

Acid Treatment*	Total Acid Added (%)
Control	---
Propionic (P)	0.5
P	1.0
Formic (F)	0.5
F	1.0
1 P : 1 F	0.5
1 P : 1 F	1.0

Treatments were in duplicate with and without packing.

TABLE 3

EFFECT OF ACID TREATMENT ON RYE FORAGE TEMPERATURES
(PART 1, TRIAL I)

Treatment	Weeks After Treatment				
	0	1	2	3	4
	Average °C				
Control	28.3[a]	43.7[a]	51.8[a]	53.9[a]	41.8[a]
AP	21.9[b]	27.9[b]	38.4[b]	40.0[b]	34.4[b]
F	25.5[b]	29.8[b]	38.1[b]	39.1[b]	32.3[b]

[a,b]Values with different superscript are statistically significant ($P < .05$).

TABLE 4

EFFECT OF ACID TREATMENT ON RYE FORAGE PH
(PART 1, TRIAL I)

Treatment	Weeks After Treatment				
	0	1	2	3	4
Control	6.36[a]	6.52[a]	6.14[a]	6.99[a]	5.96[a]
AP	4.49[b]	4.43[b]	4.28[b]	4.33[b]	4.64[b]
F	4.26[b]	3.78[b]	3.80[b]	3.96[b]	3.97[b]

[a,b]Values with different superscript are statistically significant ($P < .05$).

TABLE 5

EFFECT OF ACID TREATMENT ON VFA AND FORMIC ACID CONTENT OF RYE FORAGE (PART 1, TRIAL I)

Acid Determined	Treatment	Weeks After Treatment				
		0	1	2	3	4
		% DM				
Acetic	Control	----	0.55	0.60	0.26	0.41
	AP	1.88	3.73	2.34	2.95	1.92
	F	----	0.29	0.66	0.50	0.58
Propionic	Control	----	0.35	0.10	----	0.09
	AP	1.23	2.46	1.30	1.52	0.77
	F	----	0.06	0.10	----	----
Butyric	Control	0.32	0.44	0.25	----	0.26
	AP	0.11	0.32	0.32	----	----
	F	0.55	0.25	0.16	----	0.55
Formic	F	3.53	3.30	3.22	3.12	3.19

TABLE 6

EFFECT OF ACID TREATMENT ON LACTIC ACID CONTENT OF RYE FORAGE (PART 1, TRIAL I)

Treatment	Weeks After Treatment			
	(10 days)	2	3	4*
	(% Dry Matter)			
Control	0.75	0.28	0.64	3.58
AP	----	----	0.81	4.19
F	0.49	0.33	0.90	3.34

*From forage sampled after spoilage was removed.

TABLE 7

EFFECT OF ACID TREATMENT ON CRUDE PROTEIN CONTENT OF RYE FORAGE (PART 1, TRIAL I)

Treatment[a]	Weeks[b] After Treatment				
	0	1	2	3	4
	% Dry Matter				
Control	13.59	14.26	16.23	15.45	13.45
AP	12.68	14.06	13.50	13.81	13.58
F	13.01	14.33	14.74	14.56	14.38

[a]Differences among treatments were not significant (P > .05).

[b]Differences among treatments due to time were not significant (P > .01).

TABLE 8

EFFECT OF ACID TREATMENT ON NPN CONTENT OF RYE FORAGE (PART 1, TRIAL I)

Treatment	Weeks After Treatment				
	0	1	2	3	4
	% Dry Matter				
Control	0.45^a	1.08^b	1.31^b	1.19^b	1.14^b
AP	0.41^a	0.83^b	1.09^b	0.77^b	0.95^b
F	0.41^a	0.70^b	0.84^b	0.98^b	1.06^b

[a,b]Values with different superscript are statistically significant (P < .05).

TABLE 9

EFFECT OF ACID TREATMENT ON DM OF RYE FORAGE
(PART 1, TRIAL I)

Treatment*	Weeks After Treatment				
	0	1	2	3	4
	-------------------------%	---------------------------			
Control	28.92	30.06	31.30	30.38	26.08
AP	28.08	28.44	29.38	26.99	26.87
F	28.28	28.03	27.52	24.77	25.80

*Treatment differences were not statistically significant ($P > .05$). Differences with time are not statistically significant ($P > .01$).

TABLE 10

EFFECT OF ACID TREATMENT ON FORAGE TEMPERATURE AND TIME OF SPOILAGE (PART 1, TRIAL II)

Treatment	Days After Treatment					Spoilage Time (days)
	0	4	8	15	21	
	--------------------C°--------------------					
1 -Control	36.0	37.1	28.7	35.7	35.1	2
2 -0.5 (F)	16.0	32.3	37.7	35.5	34.7	5
3 -0.5 (AP)	16.0	26.5	38.6	38.6	39.8	4
4 -1.0 (1F:1AP)	15.0	15.1	13.1	27.9	38.6	15
5 -1.0 (1F:3AP)	17.0	16.8	24.2	37.9	37.5	5
6 -1.0 (3F:1AP)	16.0	16.4	21.4	43.4	39.8	9
7 -1.5 (1F:1AP)	15.0	15.0	12.9	26.2	41.1	18
8 -0.25 (F)	20.0	37.0	27.7	34.5	36.9	3
9 -0.25 (AP)	20.0	36.4	31.5	39.2	36.1	3
10-0.75 (F)	16.5	17.0	32.1	37.1	41.6	6
11-0.75 (AP)	17.0	17.6	30.4	39.0	40.4	5
Ambient Temperature	16.5	17.5	13.0	20.0	24.1	

TABLE 11

EFFECT OF ACID TREATMENT ON pH OF FORAGES (PART 1, TRIAL II)

Treatment	Weeks After Treatment			
	0	1	2	3
1 -Control	6.2	7.3	6.5	8.2
2 -0.5 (F)	4.1	5.3	5.9	7.1
3 -0.5 (AP)	4.7	5.3	4.8	4.3
4 -1.0 (1F:1AP)	3.9	3.9	4.3	4.8
5 -1.0 (1F:3AP)	3.6	4.5	5.6	5.9
6 -1.0 (3F:1AP)	3.7	3.7	5.7	6.0
7 -1.5 (1F:1AP)	3.7	3.7	3.8	4.2
8 -0.25 (F)	5.2	6.4	5.8	7.1
9 -0.25 (AP)	5.1	5.9	4.5	4.7
10-0.75 (F)	3.9	4.5	4.4	5.3
11-0.75 (AP)	4.5	4.7	5.2	5.8

TABLE 12

EFFECT OF ACID TREATMENT ON ACETIC ACID CONCENTRATIONS
(PART 1, TRIAL II)

Treatment	Weeks After Treatment			
	0	1	2	3
	------------------% of DM------------------			
1. Control	0.15	0.39	0.66	0.31
2. 0.5 (F)	----	0.16	0.59	0.63
3. 0.5 (AP)	1.38	0.71	1.92	3.33
4. 1.0 (1F:1AP)	1.26	1.01	0.97	0.66
5. 1.0 (1F:3AP)	1.85	1.17	0.95	1.04
6. 1.0 (3F:1AP)	0.70	0.50	1.06	1.25
7. 1.5 (1F:1AP)	1.60	1.73	1.34	1.00
8. 0.25 (F)	----	0.59	1.25	1.14
9. 0.25 (AP)	0.60	0.69	0.96	1.83
10. 0.75 (F)	----	0.06	0.58	1.29
11. 0.75 (AP)	1.78	1.22	1.05	1.58

TABLE 13

EFFECT OF ACID TREATMENT ON PROPIONIC ACID CONCENTRATIONS
(PART 1, TRIAL II)

Treatment	Weeks After Treatment			
	0	1	2	3
	------------------% of DM------------------			
1. Control	----	0.27	----	----
2. 0.5 (F)	----	----	----	----
3. 0.5 (AP)	0.81	0.36	0.29	0.37
4. 1.0 (1F:1AP)	0.78	0.48	0.41	0.09
5. 1.0 (1F:3AP)	1.12	0.75	0.33	0.24
6. 1.0 (3F:1AP)	0.36	0.27	0.05	----
7. 1.5 (1F:1AP)	0.91	1.04	0.71	0.42
8. 0.25 (F)	----	0.10	----	----
9. 0.25 (AP)	0.18	0.15	----	----
10. 0.75 (F)	----	----	----	----
11. 0.75 (AP)	1.18	0.93	0.32	0.12

TABLE 14

EFFECT OF ACID TREATMENT ON BUTYRIC ACID CONCENTRATIONS
(PART 1, TRIAL II)

Treatment	Weeks After Treatment			
	0	1	2	3
	------------------% of DM------------------			
1. Control	0.32	0.10	0.09	----
2. 0.5 (F)	0.42	0.11	0.21	----
3. 0.5 (AP)	0.22	0.24	0.15	----
4. 1.0 (1F:1AP)	0.56	0.32	0.40	0.14
5. 1.0 (1F:3AP)	0.36	0.31	0.28	0.15
6. 1.0 (3F:1AP)	0.47	0.25	0.16	----
7. 1.0 (1F:1AP)	0.34	0.28	0.36	0.41
8. 0.25 (F)	0.34	0.17	0.28	----
9. 0.25 (AP)	0.11	0.25	0.10	----
10. 0.75 (F)	0.23	0.37	0.16	----
11. 0.75 (AP)	0.21	0.38	0.09	----

TABLE 15

EFFECT OF ACID TREATMENT ON LACTIC ACID CONCENTRATIONS
(PART 1, TRIAL II)

Treatment	Weeks After Treatment		
	(10 days)	2	3
	------------------% of DM------------------		
1. Control	2.05	0.41	----
2. 0.5 (F)	----	0.30	0.10
3. 0.5 (AP)	1.17	2.45	2.21
4. 1.0 (1F:1AP)	----	----	0.48
5. 1.0 (1F:3AP)	----	----	0.78
6. 1.0 (3F:1AP)	0.48	1.52	0.91
7. 1.5 (1F:1AP)	----	----	0.50
8. 0.25 (F)	0.52	1.27	1.23
9. 0.25 (AP)	3.99	1.97	2.71
10. 0.75 (F)	0.90	0.47	2.33
11. 0.75 (AP)	0.78	0.95	2.66

TABLE 16

FORMIC ACID CONTENT AND RECOVERY (PART 1, TRIAL II)

Treatment	Weeks After Treatment 0	1	2	3	% Recovery
	------------% of DM------------				
2. 0.5 (F)	1.92	1.38	1.01	0.83	43.5
4. 1.0 (1F:1AP)	2.01	1.82	1.68	1.21	60.1
5. 1.0 (1F:3AP)	1.00	0.83	0.45	0.54	54.0
6. 1.0 (3F:1AP)	2.73	2.42	1.55	1.93	70.6
7. 1.5 (1F:1AP)	2.91	2.72	2.09	2.32	79.7
8. 0.25 (F)	1.12	0.77	----	----	Trace
10. 0.75 (F)	2.84	2.37	1.17	1.53	53.9

TABLE 17

EFFECT OF ACID TREATMENT ON DM CONTENT OF THE FORAGES (PART 1, TRIAL II)

Treatment	Weeks After Treatment 0	1	2	3	Change (0-3 wk)
	----------------%----------------				
1. Control	28.4	30.6	36.7	36.3	+ 7.9
2. 0.5 (F)	28.8	30.6	27.8	24.9	- 3.9
3. 0.5 (AP)	27.7	29.6	28.2	25.9	- 1.8
4. 1.0 (1F:1AP)	27.2	28.9	30.2	32.3	+ 5.1
5. 1.0 (1F:3AP)	25.0	27.4	28.1	26.2	+ 1.2
6. 1.0 (3F:1AP)	27.2	29.5	27.8	23.6	- 3.6
7. 1.5 (1F:1AP)	26.6	27.2	28.8	32.3	+ 5.7
8. 0.25 (F)	27.2	29.5	23.7	19.2	+ 8.0
9. 0.25 (AP)	28.2	28.7	27.5	28.5	+ 0.3
10. 0.75 (F)	27.5	27.1	27.5	23.2	- 4.3
11. 0.75 (AP)	27.9	27.0	31.0	25.5	- 2.4

TABLE 18

EFFECT OF ACID TREATMENT ON CRUDE PROTEIN
(PART 1, TRIAL II)

Treatment	Weeks After Treatment				Change (0-3 wk)
	0	1	2	3	
	--------------% of DM--------------				
1. Control	13.52	22.22	---	---	+ 8.70*
2. 0.5 (F)	12.95	16.24	15.59	17.40	+ 4.45
3. 0.5 (AP)	12.96	14.01	13.45	13.69	+ 0.73
4. 1.0 (1F:1AP)	13.23	12.79	13.20	12.98	- 0.25
5. 1.0 (1F:3AP)	13.56	14.23	14.17	15.56	+ 2.00
6. 1.0 (3F:1AP)	13.75	13.12	15.30	17.67	+ 3.93
7. 1.5 (1F:1AP)	13.42	12.44	13.03	12.95	- 0.47
8. 0.25 (F)	14.12	19.42	18.73	24.91	+10.79
9. 0.25 (AP)	13.16	19.26	14.33	14.67	+ 1.51
10. 0.75 (F)	13.56	14.75	14.34	15.80	+ 2.24
11. 0.75 (AP)	12.83	14.30	13.52	15.95	+ 3.08

*Only 1 wk change.

