THE CHEMISTRY, BACTERIOLOGY, AND NUTRITIVE VALUE OF ENSILED HIGH-MOISTURE GROUND EAR CORN

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William G. Schmutz

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By

William G. Schmutz

AN ABSTRACT OF A THESIS

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ABSTRACT

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During a two-year period, ground ear corn at varying moisture levels was ensiled with the addition of different compounds. Ammonical-N, urea, pH, organic acids, ethyl alcohol, and crude protein were determined over a 60-day fermentation period. The total counts, lactobacilli, yeasts, molds, and anaerobic counts were followed using six silages. Temperature studies were included in one study.

Following the 60-day fermentation period, the silages were fed to growing dairy heifers. Weight gains, feed fed, and rejections were recorded on each heifer. Correlation analysis was conducted using the silage quality measurements and animal performance data.

Silages with 20 pounds of urea per ton increased in pH throughout the fermentation period. With 15 pounds of urea per ton, this effect was not noted. The silages containing 20, 15, and 0 pounds of added urea had an initial pH of 4.7, 6.0, and 6.3; but following 60 days fermentation the pH had changed to 7.4, 5.1, and 5.2. In

a second trial there was a depression ($P < 0.01$) of pH with high moisture and with the addition of one percent monobasic calcium phosphate. In a third trial, 40 and 34 percent moisture silages depressed the pH ($P < 0.01$) as compared with 24 percent moisture silages.

There was no direct pattern for butyric and propionic acid production in individual silos; but there was a tendency for more butyric and propionic acid production in the higher moisture silages (34-45% moisture). One percent monobasic calcium phosphate reduced the concentration of these two acids at higher moisture levels. In all three trials, acetic and lactic acids were significantly higher at the higher moisture levels. Lactic acid increased and acetic acid decreased with the addition of one percent monobasic calcium phosphate.

In general, 50 percent of the urea was broken down within 20 days and 80 percent within 60 days. Monobasic calcium phosphate depressed ($P < 0.01$) the rate of breakdown of urea in one of two trials. There was an increase ($P < 0.01$) in crude protein with additions of 20 pounds of urea. In two trials there was a slight increase ($P < .23$, $P < .25$) in crude protein with the higher moisture silages. This effect was not noted in a third trial.

The ethyl alcohol content of the silages was increased in the higher moisture silages. The average content was 0.2 percent.

The total microbial counts were within the same log range for 40, 34, and 24 percent moisture silages. The mean log counts of Lactobacilli from the 45- and 60-day samples for 40, 34, and 24 percent moisture silage were 8.3, 8.6, and 7.9, respectively. Yeast counts increased and anaerobe counts decreased with decreasing moisture.

With the exception of one growth study, there were no significant differences in weight gains when ensiled ground ear corn (24-45% moisture) was compared to ground dry corn. One percent monobasic calcium phosphate increased gains by 19 percent. In two growth studies, animals fed the wetter silages (34-45% moisture) required less ($P < 0.05$, $P < 0.25$) dry matter per pound of gain. Similarly heifers fed the wetter silages consumed less ($P < 0.01$) dry matter per day than heifers fed