TABLE 19

EFFECT OF ACID TREATMENT ON NPN CONTENT
(PART 1, TRIAL II)

Treatment	Weeks After Treatment			
	0	1	2	3
	--------------% Dry Matter----------------			
1. Control	0.47	1.39	----	----
2. 0.5 (F)	0.41	0.78	1.02	1.10
3. 0.5 (AP)	0.42	0.49	0.79	0.84
4. 1.0 (1F:1AP)	0.44	0.52	0.85	0.77
5. 1.0 (1F:3AP)	0.41	0.71	0.85	0.84
6. 1.0 (3F:1AP)	0.51	0.61	0.90	1.05
7. 1.5 (1F:1AP)	0.39	0.61	0.72	0.77
8. 0.25 (F)	0.57	0.88	0.84	0.88
9. 0.25 (AP)	0.41	0.97	0.99	1.11
10. 0.75 (F)	0.54	0.69	0.87	0.90
11. 0.75 (AP)	0.51	1.00	1.25	1.48

TABLE 20

DRY MATTER CONTENT OF RYE FORAGES
(PART 1, TRIAL III)

Treatment	Weeks After Treatment					
	0	1	2		3	
	UPK and PK*	PK	UPK	PK	UPK	PK
	%					
Control	33.7^{a}	32.8^{a}	----	31.5^{a}	----	26.7^{a}
0.5% P	40.5^{b}	38.7^{b}	42.0	37.6^{b}	----	36.1^{b}
1.0% P	39.5^{b}	40.0^{b}	40.1	40.8^{b}	42.5	39.7^{b}
0.5% F	35.0^{a}	33.3^{a}	----	31.4^{a}	----	30.2^{a}
1.0% F	35.7^{ab}	39.4^{b}	----	37.6^{b}	----	32.6^{ab}
0.5% Mix	40.5^{b}	42.9^{b}	----	38.5^{b}	----	33.0^{b}
1.0% Mix	40.0^{b}	38.6^{b}	39.4	39.2^{b}	41.7	35.6^{b}

*UPK = Unpacked; PK = Packed.

^{a,b}Values with different superscript are significant ($P < .05$).

TABLE 21

EFFECT OF ACID TREATMENT AND PACKING ON TEMPERATURE AND TIME OF SPOILAGE
(PART 1, TRIAL III)

Treatment	Weeks After Treatment								Time of Spoilage	
	0		1		2		3			
	UPK	PK*	UPK	PK	UPK	PK	UPK	PK	UPK	PK
	--------------------------------C°--------------------------------									
Control	37.0	36.0^{b}	47.0	30.5^{b}	38.9	25.0^{b}	----	34.0^{b}	4	4
0.5% P	24.0	29.0^{ab}	18.2	25.7^{ab}	30.0	27.0^{ab}	----	38.0^{ab}	13	14
1.0% P	24.5	28.0^{a}	17.0	18.3^{a}	23.0	20.7^{a}	25.0	32.0^{a}	14	14
0.5% F	23.0	28.0^{ab}	38.5	32.8^{ab}	25.3	26.5^{ab}	----	37.0^{ab}	4	4
1.0% F	23.0	28.0^{ab}	32.3	30.5^{ab}	43.7	27.6^{ab}	----	37.0^{ab}	10	11
0.5% Mix	27.0	29.0^{ab}	38.8	26.7^{ab}	42.9	27.2^{ab}	----	35.5^{ab}	10	11
1.0% Mix	25.0	27.5^{a}	22.8	19.3^{a}	34.0	23.7^{a}	29.5	33.5^{a}	11	12
Ambient Temperature	19.0		19.0		20.2		16.0			

*UPK = Unpacked; PK = Packed.

^{a,b}Values with different superscripts are statistically different ($P < .05$).

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1

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0
0
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TABLE 22

EFFECT OF ACID TREATMENT AND PACKING ON DM RECOVERY AND INVISIBLE LOSSES OF RYE FORAGES (PART 1, TRIAL III)

Treatment	Weeks After Treatment				
	2		3		
	Molded DM[a]		Molded DM	DM Loss[b]	DM Recovery[c]
	Unpacked	Packed	Packed		
	--------------------------	----------	%---------	----------	----------
Control	All	28.9	58.3	34.5	7.2
0.5% P	58.8	24.7	48.5	31.4	20.1
1.0% P	16.6	3.7	20.2	8.1	71.7
0.5% F	All	34.8	61.1	34.8	4.1
1.0% F	All	36.0	69.9	13.0	17.1
0.5% Mix	All	18.6	41.5	39.2	19.3
1.0% Mix	56.3	31.2	66.9	10.3	22.8

[a]Molded dry matter was sampled and discarded.
[b]This is invisible dry matter loss taken by difference.
[c]100--(% molded dry matter + dry matter loss) Refers only to packed treatments.

TABLE 23

EFFECT OF ACID TREATMENT AND PACKING ON pH OF RYE FORAGE (PART 1, TRIAL III)

Treatment	Weeks After Treatment					
	0	1	2		3	
	UPK and PK*	PK	UPK	PK	UPK	PK
Control	6.2	4.8	---	4.4	---	4.9
0.5% P	5.2	4.4	4.9	4.3	---	4.3
1.0% P	4.8	4.9	4.8	4.6	4.6	4.2
0.5% F	5.0	4.4	---	4.4	---	5.1
1.0% F	4.1	4.9	---	4.5	---	4.4
0.5% Mix	4.6	4.6	---	4.2	---	4.2
1.0% Mix	4.5	4.6	4.5	4.6	4.6	4.4

*Changes in pH of packed treatments are not significantly different ($P > .05$).

TABLE 24

EFFECT OF ACID TREATMENT AND PACKING ON ACETIC ACID CONCENTRATIONS OF RYE FORAGE (PART 1, TRIAL III)

Treatment	Weeks After Treatment					
	0	1	2		3	
	UPK and PK*	PK	UPK	PK	UPK	PK
	% of DM					
Control	0.15	2.10^{b}	----	2.47^{b}	----	4.68^{b}
0.5% P	----	1.94^{ab}	1.07	1.53^{ab}	----	1.53^{ab}
1.0% P	----	0.50^{a}	0.34	0.50^{a}	0.55	0.34^{a}
0.5% F	----	0.75^{ab}	----	1.28^{ab}	----	3.07^{ab}
1.0% F	----	0.36^{a}	----	0.79^{a}	----	1.20^{a}
0.5% Mix	----	0.58^{a}	----	0.80^{a}	----	1.30^{a}
1.0% Mix	0.12	0.67^{a}	0.43	0.64^{a}	----	1.13^{a}

*UPK = Unpacked; PK = Packed

^{a,b}Values with different superscripts are significant ($P < .05$).

TABLE 25

EFFECT OF ACID TREATMENT AND PACKING ON PROPIONIC ACID CONCENTRATIONS OF RYE FORAGE (PART 1, TRIAL III)

Treatment	Weeks After Treatment						% Recovery at 3 wks.	
	0	1	2		3			
	UPK and PK*	PK	UPK	PK	UPK	PK	UPK	PK
	% of DM							
Control	0.13	----	----	0.15	----	0.24		
0.5% P	1.43	1.81	1.19	1.33	----	1.04	----	72.7
1.0% P	3.10	3.07	2.52	3.03	2.52	2.60	81.3	83.9
0.5% F	----	----	----	----	----	0.14		
1.0% F	----	----	----	----	----	0.06		
0.5% Mix	0.98	0.77	----	0.65	----	0.55	----	56.1
1.0% Mix	1.31	1.70	1.55	1.33	----	0.75	----	57.3

*UPK = Unpacked; PK = Packed.

TABLE 26

EFFECT OF ACID TREATMENT AND PACKING ON BUTYRIC ACID CONCENTRATIONS OF RYE FORAGE (PART 1, TRIAL III)

Treatment	Weeks After Treatment					
	0	1	2		3	
	UPK and PK*	PK	UPK	PK	UPK	PK
	% of DM					
Control	0.88	0.77	----	0.43	----	0.13
0.5% P	1.17	0.69	1.18	0.65	----	0.40
1.0% P	1.10	1.63	1.30	1.03	1.25	0.66
0.5% F	1.45	0.69	----	0.60	----	0.25
1.0% F	1.32	1.48	----	1.85	----	1.20
0.5% Mix	1.28	1.07	----	0.82	----	0.65
1.0% Mix	1.33	1.60	1.6	1.90	----	1.10

*UPK = Unpacked; PK = Packed.

TABLE 27

EFFECT OF ACID TREATMENT AND PACKING ON LACTIC ACID CONCENTRATIONS OF RYE FORAGE (PART 1, TRIAL III)

Treatment	Weeks After Treatment				
	1	2		3	
	PK[ab]	UPK[a]	PK	UPK	PK
	% Dry Matter				
Control	6.71	----	9.59	----	7.09
0.5% P	10.23	3.17	5.31	----	10.83
1.0% P	2.71	2.68	5.60	3.72	7.16
0.5% F	7.73	----	7.91	----	4.26
1.0% F	2.03	----	4.01	----	5.17
0.5% Mix	5.61	----	9.91	----	7.53
1.0% Mix	3.56	3.36	3.40	0.79	5.28

[a]UPK = Unpacked; PK = Packed.
[b]Changes in lactic acid concentrations of packed treatments are not significantly different ($P > .05$).

TABLE 28

EFFECT OF ACID TREATMENT AND PACKING ON FORMIC ACID CONTENT AND RECOVERY IN RYE FORAGE (PART 1, TRIAL III)

Treatment	Weeks After Treatment						% Recovery at 3 wks.	
	0	1	2		3			
	UPK and PK*	PK	UPK	PK	UPK	PK	UPK	PK
	-------------------%							
0.5% F	1.75	0.60	---	Trace	----	Trace	----	----
1.0% F	3.43	3.35	---	3.26	----	1.90	----	55.4
0.5% Mix	1.02	1.32	---	Trace	----	Trace	----	----
1.0% Mix	2.06	1.95	2.0	2.0	1.96	0.85	95.1	41.3

*UPK = Unpacked; PK = Packed.

TABLE 29

EFFECT OF ACID TREATMENT AND PACKING ON TOTAL NITROGEN CONTENT OF RYE FORAGE (PART 1, TRIAL III)

Treatment	Weeks After Treatment					
	0	1	2		3	
	UPK and PK*	PK	UPK	PK	UPK	PK
	---------------------% Dry Matter---------------------					
Control	1.58	1.70	----	1.78	----	1.81
0.5% P	1.58	1.51	1.50	1.76	----	1.68
1.0% P	1.50	1.47	1.47	1.61	1.40	1.41
0.5% F	1.68	1.62	----	1.60	----	1.61
1.0% F	1.52	1.51	----	1.45	----	1.61
0.5% Mix	1.60	1.46	----	1.53	----	1.70
1.0% Mix	1.52	1.65	1.51	1.39	1.68	1.55

*UPK = Unpacked; PK = Packed.

TABLE 30

EFFECT OF ACID TREATMENT AND PACKING ON NPN CONTENT OF RYE FORAGE (PART 1, TRIAL III)

Treatment	Weeks After Treatment[b]					
	0	1	2		3	
	UPK and PK[ac]	PK	UPK	PK	UPK	PK
	-----------------------% of DM					
Control	0.51	1.02	----	0.95	----	1.32
0.5% P	0.49	1.04	0.89	1.00	----	1.36
1.0% P	0.51	0.65	0.67	0.52	0.90	0.88
0.5% F	0.59	0.87	----	1.08	----	1.12
1.0% F	0.66	0.87	----	0.95	----	1.02
0.5% Mix	0.74	0.83	----	1.00	----	0.89
1.0% Mix	0.53	0.81	0.85	0.95	0.84	1.08

[a]UPK = Unpacked; PK = packed.

[b]Means of weeks 1, 2, and 3 in packed forage are higher ($P < .05$) than for the initial sampling time.

[c]Changes in NPN content of packed treatments are not significantly different ($P > .05$).

TABLE 31

EFFECT OF ACID TREATMENT AND PACKING ON ADF CONTENT OF RYE FORAGE (PART 1, TRIAL III)

Treatment	Weeks After Treatment					
	0	1	2		3	
	UPK and PK*	PK	UPK	PK	UPK	PK
	-------------------% Dry Matter					
Control	40.9[a]	42.7[a]	----	42.8[a]	----	45.2[a]
0.5% P	40.2[bc]	40.5[bc]	40.7	41.1[bc]	----	44.1[bc]
1.0% P	39.2[bd]	41.3[bd]	40.2	39.8[bd]	40.9	42.6[bd]
0.5% F	39.5[ac]	42.6[ac]	----	42.2[ac]	----	44.3[ac]
1.0% F	40.4[bc]	40.1[bc]	----	41.2[bc]	----	42.1[bc]
0.5% Mix	40.5[acd]	41.6[acd]	----	41.2[acd]	----	43.1[acd]
1.0% Mix	40.2[bc]	40.7[bc]	41.0	40.7[bc]	40.4	42.2[bc]

*UPK = Unpacked; PK = Packed.

[a,b,c,d]Values with different superscripts are significantly different ($P < .05$). Differences due to time of sampling are significant ($P < .05$).

TABLE 32

EFFECT OF ACID TREATMENT AND PACKING ON ADF-N OF RYE FORAGE (PART 1, TRIAL III)[a]

Treatment	Weeks After Treatment					
	0	1	2		3	
	UPK and PK[b]	PK	UPK	PK	UPK	PK
	% Dry Matter					
Control	.098	.116	----	.119	----	.110
0.5% P	.100	.108	.084	.125	----	.098
1.0% P	.078	.101	.080	.080	.109	.095
0.5% F	.111	.101	----	.108	----	.096
1.0% F	.078	.094	----	.107	----	.088
0.5% Mix	.067	.090	----	.093	----	.128
1.0% Mix	.067	.069	.082	.091	.085	.097

[a]None of the treatment or time differences were significant ($P < .05$).

[b]UPK = Unpacked; PK = Packed.

TABLE 33

MILK PRODUCTION PERSISTENCY AND MILK COMPOSITION ON THE DIFFERENT SILAGES (PART 1, TRIAL IV)[a]

Treatment	Milk	Persistency[b]	Milk Protein	Milk Fat	Milk Solids
	kg/day		---------------	%	---------------
Alf-Haylage	20.8	95.0	2.93	3.6	12.38
Control-Rye	19.6	94.0	3.06	3.7	12.80
Formic-Rye	21.1	96.7	2.91	3.4	12.26

[a]Differences among treatments were not significant ($P > .05$) for any of the parameters used.

[b] $\frac{\text{Treatment yield}}{\text{Standardization yield}} \times 100$

TABLE 34

DRY MATTER CONTENT AND CONSUMPTION OF SILAGES AND CONCENTRATE (PART 1, TRIAL IV)

Treatment	DM	Silage DM	DM Intake	Concentrate
	%	kg/day	(% of body weight)	kg/day
Alf-Haylage	60.75[a]	9.5	1.6	7.5
Control Rye	26.17[b]	7.6	1.3	7.1
Formic Rye	25.62[b]	8.3	1.5	7.6

[a,b]Values with different superscript are statistically significant ($P < .05$).

TABLE 35

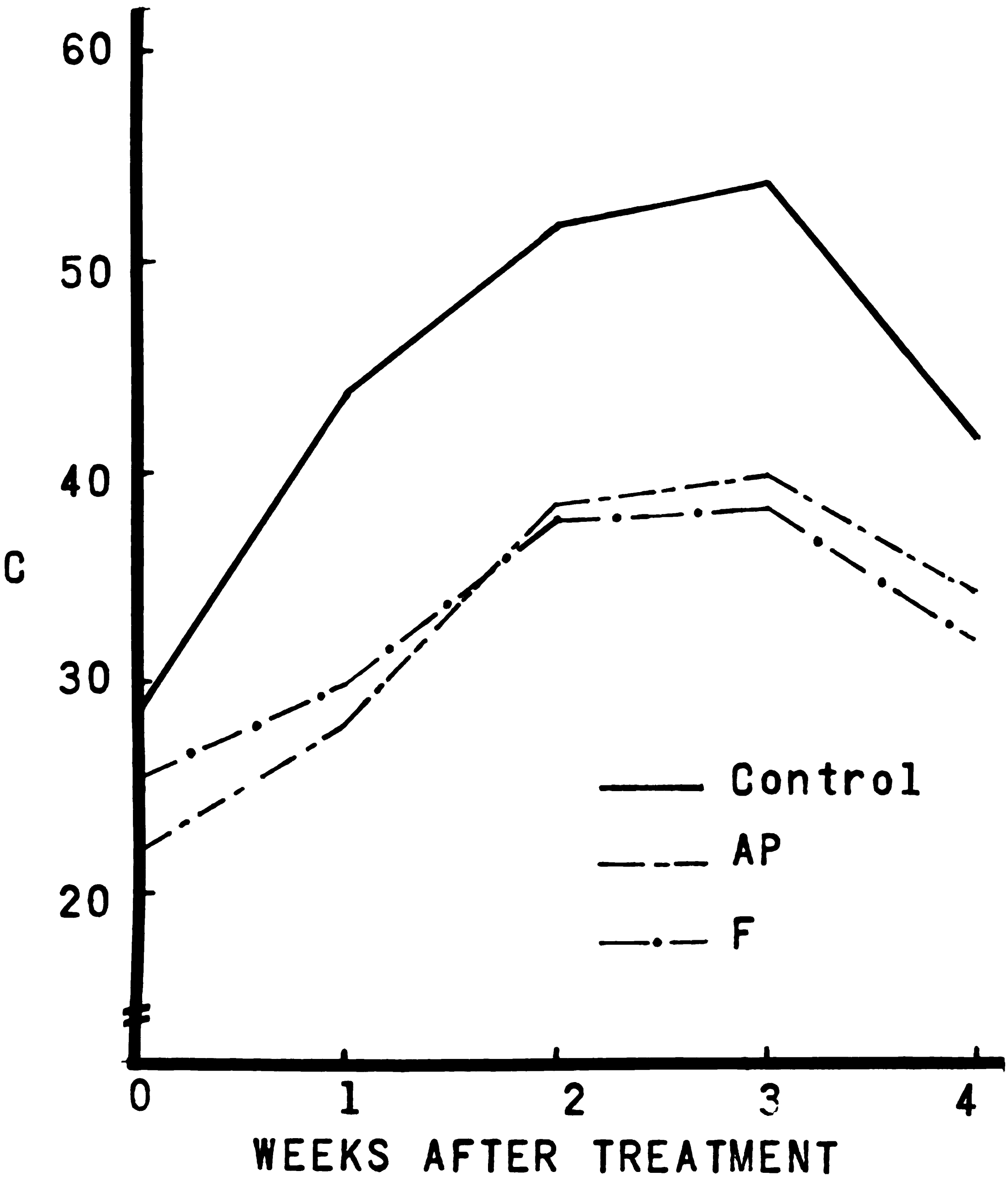
AVERAGE NITROGEN AND NPN CONTENT OF THE SILAGES
(PART 1, TRIAL IV)

Treatment	Total N*	NPN
	---------------% of DM	------------
Alfalfa haylage	3.00	1.24[a]
Control-rye	2.72	1.69[b]
Formic-rye	2.70	1.66[b]

[a,b]Values not sharing a common superscript are significantly different ($P < .01$).

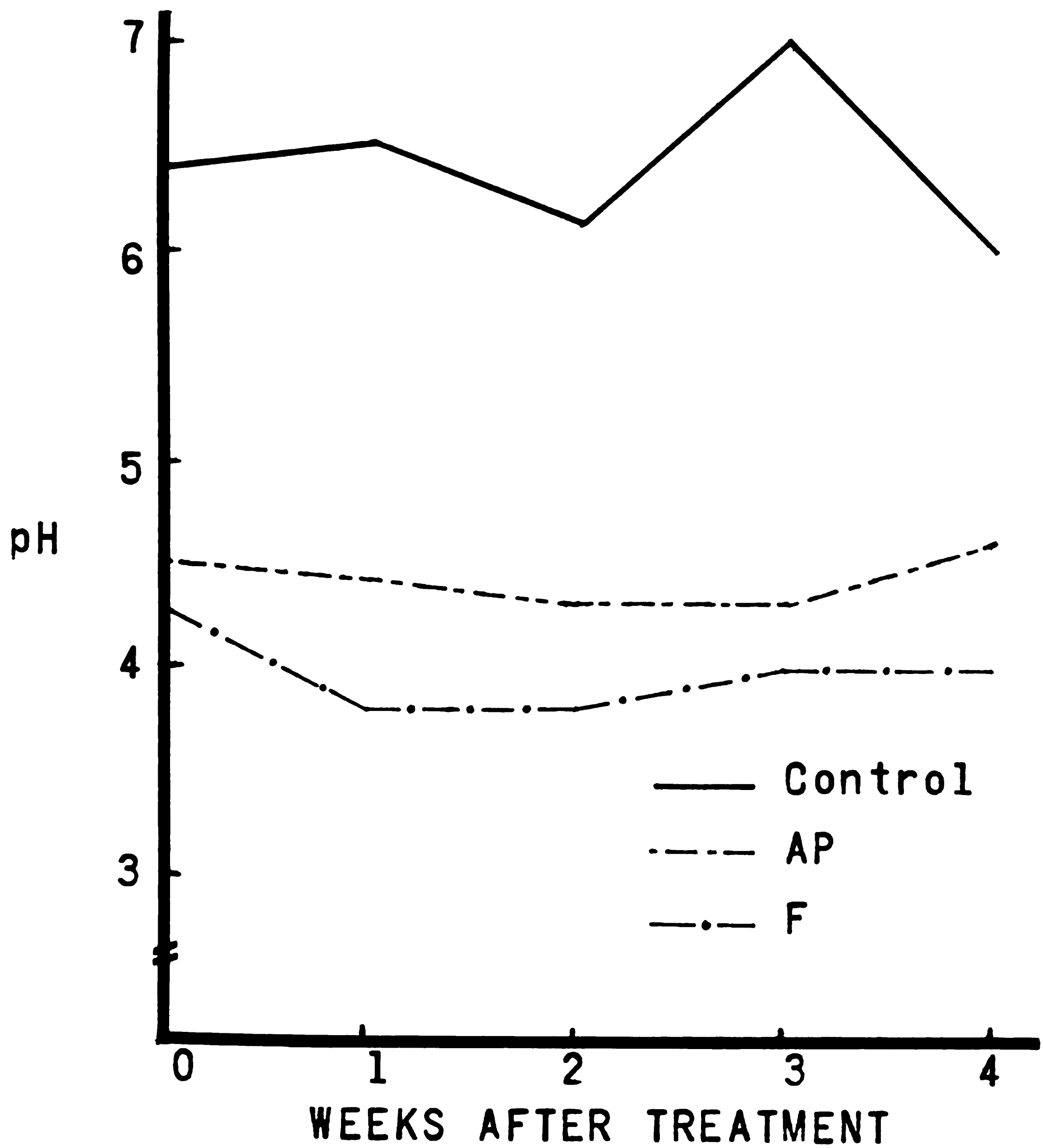
*Differences in total N were not significant ($P > .01$).

Fig. 1.--The Effect of Acid Treatment on Rye Forage Temperature (Part 1, Trial 1).



60
50
40
C
30
20
0
1
2
3
4
WEEKS AFTER TREATMENT
Control
AP
F

Fig. 2.--The Effect of Acid Treatment on Rye Forage pH (Part 1, Trial I).



7
6
5
pH
4
3
Control
AP
F
0
1
2
3
4
WEEKS AFTER TREATMENT

Fig. 3.--Temperatures of Packed Rye Forages Treated With Varying Levels of Formic (F) or Propionic (P) Acids (Part 1, Trial III).

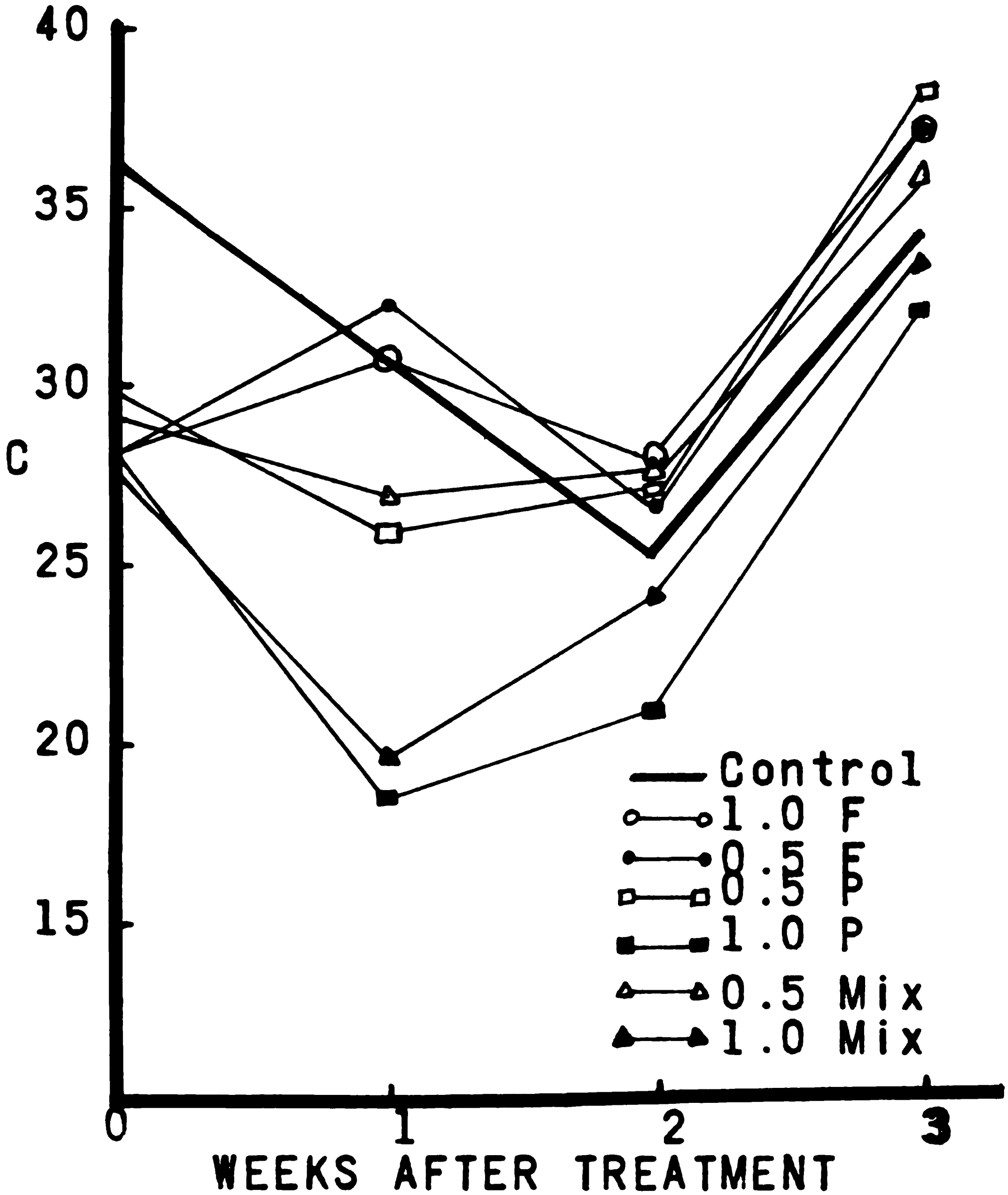
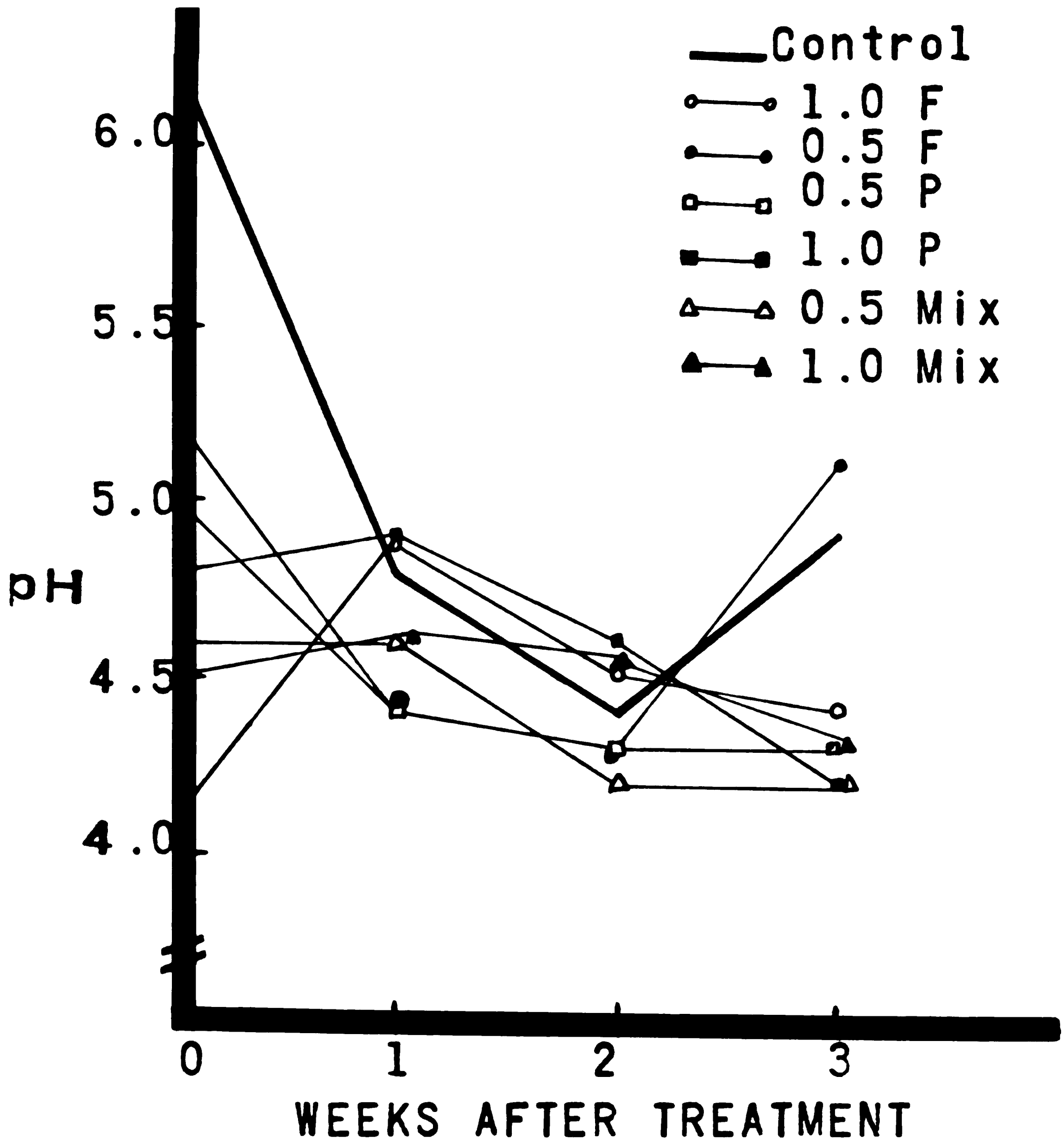

40
35
30
25
20
15
C
0
1
2
3
WEEKS AFTER TREATMENT
Control
1.0 F
0.5 F
0.5 P
1.0 P
0.5 Mix
1.0 Mix

Fig. 4.--Changes in pH of Packed Rye Forages Treated With Varying Levels of Formic (F) or Propionic (P) Acids (Part 1, Trial III).


Control
1.0 F
0.5 F
0.5 P
1.0 P
0.5 Mix
1.0 Mix
6.0
5.5
5.0
4.5
4.0
pH
0
1
2
3
WEEKS AFTER TREATMENT

PART 2

EFFECT OF ACID TREATMENT ON THE PRESERVATION OF UNPROTECTED CORN FORAGE

INTRODUCTION

In the rye experiments, increased DM recoveries resulted from treatment of forages which were left under completely aerobic conditions with minimal protection. Propionic acid was superior to formic acid as a preservative of poorly protected forage. The acids probably inhibited microbial growth which delayed fermentation and heating of acid-treated forages. In addition, forages preserved with up to 1.5% acid (on a wet basis) were readily accepted by animals.

The purpose of this study was to further examine the preservative effect of different organic acids on corn, which is a high energy forage crop, when left under conditions similar to those used in the rye forage studies. Also, the best level and combination of acids needed to preserve corn forage as well as stability and acceptability of acid treated forages were studied.

MATERIALS AND METHODS

Trial I

Chopped corn forage (38% DM) was used in this trial. Treatments were: control, 1% AP, 1% formic, 1% AP + formic, 1% propionic, and 1% acetic acid. The acids were diluted 1:1 with water and added to chopped corn at the blower. The forages were ensiled in temporary silos (3 x 1.5 m) in a manner similar to the first rye trial. Forages were sampled immediately before and after treatment and samples were frozen at -5 C for analyses similar to those performed on rye samples. Daily temperatures and spoilage dates were recorded for the different treatments. Six weeks after harvest the spoiled layers were removed, weighed and sampled for DM determination. The preserved material, except for the acetic acid treatment, was fed in a short acceptability trial to 5 groups of 14 heifers each (437 kg body wt.). In addition to the forage each group was also fed 6.4 kg of a high protein concentrate (85% SBM) per day. The acceptability trial lasted for 5 days during which forages were observed for heating.

Trial II

In the second trial corn forage of the same cut as in trial I was placed loose in 220 liter experimental silos. The different acid levels and combinations shown in Table 36 were tested. The acids were diluted 1:1 with water and mixed for several minutes with 32 kg portions of the chopped corn forage in a cement mixer. Temperatures were recorded daily and dates when spoilage was first observed were monitored. At the end of five weeks the drums were emptied and spoiled forage was removed.

RESULTS AND DISCUSSION

Trial I

Temperature and Amount of Spoilage

Temperatures during the experimental period are given in Table 37. As in previous trials the first temperature recorded was 4 hours after treatment. At this time temperatures of the control treatment were already higher (27 C) than those of acid treatments (24 C). Within two days the control forage reached 40 C; which corresponded to the first detection of spoilage. This observation is in agreement with that of Zimmer and Gordon (1964), of Honig (1969) and Federson (1971) who observed that oxidation was accompanied by large rises in temperature and DM losses. The propionic acid, the AP and formic acid treatments maintained the lowest temperatures (25-26 C) during the first week. These low temperatures indicate that little fermentation occurred and that microbial action was inhibited. The control and acetic acid treatments had the highest temperatures during the first week; they averaged 37 and 31 C, respectively. In ten days, mold was detected on the acetic acid treatment at a temperature of 43 C. At 13 days after treatment mold was detected on the AP treatment and a temperature of 39 C was recorded. On day 20 mold was detected on the formic acid treatment which had a temperature of 52 C. This temperature was as high as that obtained for control rye forage. The AP + F treatment molded in 24 days at which time a temperature of 50 C was recorded. The temperature of the propionic acid treatment started to increase between the 3rd and 4th week. However, it maintained the lowest temperatures during the entire 6 week period. This treatment molded at 32 days at which time temperatures of 44 C were recorded.

The time of spoilage detection was negatively correlated (-0.81) with the average temperature for the entire 6 weeks. This was in agreement with the findings of the rye study which suggested that as the temperature increased to about 40-50 C spoilage would occur.

Even though acetic acid has bactericidic properties, it was less effective (52% of DM spoiled) than propionic or formic acids in preserving unprotected corn forage (Table 39). Contrary to what was observed on the previous trials, relatively little spoilage (33.6%) was detected on the control treatment. This might be due to a larger amount of forage (6 tons) used in the control compared to AP (5 tons) or other treatments (4.5 tons). The least spoilage (27%) was observed on the AP treatment which agrees with results of the first rye trial, when AP spoilage was less than that on formic or control treatments.

It also agrees with the work of Gordon and Goering (1972) who added twice the level of acid under minimally protected conditions.

Spoilage on propionic acid, formic acid and AP + F amounted to 32.3, 43.1, and 44.1% of the DM, respectively. As noted with rye forage (trial 3) invisible losses were probably lowest for forages treated with propionic acid. Daniel et al. (1970) observed 4.5 times more CO_2 production on control forage than that treated with 1% propionic acid (18 vs 4 g CO_2/kg DM).

A correlation of +0.4 (similar to the rye experiment) was obtained between temperature and amount of spoilage. Data on temperature, time of spoilage, and amount of preservation again showed the superiority of propionic acid over formic or acetic acids in preserving uncompacted and unprotected corn forage.

Fermentation Characteristics

Changes in pH and VFA concentrations are given in Table 38. In order to avoid excessive exposure of the forage mass, samples were only taken immediately after treatment and after the removal of spoiled material. Similar to previous observations, the control forage had the highest and the formic acid treated forage the lowest pH values at the beginning of the study (5.5 vs 3.5). Other treatments were intermediate. The low pH values observed for formic acid treatments are due to the strongly acidic nature of formic acid (Carpintero et al., 1969). At the end of storage little difference in pH was obtained for the different treatments. In general, the pH values observed at the end of the study were not different from those reported or recommended for good quality silages.

Because material was sampled only twice during this study a low positive correlation, +0.11 (compared to previous trials) was obtained between average temperature and pH values. A negative correlation (-0.61) was observed between pH and the days after harvest when spoilage was first detected; indicating that spoilage occurred at an earlier date in forages with higher pH values.

Organic Acids

Only acetic acid treatments contained this acid in significant concentrations at the beginning of the study (Table 38). Acetic acid was detected on the propionic acid treatment but at a very low level (0.2%). By the end of the study acetate concentrations had increased on all treatments except that treated with only acetic acid. The decrease on the acetic treatment might be related to the poor preservation qualities of acetic relative to other acids as indicated by the faster rise in temperatures. However, specific inhibition of added acetate on production of the acid was observed previously (Huber et al., 1972) and appears a more logical explanation in view of the levels of lactic acid (2.4% of DM) on this treatment. Greatest increases in acetic acid were noted on forages not treated with acetate (control, propionic and formic acids) which substantiates the specific inhibition of acetic acid on silage acetate production.

Propionic acid was only detected in forages with added propionate. Concentrations decreased to 25% of original by the end of 6 weeks on AP with little change for the propionic or AP + F treatments.

Formic acid apparently inhibits micro-organisms which produce propionic acid and has a general depressing effect on fermentation of corn forage as indicated by decreased lactic acid levels (Huber et al., 1972). The absence of propionic acid on the acetic acid and control treatments may be related to the high temperatures observed during early fermentation.

Butyric acid was detected 4 hours after treatment only in forages containing propionic acid. At 6 weeks some butyric acid had appeared (0.61%) in formic-treated forage and it had disappeared on the AP treatment.

At the end of the six week period, lactic acid was highest on the control (3.5% of DM) and lower in all treatments with added acid. This finding is in general agreement with Huber et al. (1972) who observed marked decreases in lactic acid of normal corn silage after formic acid treatment, but smaller decreases with added acetic or propionic acids. However, their studies used lower levels of acid (0.4-0.6%).

More total acid production was observed on the control compared to acid treatments. Formic acid in these unprotected conditions did not have as strong or depressing effect on fermentation relative to propionic and acetic as has been previously observed (Huber et al., 1972).

The recovery of acetic acid was very low (8%) on the acetic treatment indicating faster metabolism by micro-organisms (Table 39). When propionic acid was mixed with acetic the recovery of the latter was increased by more than three-fold. However, the recovery of propionic acid was low on this treatment. When only propionic acid or propionic plus formic (AP + F) were added, essentially all the propionic was recovered indicating the strong inhibitory effect of these acids on factors which might degrade or release propionate. The formic acid recovery was 66 and 69% of that added which is considerably higher than that reported for silage addition (Huber et al., 1972).

Protein and NPN Content of Corn Forages

The crude protein content of the different forages averaged about 9% of the DM (Table 40). This level did not change appreciably for any of the treatments during the 6 weeks of storage. However, highest decreases were observed on control and acetic acid treatments which probably resulted from the faster temperature rises. These observations support those of Huber et al. (1972) who observed higher increases in total nitrogen on acid than control treated silages.

Increases in NPN content during storage did not differ between treatments. Thus, no apparent decrease in proteolysis resulted from acid treatment as shown in previous studies (Huber et al., 1972; Saue and Breirem, 1969), which did not use unprotected forages.

Acceptability of Corn Forage

All forages except that treated with acetic acid were fed ad libitum to 70 heifers averaging 437 kg in body weight (14 per group). In addition to the forages 6.4 kg protein supplement was fed (0.45 kg/heifer). The acceptability trial was only for a short duration (5 days) because of the limited amount of silage available and tested whether heifers would consume corn forage treated with about double the normal level of acid. Highest intakes (Table 41) were recorded for the control forage (14.4 kg of DM) and the lowest on propionic acid (9.7 kg). This lower intake on propionate might be related to a greater depression in fermentation or the pungent smell usually reported for propionate treatments. More data are needed to definitely establish the relative influence of high levels of the acids on intake of ruminants, but these do show that forages treated with as high as 3% acid (on DM basis) will be consumed by cattle.

During the feeding trial the temperature was recorded for the different forages (Table 41). Lowest temperatures were observed on the AP and propionic treatments. These data support the depression in after-fermentation by propionic acid which was reported with rye forage and is in agreement with observations of Daniel et al. (1970) and Weise and Daniel (1970). The high temperature observed on the control treatment during the feeding trial might be expected to decrease intake and increase spoilage if the forages were held for a longer period of time.

Trial II

Temperature and Amount of Spoilage

In this study, changes in temperature and time when spoilage first occurred were recorded. Results are given in Table 42 and treatments are referred to according to number given in Table 36. Dry matter of the first 47 treatments averaged 38%, while that of the last 4 treatments averaged 44%. The initial temperature for the first 47 treatments ranged from 18-23 C while that of higher DM treatments averaged 27.5 C. Similar to previous findings, spoilage was first detected on the control treatment, at 3 days. The last treatments to spoil were 1.5, 1.0, and 1.25% propionic acid, at 28, 25, and 23 days after storage, respectively. Nineteen to twenty days after treatment spoilage was detected on treatments 25, 4, 20, 32, and 33. When comparisons are made according to level of acid used (Figure 5), propionic acid treatments seemed to delay spoilage more than any other acid or combination of acids. The combination of propionic acid and formic acid at (1.0, 1.25, 1.5, and 0.75%) was more effective in delaying spoilage than when acetic was present. When all three acids were used in different combinations and levels spoilage was detected earlier as the contribution of the acetic acid increased. Also, as the propionic acid level increased spoilage was delayed while the effect of formic acid retarding spoilage was intermediate. These results agree with those of the previous trials and of other researchers (Daniel et al., 1970; Weise and Daniel, 1970) who observed strong fungicidal properties for propionic acid while formic acid was the most effective in retarding bacterial growth.

Similar to previous results, a negative correlation was found between average temperature and time of spoilage (-0.54). At the end of the five weeks experimental period most treatments had spoiled completely and only very little recovery occurred on treatments 3, 16, 24, which were propionic acid treatments.

The results are in agreement with those reported earlier indicating the superiority of propionic acid as a preservative under aerobic conditions followed by formic acid. Also, they suggest that acetic acid is not as good a preservative for minimally protected forages as propionic or formic.

TABLE 36

EXPERIMENTAL TREATMENTS FOR CORN FORAGE (PART 2, TRIAL II)

Treatment Number	Acid Treatment	Total Acid Added (%)
1	Control	----
2	Acetic acid (A)	1.0
3	Propionic acid (P)	1.0
4	Formic acid (F)	1.0
5	1 A : 1 P	1.0
6	1 A : 1 F	1.0
7	1 P : 1 F	1.0
8	1 A : 1 P : 1 F	1.0
9	0.6 A : 0.4 P : 1 F	1.0
10	0.4 A : 0.6 P : 1 F	1.0
11	1 A : 0.4 P : 0.6 F	1.0
12	1 A : 0.6 P : 0.4 F	1.0
13	0.4 A : 1 P : 0.6 F	1.0
14	0.6 A : 1 P : 0.4 F	1.0
15	A	1.25
16	P	1.25
17	F	1.25
18	1 A : 1 P	1.25
19	1 A : 1 F	1.25
20	1 P : 1 F	1.25

21	1 A : 1 P : 1 F	1.25
22	0.6 A : 0.4 P : 1 F	1.25
23	A	1.50
24	P	1.50
25	F	1.50
26	1 A : 1 P	1.50
27	1 A : 1 F	1.50
28	1 P : 1 F	1.50
29	1 A : 1 P : 1 F	1.50
30	0.6 A : 0.4 P : 1 F	1.50
31	0.6 A : 1 P : 0.4 F	1.50
32	0.4 A : 0.6 P : 1 F	1.50
33	0.4 A : 1 P : 0.6 F	1.50
34	1 A : 0.6 P : 0.4 F	1.50
35	1 A : 0.4 P : 0.6 F	1.50
36	A	0.75
37	P	0.75
38	F	0.75
39	1 A : 1 P	0.75
40	1 A : 1 F	0.75
41	1 P : 1 F	0.75
42	1 A : 1 P : 1 F	0.75
43	0.6 A : 0.4 P : 1 F	0.75
44	0.6 A : 1 P : 0.4 F	0.75
45	0.4 A : 1 P : 0.6 F	0.75
46	1 A : 0.4 P : 0.6 F	0.75
47	1 A : 0.6 P : 0.4 F	0.75
48*	P	0.25
49*	P	0.30
50*	P	0.50
51*	P	0.75

*Corn silage used was of higher DM (43%).

TABLE 37

DRY MATTER, TEMPERATURE CHANGES, TIME AND AMOUNT OF SPOILAGE OF UNPROTECTED CORN FORAGE AS AFFECTED BY ACID TREATMENT (PART 2, TRIAL I)

Treatment	DM %		Temperatures (°C)							DM Spoiled %	Days After Harvest Spoilage First Detected
	Weeks		Weeks								
	0	6	0	1	2	3	4	5	6		
Control	37.5	36.9	27.0	37.0	41.9	46.0	50.4	51.0	51.5	33.6	2
AP	34.8	38.7	24.0	29.7	37.5	40.6	44.9	47.5	49.5	27.0	13
F	37.4	33.2	25.0	25.8	39.9	48.7	49.8	52.0	57.5	44.1	20
AP + F	38.4	40.1	24.0	25.3	33.1	41.6	48.4	49.0	50.5	43.1	24
P	38.6	40.4	24.0	24.6	25.4	29.1	34.5	39.0	44.5	32.3	32
A	37.3	40.5	24.0	31.1	41.8	45.6	49.3	50.0	51.0	52.1	10

TABLE 38

EFFECT OF ACID TREATMENT ON CORN FORAGE pH, VFA AND LACTIC ACID CONCENTRATIONS (PART 2, TRIAL I)

Treatment	pH		Acetic		Propionic		Butyric		Lactic		Formic		Total Acid[a]
	0	6	0	6	0	6	0	6	0	6	0	6	Production 6
	% Dry Matter												
Control	5.5	3.8	----	1.41	----	----	----	----	----	3.51			4.92
AP	4.3	3.8	1.99	2.01	1.16	0.28	0.30	----	----	2.40			2.42
F	3.5	3.8	----	0.88	----	----	----	0.61	----	1.73	2.84	1.86	3.22
AP + F	3.7	4.0	1.02	1.34	0.42	0.46	0.27	0.45	----	1.35	1.50	1.04	1.89
P	4.3	4.0	0.23	0.78	3.23	3.47	0.20	0.55	----	1.46			2.60
A	4.3	4.1	2.59	1.63	----	----	----	----	----	2.42			2.42

[a]Original level of added acid deducted from total.

TABLE 39

ORGANIC ACID RECOVERY ON THE UNPROTECTED CORN FORAGE TREATMENTS SIX WEEKS AFTER TREATMENT (PART 2, TRIAL I)

Treatment	Acetic	Propionic	Formic
	---------------------%	---------------------	
AP	30	25	--
F	--	---	66
AP + F	--	100	69
P	--	100	--
A	8	---	--

TABLE 40

EFFECT OF ACID TREATMENT OF CORN FORAGE ON CRUDE PROTEIN AND NPN CONTENTS (PART 2, TRIAL I)

Treatment	Crude Protein		NPN	
	Weeks			
	0	6	0	6
	-----------------% Dry Matter-----------------			
Control	9.42	8.91	0.24	0.53
AP	8.84	8.62	0.26	0.51
F	8.75	8.55	0.26	0.54
AP + F	9.45	9.37	0.24	0.54
P	9.64	9.41	0.26	0.46
A	8.95	8.52	0.24	0.55

TABLE 41

EFFECT OF ACID TREATMENT ON DM INTAKE AND TEMPERATURE DURING THE ACCEPTABILITY TRIAL (PART 2, TRIAL I)

Treatment	DM Intake* kg/day	Temperature °C
Control	14.4	40
AP	12.3	27
F	12.2	37
AP + F	13.8	38
P	9.7	34
A	Not fed	48

*14 heifers per treatment for 5 days.

TABLE 42

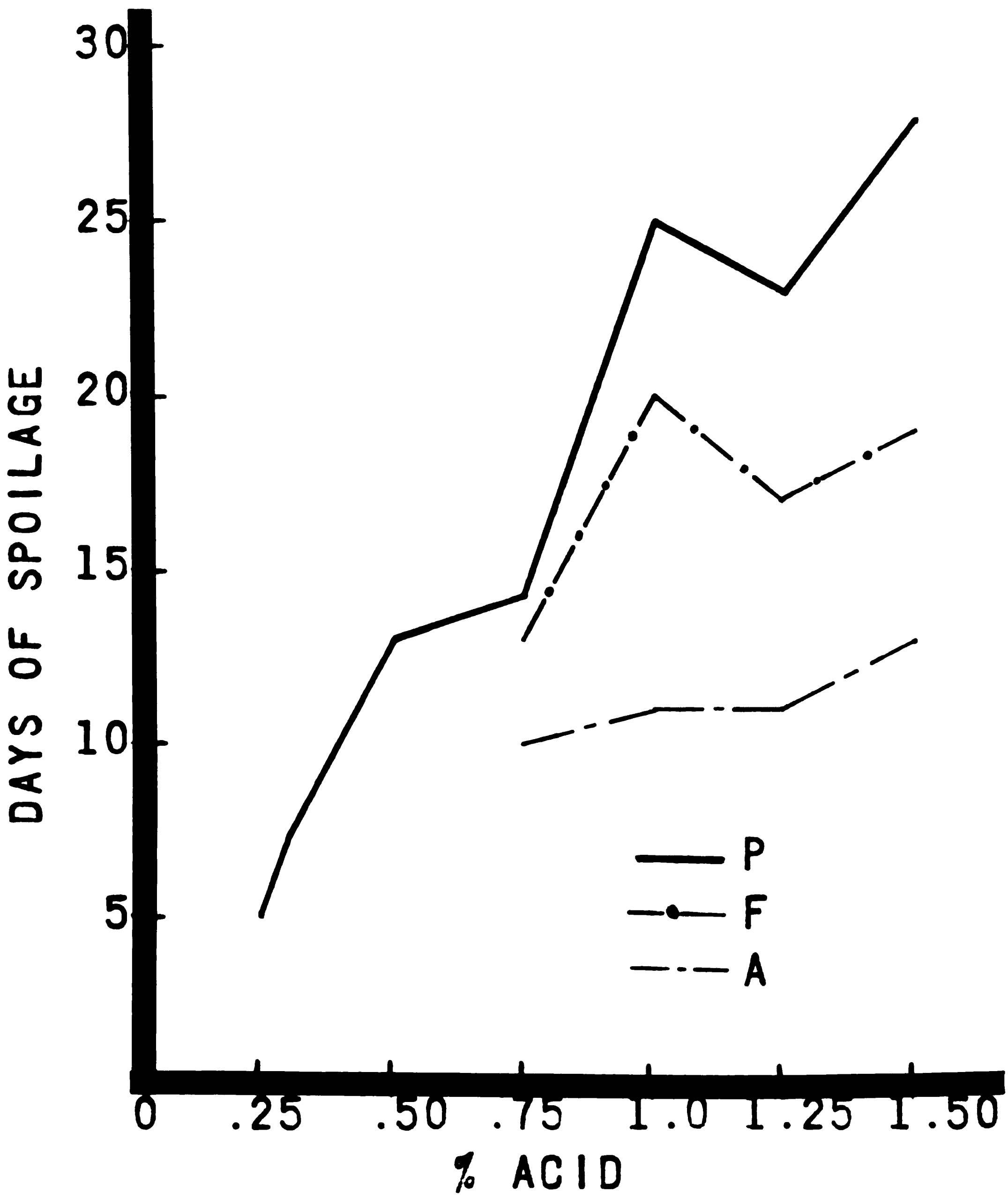
EFFECT OF DIFFERENT ACID TREATMENTS ON TEMPERATURE CHANGES AND TIME OF SPOILAGE (PART 2, TRIAL II)

Treatment Number	Weeks After Treatment						Time of Spoilage (days)
	0	1	2	3	4	5	
	C						
1	21.0	27.0	30.4	31.4	28.8	27.0	3
2	19.0	24.4	31.6	33.7	30.2	28.0	11
3	19.0	17.6	18.4	23.4	25.4	38.0	25
4	18.0	17.3	18.6	28.8	30.1	31.0	20
5	19.0	17.3	18.3	30.5	31.5	37.0	17
6	19.0	17.4	19.1	33.9	27.7	28.5	15
7	19.0	17.6	18.1	27.7	32.7	33.0	20
8	19.5	17.9	21.0	33.1	30.2	32.0	15
9	19.0	23.0	34.1	33.1	30.4	29.0	10
10	19.5	24.4	32.8	32.9	27.1	25.0	10
11	19.5	25.6	34.1	34.1	30.0	26.0	5
12	19.0	24.9	34.4	33.9	24.1	22.5	5
13	20.0	26.9	32.0	34.6	29.2	24.2	10
14	20.0	22.9	28.7	33.6	28.0	25.0	11
15	23.0	28.9	28.8	33.3	26.3	24.0	11
16	23.0	23.1	30.6	31.8	27.3	27.5	23
17	20.0	19.1	26.3	32.7	29.7	32.0	17
18	20.5	27.1	29.2	31.5	26.9	26.0	11
19	20.0	19.1	28.2	32.7	29.2	31.0	11
20	20.0	17.8	18.9	28.1	29.4	31.0	20
21	22.0	28.1	30.7	33.1	31.3	28.0	9

22	20.0	19.7	24.2	31.4	32.1	33.5	16
23	20.0	29.7	33.1	35.3	28.1	27.0	13
24	20.5	20.7	25.1	27.6	25.6	37.2	28
25	20.0	21.3	28.1	30.6	28.8	29.0	19
26	20.0	20.5	24.9	29.5	25.7	23.5	14
27	20.0	18.9	23.8	35.6	25.5	25.0	12
28	19.5	20.0	24.3	29.0	26.0	25.5	18
29	20.0	17.1	18.9	30.6	25.7	27.0	16
30	20.0	20.2	24.5	31.8	26.2	26.0	13
31	20.5	16.9	17.1	25.5	31.1	30.5	18
32	21.0	17.9	22.4	30.0	26.5	25.0	20
33	20.5	17.1	17.1	25.4	32.9	32.5	21
34	21.0	17.8	25.7	32.8	26.2	26.0	13
35	20.5	21.9	31.6	30.4	24.1	22.0	10
36	20.0	26.2	30.9	34.4	27.5	27.5	10
37	20.5	26.6	30.3	29.9	23.3	23.0	15
38	20.5	23.5	28.6	30.9	23.3	22.5	13
39	22.5	27.6	31.6	29.7	25.3	25.5	11
40	20.5	22.4	31.4	30.6	34.2	16.3	10
41	20.5	18.6	28.5	32.1	29.4	28.5	12
42	21.0	23.0	32.4	31.3	23.4	23.5	9
43	21.0	23.9	28.6	32.5	26.3	23.0	9
44	20.0	23.4	31.3	31.4	26.5	23.5	9
45	20.5	26.6	31.6	31.4	27.4	24.5	11
46	20.0	23.6	27.9	32.9	32.1	26.0	8
47	20.0	23.3	32.4	33.1	27.1	24.0	8
48*	28.0	29.1	31.3	29.9	23.3	20.5	5
49*	27.0	32.1	32.3	30.7	25.0	22.5	7
50*	27.5	29.5	32.3	30.4	25.5	23.5	13
51*	27.5	25.4	32.4	31.0	27.5	24.8	14

*Corn silage used was of higher DM (43%).

Fig. 5.--Relationship of Acid Level and Type to Days After Harvest
Spoilage Was First Detected.


30
25
20
15
10
5
DAYS OF SPOILAGE
P
F
A
0
.25
.50
.75
1.0
1.25
1.50
% ACID

PART 3

PERIPHERAL PRESERVATION OF SILAGES

INTRODUCTION

Parts I and II showed that the organic acids markedly retarded spoilage of forages stored under minimally protected conditions. In addition to the preservative effect of acids, animals consumed and performed well on the acid treated forages. Also, acid treated forages were more stable during the acceptability trials.

Under field conditions spoilage may account for 10% or more loss of ensiled DM even under good ensiling practices in upright silos. Higher losses are usually encountered in horizontal silos due to a greater exposure to air.

The purpose of this study was to determine which acid or combination of acids would most effectively decrease peripheral losses. Also, the acceptability of the treated silage by animals was ascertained.

MATERIALS AND METHODS

Trial I

In this trial, the last load of chopped corn or sorghum stored in conventional upright silos was treated with the different acids. Shredded plastic silo paper was placed between layers to differentiate acid treated from other silages. The acids were diluted 1:1 with water as in the previous experiments and the required amounts were applied into the blower housing as each load was blown into the silos. In addition to the silos at the Dairy Research Center some of the silos at the Beef Research Center were used. Tables 43 and 44 show the different treatments used. When silos were opened silage containing visible mold which is normally discarded was weighed and sampled for DM losses. Four of the treatments were fed to 34 lactating cows in a 2-day acceptability trial and DM intakes were recorded.

Trial II

In addition to the peripheral treatment of upright silos, two bunker (horizontal) silos located in Grand Ledge, Michigan, were used to determine the effectiveness of organic acids as preservatives for corn silage left uncovered and subjected to rain, snow, and other environmental conditions. The corn silage (35-40% DM) was distributed and packed by a heavy tractor. In the first silo 5 equal areas (4 x 5 m) were measured, marked, and treated with 2.5 kg/sq. meter of an acid solution (1:1 with water) about 5 hours after ensiling was completed. The level of acid addition to the top 30 cm of silage was estimated at 1% of the fresh weight. The acids were applied as uniformly as possible by using a garden sprinkler. The treatments were two controls, formic, AP + F, and AP. Another area 10 x 10 m was treated with AP at the same level as used before. This area had already spoiled before treatment and was used to examine the effectiveness of acids in retarding further spoilage.

In the second bunker silo five areas were also measured and treated with acids. The treatments were control, propionic, formic, AP and AP + F. This silo was treated five days after ensiling, therefore, spoiled material was removed before treatment. After about two months 1 x 1 m squares were measured in the middle of each treatment in order to estimate the amount of spoilage. Also the thickness of the spoiled layer was measured. Samples were taken from the first good layer observed after spoilage removal and also at a depth of 30 cm below that in order to determine acid recoveries.

RESULTS AND DISCUSSION

Trial I

The results of this study are given in Table 43. The amount of treated silage varied from 1-8 tons of DM. Acids were used at 1% on a fresh basis, with the exception of 0.5% AP. More packing occurred with the larger amounts of treated material. Packing resulted in less spoilage because oxidation time was decreased due to the shortage in O_2 needed by the aerobic micro-organisms. After 2 months of storage spoilage on the 1% AP and 0.5% AP was negligible (7.84 vs 8.52% of DM). This observation suggests that AP was quite effective in preserving the top silage in upright silos. Our previous studies indicate the preservative effect was mainly due to propionic acid. The degree of packing may have interacted with acid treatment. About 33% more silage was treated with 0.5% AP and spoilage was not higher than 1% AP. Previous work reported in this thesis also showed that acid-treated forage better preserved after moderate compaction of the mass. Gordon and Goering (1972) also reported better recovery for material treated with 2.1% AP than for untreated controls when left under aerobic conditions.

For the four sorghum treatments the percent spoilage was highest for formic, followed by AP + F, AP and control in that descending order. However because of different amounts of material treated the absolute spoilage was 0.50, 0.35, 0.75, and 1.28 tons, respectively. Again less sorghum spoiled when treated with acid but because of a large quantity of material, the percent which spoiled on the control treatment was lowest.

Approximately 1.5 tons of DM in top of each of 10 silos at the Dairy Cattle Center were used in two comparisons. Treatments and results are listed in Table 44. In the first set of four silos, the most spoilage was observed on the control treatment (64% of DM) and the least for AP, 23.8%. There was 26.2% spoilage on the AP + F and 42.2% for formic acid which again demonstrates the superiority of propionic acid to formic acid in retarding spoilage. This observation also indicates that as the amount of propionic acid increases better preservation can be expected.

The forages were fed in a short acceptability trial (2 days) to 32 lactating cows per treatment as the only roughage source. Dry matter intakes averaged 9.5, 9.4, 8.3, and 9.0 kg/day for the AP + F, AP, F and control treatments, respectively, and compare favorably with those which have been reported for good quality corn silage. Again the high acid levels used did not depress silage intake. This observation substantiates those of the previous trials and suggests that no problem should arise from feeding peripheral silage treated with large amounts of acid.

In a second set of 5 silos at the Dairy Cattle Center high DM corn silages (50% DM) were used to determine the most effective acid on peripheral preservation. Amount of spoilage was determined 4 months after treatment. The highest amount of spoilage (90% of DM) occurred on the untreated silage and the least (9.7%) for that treated with propionic acid. Formic acid gave better protection (27.6% spoilage) than acetic (82.6% spoilage) and the mixtures were intermediate. The high amount of spoilage observed on the AP treatment (62.9%) in this comparison relative to the previous trials suggests that acetic acid is less effective in peripheral preservation as silage DM increases from 35 to 50%.

The results of these two comparisons clearly indicate that propionic acid is a very good preservative for minimally protected silage of varying DM content. Formic acid also preserved forage in the top of upright silos, but not as effectively as propionate. Preservation by these acids are probably due to the fungal inhibition by propionic acid and the bacteriocidal properties of formic acid.

Trial II

Spoilage was determined on the top of the bunker silo by measuring 1 m squares about 2.2 months after the surface treatment with 1.2 kg of various acids/sq m. The highest amount of spoilage kg of DM/sq m, was on the control treatment and the least on the AP treatment (34 vs 25 kg), while the formic and the AP + F treated silages were intermediate (27 and 33 kg). The lower amount of spoilage on the AP than control treatment agree with previous results.

In the second bunker silo the amount of spoilage was determined in a similar manner to that used for the first bunker silo. Similar to the previous observations, the most spoilage was observed on the control and least for the propionic acid treatment (34.6 vs 22.4 kg of DM/sq m, respectively) with other treatments intermediate.

The somewhat lower amounts of spoilage observed on the second than the first bunker silo might be due to the fact that spoiled material was removed before treatment of the second silo indicating a more beneficial effect of acid treatment of unspoiled forage. The observations reported here again follow the same trend observed previously, indicating that propionic acid was superior to the other acids or combinations tested for preserving silages exposed to weather. Spraying with 1% AP was quite effective for preventing further spoilage of the top layer of corn ensiled for several days in the 10 x 10 m area.

Spoiled material amounted to 25.6 kg of DM/sq m, which was comparable to that observed for the AP treatment in the other two trials with bunker silos and lower than spoilage on control treatments.

With respect to pH changes, all treatments except the control started with lower pH values than were observed at the end of the study (Table 45). Little difference in pH was noted between the first layer of good silage and that at a one ft depth. As shown in previous trials, a direct correlation was obtained between pH and amount of spoilage (+0.66), indicating that as the pH increases also spoilage increases.

All the added acids, with the exception of some formic acid disappeared by the end of the study and only 25% of the formic was recovered. This could be due to decomposition of the acids because of the open conditions of the experiment, or they could have leached down due to rain.

Acetic acid (Table 45) was detected in most treatments with a trend for higher concentrations occurring in the samples of one ft depth. This observation is in general agreement with that of Greathouse et al. (1972) who observed higher organic acid concentrations in samples taken one ft from the bottom of bunker silos than those taken one ft from the top.

However, lactic acid concentrations were usually higher in the first good layer of silage than at one ft depth. This does not mean that fermentation was not delayed by acid addition but it might indicate that after such a long period (2 months and more) the added acids leached down and did not exert lactate fermentation of the upper layer of good silage.

The lactic acid concentrations, even in the upper layer of good silage, are lower than normally shown for well-preserved corn silage, but they do suggest that considerable fermentation occurred.

The crude protein and NPN contents (Table 45) of the silages were not affected by the different acid treatments under the condition of this study. However, a trend for a slightly higher NPN was observed on the deeper samples and a somewhat higher protein content on the treatments where propionic acid was applied. These studies support the recommendation of Weise and Daniel (1970) for treatment of bunker silos with propionic acid to prevent molding and rapid spoilage.

TABLE 43

EFFECT OF ACID TREATMENT ON AMOUNT OF SPOILAGE
(PART 3, TRIAL I)

Treatment	Crop Ensiled	Amount Treated	Amount Spoiled	Amount Spoiled	Storage Period
		tons DM	% DM	tons DM	days
AP (0.5%)	Corn	3.6	8.52	0.31	70
AP	Corn	3.4	7.84	0.27	68
Control	Forage Sorghum	8.1	16.00	1.30	93
F + AP	Forage Sorghum	3.5	21.43	0.75	89
F	Grain Sorghum	1.2	39.40	0.47	85
AP	Grain Sorghum	1.5	28.33	0.42	81

*1% acid level unless otherwise indicated.

TABLE 44

PERIPHERAL TREATMENT OF SILAGES (PART 3, TRIAL I)[b]

Treatment	Amount Treated	Amount Spoiled	Amount Spoiled	Storage Period
	tons DM	%	tons DM	days
AP	1.5	23.8	0.36	45
AP + F	1.4	26.2	0.37	44
F	1.6	42.2	0.65	48
Control	1.4	64.2	0.90	49
Control[a]	1.4	89.9	1.26	123
P[b]	1.7	9.7	0.16	120
F[b]	1.6	27.6	0.44	118
AP[b]	1.8	62.9	1.11	133
A[b]	2.3	82.6	1.89	118

[a]High DM (50%).

[b]1% acid level.

TABLE 45

PERIPHERAL TREATMENT OF BUNKER SILOS WITH ORGANIC ACIDS (PART 3, TRIAL II)

Treatment	DM	Acetic Acid	Lactic Acid	NPN	Crude Protein	pH	Thickness Molded Layer
	%	----------	----------% DM	----------	----------		
Control--initial	35.8	0.35	3.19	0.29	7.16	5.8	
--first good	33.3	0.92	4.16	0.25	7.25	3.6	18.3
--1 ft deep	38.4	0.93	1.93	0.35	6.96	4.0	
AP --initial	40.0	8.65	1.39	0.14	6.72	3.3	
--first good	31.8	1.58	4.62	0.29	7.03	3.8	12.5
--1 ft deep	39.0	1.74	4.07	0.35	6.70	3.8	
AP + F --initial	39.0	2.30	0.30	0.17	6.75	3.1	
--first good	34.1	1.08	3.92	0.32	6.43	3.8	15.0
--1 ft deep	35.1	1.41	2.77	0.35	6.23	3.9	
F --initial	38.8	1.06	2.41	0.41	7.25	2.5	
--first good	34.7	0.83	1.53	0.35	6.43	3.8	13.8
--1 ft deep	36.3	1.50	2.05	0.44	6.52	3.7	
P --initial	32.6	0.45	1.05	0.20	7.73	3.3	
--first good	31.6	0.43	6.25	0.21	7.09	3.6	8.8
--1 ft deep	36.3	0.53	3.12	0.40	6.67	3.6	

PART 4

EFFECT OF ORGANIC ACID TREATMENT ON HMEC WITH AND WITHOUT UREA

INTRODUCTION

High moisture ear corn (HMEC) feeding is one of the most economical ways of feeding grain to cattle. However, HMEC is low in protein content and should be supplemented in order to be fed as the sole source of grain. Urea supplementation could be the answer; but urea degradation after addition to HMEC is high (Schmutz *et al*., 1962) and the resulting ammoniacal odors are offensive to cattle. Therefore, an additive to decrease this degradation would be beneficial.

In addition to the low protein content, intakes of untreated HMEC are often lower than those observed on other grains. It has been suggested that a poor fermentation characterized by a large amount of proteolysis is responsible for the poor intakes. A possible way to depress this undesirable fermentation might be the addition of organic acids.

Therefore, a study was initiated to determine the effectiveness of various acids in improving the acceptability by dairy animals of the urea-treated-HMEC.

MATERIALS AND METHODS

Trial I

High moisture ear corn averaging about 53% DM was ground through a Fox silage chopper fitted with 5 cm screens, treated with acid, and ensiled in small 1.2 x 3 m silos. The treatments were: control, 0.5% formic acid, 2% Pro-Sil, and 0.5% formic acid plus 0.5% urea. Acids were diluted to 20% with water. Twenty-four Holstein cows (6 per group) averaging not less than 18 kg of milk/day were used to compare treatments in a randomized block design. The cows received alfalfa haylage ad libitum and soybean meal to meet their protein needs. The HMEC was fed at the level of 1 kg to 2.5 kg of milk. The experimental period was for four weeks which followed a two-week standardization period. The HMEC was sampled three times weekly, composited on a weekly basis and analyzed as described for silages. Feed intakes and milk yields were recorded. A daily composite milk sample was taken biweekly for composition analyses.

Trial II

In the second trial, HMEC (63-65% DM) was ground, treated and stored as described in the previous trial, but several acids were compared (Table 48). Thirty-six Holstein cows averaging not less than 18 kg of milk/day were alloted to the six different treatments according to a randomized block design. Blocks were assigned on the basis of milk yields during a 2-week standardization period when all cows were fed the grain ad libitum. During the experimental period (3 weeks), cows were fed 1 kg HMEC to 2 kg milk. Alfalfa haylage was fed ad libitum for all five weeks. Milk yields and feed intakes were recorded daily. Milk and feed were sampled and analyzed as in the previous trial. In addition, daily temperatures during the feeding trial were recorded in corn receiving the different acid treatments.

RESULTS AND DISCUSSION

Trial I

The results of this study are given in Tables 46 and 47. Total nitrogen content was higher on the urea or Pro-Sil treated HMC, 3.18 and 2.95% of the DM, respectively. Also, high NPN was observed on these treatments. Corn treated with formic acid alone or the formic acid plus urea HMEC had slightly lower pH values than control or Pro-Sil treatments. Formic acid treatment with or without urea depressed lactic acid production, as reported previously in this thesis and by Huber *et al*. (1972). Pro-Sil treatment resulted in the highest lactic acid concentration (4.25% of the DM); which is in agreement with the literature that ammonia treatment of silages resulted in higher lactic acid concentrations. These results are also in agreement with those reported by Otterby and Murphy (1971) on lower concentrations of lactic acid on treatments with 1% urea + 1% acetic acid or 1% acetic or propionic acids than the control. Therefore, the lower concentrations of lactic acid on formic acid treated HMEC could be related to inhibitory effect of this strong acid on micro-organisms thus resulting in depressed fermentation.

Milk production and persistency, milk butterfat and feed intake values are shown in Table 47. High moisture ear corn intake was higher on the formic plus urea treatments compared to other treatments. However, differences were not statistically significant ($P > .05$). Also, silage DM intakes did not differ between treatments ($P > .05$).

The average milk production and persistencies for the 4-week experimental period were not significantly different ($P > .05$) among treatments but were slightly higher on the formic acid plus urea than other groups. Butterfat content was not affected by the HMEC treatments ($P > .05$). However, highest fat percentage (3.7%) was observed on the formic acid treatment.

The formic acid treated HMEC with or without urea were apparently consumed as well as the control or Pro-Sil treatments. However, differences in palatability of the rations were not detected because intake was limited to 1 kg/2.5 kg milk. The primary concern at the beginning of the trial was whether the cows would readily consume the HMEC treatments, which they did. It was thought that ad libitum feeding might depress appetite and milk yields and make interpretation of differences very difficult. Our findings agree with reports indicating no effect on palatability due to propionic acid treatment of high moisture corn (HMC). The small differences in butterfat percent between treatments are in agreement with a recent report by Jones (1972), who concluded that depression in fat percent is not caused by feeding acid treated HMC as the only cereal grain.

The results of this study indicate that formic acid (0.5%) can be used on HMEC (54% DM) without adverse effects on feed intake, milk production, and milk fat percent.

Trial II

The HMEC used in this trial averaged 66% DM. Urea-treated HMEC was higher in crude protein (Table 48) than when no urea was added. Also, urea treatment doubled the NPN in HMEC. The higher level of crude protein in the formic-treated HMEC is difficult to explain. It might have been due to application or sampling errors, but this is doubtful. Perhaps the formic acid was more effective in decreasing proteolysis and nitrogen losses, but this was not reflected in a lower NPN content.

The pH was determined during the feeding trial and Pro-Sil treatment had the highest pH (7.0), while the lowest pH value was on the control treatment without urea. This observation indicates that the low level of acid used in this study was not sufficient to compete with high buffering effect of 1% urea. The pH values on the different treatments were not much higher than those found by Jones (1970) to inhibit mold formation and spoilage of HMC.

Acetic acid was the only VFA detected on the different HMEC samples. The highest level of acetate was found in the acetic treated material, indicating that greatest fermentation had occurred on this treatment. The propionic acid treatment had the highest lactic acid concentration, followed by the urea and the acetic acid treatments. Formic acid depressed lactic acid production, which agrees with findings of the previous trials. However, contrary to what was observed before, Pro-Sil treatment in this study depressed lactic acid production probably because of the high levels used (3.6% on a fresh basis).

Milk production, persistency, milk composition and feed intake are given in Table 49. Differences in milk production among treatments were not significant ($P > .05$). However, persistency of milk production during this study was highest on the urea treatment followed by acetic acid with the propionic acid group the lowest. These differences in milk yields might be related to differences in HMEC intakes which were also lower for cows fed propionic-treated HMEC.

Butterfat percentages were not affected on acid treated HMEC; which is in agreement with the observation of Jones (1972). Neither differ in milk protein or SNF between treatments, which is also in agreement with the findings of Jones (1970), when he compared acid treated and untreated HMC.

The combination of acid plus urea treatment of HMEC did not adversely effect the intake or production of animals. However, HMEC intake was highest on control treatment without urea and lowest on the propionic acid-urea treatment, even though differences among treatments were not significant (P > .05). Cows fed the propionic acid treated HMEC also ate less alfalfa haylage even though differences were also not significant (P > .05). These observations are in apparent contrast to those reported by Marion _et al_. (1972), and Bridson (1972), who noted more gain and better efficiencies in steers fed acid treated compared to control HMC. However, more data is needed to establish this effect because none of the differences were significant and the duration of the trial was quite short.

The changes in temperature are given in Table 50. The acid treatments had the lowest temperature during the last week of standardization period and also during the three weeks of the experimental period. The lower temperatures on the acid treatments suggests less chances of spoilage or mold development. Therefore, less proteolysis and better preservation might be expected over an extended feeding period.

The results of this short feeding trial are in agreement with those of the previous trial indicating that acid treatment of HMEC did not adversely affect the performance of lactating dairy cows.

TABLE 46

DRY MATTER, NITROGEN, NPN, pH AND LACTIC ACID CONCENTRATIONS OF HMEC AS INFLUENCED BY ACID OR NPN TREATMENT (PART 4, TRIAL I)

Treatment	DM	Total Nitrogen	NPN	Lactic Acid	pH
	--------------% Dry Matter---------------				
Control	53.22	2.54	0.65	2.92	4.0
Prosil (2%)	55.30	2.95	0.78	4.25	4.3
Formic (0.5)	53.70	2.48	0.66	1.94	3.9
Formic (0.5) + Urea (0.5)	53.52	3.18	0.91	1.83	3.8

TABLE 47

MILK PRODUCTION, PERSISTENCY, BUTTERFAT AND FEED INTAKE OF COWS FED VARIOUS HMEC TREATMENTS (PART 4, TRIAL I)

Treatment	Milk Yield[b]	Persistency[ab]	Fat[b]	HMEC[b] Intake	Silage[b] Intake
	kg/day	%	%	kg DM	kg DM
Control	18.8	87.3	3.3	4.5	5.9
Prosil (2%)	19.6	90.3	3.4	4.3	5.3
Formic (0.5%)	19.2	89.4	3.7	4.5	5.3
Formic (0.5%) + Urea (0.5%)	20.6	92.4	3.2	4.7	5.7

[a] $\frac{\text{Treatment}}{\text{Standardization}} \times 100$

[b] None of the differences between treatments were significant ($P > .05$).

TABLE 48

CHEMICAL COMPOSITION OF HMEC TREATED WITH NPN AND ORGANIC ACIDS (PART 4, TRIAL II)

Treatment*	DM	Protein	NPN	Acetic Acid	Lactic Acid	pH
	------------------	% Dry Matter	------------------			
(0.7) F + U	64.84	14.03	0.69	0.34	0.74	4.6
(3.6) Prosil	67.41	11.42	0.60	0.69	0.73	7.0
(0.6) A + U	67.90	12.06	0.69	3.30	1.31	4.4
(0.6) P + U	61.80	11.35	0.72	0.11	1.52	4.6
(1.0) U	67.58	12.22	0.74	0.42	1.38	5.6
Control	68.53	9.07	0.35	0.11	0.99	4.3

*Acid treatments contained 1% urea.

TABLE 49

MILK PRODUCTION AND PERSISTENCY, MILK COMPOSITION AND FEED INTAKE OF COWS FED VARIOUS HMEC TREATMENTS (PART 4, TRIAL II)

Treatment	Milk[b]	Persistency[ab]	Butterfat[b]	SNF[b]	Milk Protein[b]	HMEC[b]	Alfalfa Haylage[b]
	kg/day	%	%	%	%	kg DM	kg DM
(0.7) F + U	19.6	93.90	3.5	8.99	3.04	6.5	10.1
(3.6) Prosil	18.1	93.22	3.4	8.86	2.87	6.3	10.8
(0.6) A + U	19.7	96.44	3.3	8.86	2.76	7.0	8.6
(0.6) P + U	17.6	91.90	3.3	8.96	2.82	5.9	8.2
(1.0) U	19.6	97.73	3.2	9.00	2.90	6.7	9.5
Control	19.1	94.59	3.2	9.01	2.68	7.4	9.6

[a] $\frac{\text{Treatment}}{\text{Standardization}} \times 100$

[b] None of the differences between treatments were significant ($P > .05$).

TABLE 50

TEMPERATURES OF HMEC TREATED WITH NPN AND ORGANIC ACIDS
(PART 4, TRIAL II)

Treatment	Weeks			
	1*A	2A	3B	4B
	C			
(0.7) F + U	28.2ab	34.7ab	35.7ab	34.1ab
(3.6) Prosil	32.0b	32.2b	43.7b	40.1b
(0.6) A + U	23.9a	26.3a	33.8a	36.6a
(0.6) P + U	28.7ab	33.3ab	37.0ab	38.3ab
(1.0) U	31.1b	33.2b	41.2b	40.7b
Control	35.6b	32.9b	43.0b	41.9b

*Standardization period.

A,B,a,b Values not sharing a common superscript are statistically significantly different ($P < .05$).

SUMMARY AND CONCLUSIONS

Experiments were conducted to determine the effect of organic acids on preserving forages left under minimal protection conditions.

Chopped rye forage ranging from 27-35% DM was used in experiment I. Acid levels varied from 0.25-1.5% (on wet basis) as single additions or mixtures. In trial I, the control treatment molded within 3 days after harvest. Also, a peak in temperature (54 C) on the control occurred by the third week after harvest which corresponded to a peak in pH. The 1% formic acid treatment was the last to spoil (14 days) and the 1% AP spoiled by 9 days. Dry matter recoveries were 83, 78, and 57%, respectively for the AP, formic and control treatments. Changes in temperature were directly correlated to amount of molded DM (+0.98). A high correlation was also obtained between pH and temperature (+0.98), and between pH and amount of molded DM (+0.92). Formic acid inhibited organic acid formation more than AP treatment and the control forage contained highest concentrations of butyric acid. Negative correlations were obtained between VFA concentrations and temperature (-0.46) and VFA and amount of molded DM (-0.61). Differences in protein and NPN contents among treatments were not significant (P > .05). Cows consumed 7.9, 7.4, and 9.6 kg of DM/day on control, formic and AP, respectively.

In a second trial using 220 liter drums, best preservation occurred on treatments containing 1.0 and 1.5% mixture of (1F:1AP). This material was readily consumed by animals and correlations followed a trend similar to those observed in trial I. In trial III, a combination of acid treatment and packing was examined in an effort to determine the possibilities of reducing the level of acid needed for good preservation. Correlation again followed a trend similar to those reported above. Propionic acid was superior to formic acid as preservative for minimally protected forages. Packing with acid treatment increased DM recovery even when ensiled material was aerated every week. Changes in ADF and ADF-N were not different among treatments (P > .05). In trial IV, the intake of 0.4% formic acid-treated rye silage, stored in conventional upright silos, were slightly higher than those of control rye (8.3 vs 7.6 kg of DM), but differences were not significant. Also, changes in milk persistencies were in favor of the treated silage.

In experiment II, chopped corn forage (38% DM) was treated with different acids and left unprotected. Similar to the previous observations, the control molded first and had the highest early temperatures. Acetic acid treated forage molded next and propionic acid treatment maintained the lowest temperature throughout the six weeks period and was the last treatment to spoil. The AP, AP + F and formic treatments were intermediate with respect to time of first spoilage detection and increased temperatures. Correlations followed a pattern similar to that observed for rye forage. Formic acid treatment maintained the lowest pH values. However, total organic acid production was higher on the control than on formic and propionic acid treatments. The protein and NPN contents were not affected by the different acid treatments. All corn forages except the acetic acid treatment were fed to heifers (for 5 days) and least intake occurred on propionic acid treatment. However, AP and propionic treatments had the lowest temperatures during the feeding period indicating an inhibition of after fermentation and better preservation if the corn were fed for an extended period.

In the second trial, 51 forages were treated with different levels and combinations of formic, acetic and propionic acids. Treatments containing 1.5, 1.0, and 1.25% propionic acid were the last to spoil. Earlier spoilage was detected as the portion of acetic acid increased.

Experiment III was conducted to determine the effectiveness of acid treatment on peripheral preservation. In trial I, more silage was lost on the control compared to AP treatment (64 vs 23.8%). Addition of propionic to formic decreased the amount of molded DM by 38% when compared to formic alone. Preserved material was fed to lactating cows and intakes of 9.5, 9.4, 8.3, and 9.0 kg of DM recorded for the AP + F, AP, formic, and control treatments, respectively. When high DM (50%) corn silage was used the control treatment resulted in the highest amount of molded DM (90%) and the propionic acid treatment had the least (9.7%), whereas, formic acid resulted in better preservation than AP or acetic acid treatments.

When acids were sprinkled on top layers of horizontal silos (trial II) similar observations to those reported above were observed indicating the superiority of propionic acid as silage preservation even under poor ensiling condition.

Experiment IV was conducted to determine the influence of organic acid treatment on urea-treated HMEC. Formic acid depressed lactate formation, indicating a depression in fermentation. However, the concentrations of lactic were normal when urea was added to formic acid treatment. The urea-formic acid treated HMEC resulted in higher intakes even though differences were not significant ($P > .05$). Also, milk production and persistency and milk composition were not affected by the acid treatments. In trial II, acetic acid-urea-treated HMEC resulted in higher intakes and milk production when compared to treatments with or without urea and treated with propionic or formic acids even those differences were not significant. The control and Pro-Sil treated HMEC had the highest temperatures during the feeding trial.

The results of these studies clearly indicate the superiority of propionic acid over formic and acetic acids or combination of acids as a silage preservative under minimal protection conditions. Propionic acid might be used by farmers to protect silage placed in open silos and allow them to expand their operations with minimal losses even if they lack storage facilities. Presently, farmers avoid open storage because of the high losses. Also, the techniques used in this study could be used by farmers who would rather not treat all their silages but want to avoid peripheral losses. Treatment of the top 10 to 15% of the silage placed in upright silos with 1% propionic acid at the blower will reduce spoilage. For horizontal silos propionic acid application to the one ft of surface material will decrease losses. These data also show that moderate compacting greatly increases the effectiveness of propionic acid in reducing wastage. Thus, less acid would be needed for moderately packed material.

The fermentation characteristics observed in these studies are similar to those reported for acid treated silages. Formic acid addition (1%) to loose forage depressed fermentation and retarded spoilage at least for 7-10 days. The same level of propionic retarded spoilage for about twice as long but did not have a depressing effect on fermentation as formic. Intake of silages by animals was not adversely affected by high acid treatments.

These studies clearly showed a direct relationship of pH to the amount of DM spoiled. Acid treatments, especially formic and propionic acid, resulted in lower pH values and less loss. However, intakes of animals were not depressed by the low pH of the silages.

The results indicate that spoilage can occur if temperatures in forages exceed 35 C. Propionic and formic acids were shown to delay the rises in temperature and therefore protected the forages for longer periods.

The farmer must take extreme precautions when applying these acids. Also, the acids should be applied or sprinkled as uniformly as possible in order to obtain the most desirable response.

Forage was preserved by 1% propionic acid, even under very poor ensiling conditions. However, if material is to be subjected to prolonged periods of rain and weathering, a higher level of acid would probably be needed.

The farmer should still harvest silage at the recommended time and use proper techniques to maximize nutritive value; however, these studies show that acids can be used as a tool to help preserve crops harvested too dry or stored in less than adequate conditions.

In part 3, more spoilage occurred on high DM control than propionic acid treated silage (1.26 vs 0.16 tons of DM). Thus, acid treatment resulted in a net savings of $5.00 assuming the value of silage DM to be $17.00/ton and cost of acid $8.00/ton of silage DM.

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APPENDIX

APPENDIX

TABLE A1

SIMPLE CORRELATION COEFFICIENTS

Part & Trial	Variable I	Variable II	d.f.	r
1, I	Changes in Temperature	Amount of Molded DM	1	+0.98
	Changes in Temperature	Changes in pH	1	+0.98
	Changes in Temperature	Changes in VFA	1	-0.46
	Changes in Temperature	Changes in Crude Protein	1	-0.62
	Changes in Temperature	Changes in NPN	1	+0.82
	Changes in pH	Amount of Molded DM	1	+0.92
	Changes in pH	Changes in VFA	1	-0.29
	Amount of Molded DM	Changes in VFA	1	-0.61
1, II	Changes in Temperature	Date of First Mold Detection	9	-0.93*
	Changes in Temperature	Changes in pH	9	+0.76*
1, III	Changes in Temperature	Amount of Molded DM	5	+0.53
	Changes in Temperature	Amount of Invisible Loss	5	+0.69
	Changes in Temperature	Changes in pH	5	+0.37
	Changes in pH	Amount of Molded DM	5	+0.13
	Changes in pH	Amount of Invisible Loss	5	+0.29
2, I	Changes in Temperature	Date of First Mold Detection	4	-0.81*
	Changes in Temperature	Amount of Molded DM	4	+0.40
	Changes in Temperature	Changes in pH	4	+0.11
	Changes in pH	Date of First Mold Detection	4	-0.46
2, II	Changes in Temperature	Date of First Mold Detection	49	-0.54*
3, II	Changes in pH	Amount of Molded DM	3	+0.66

*($P < .05$).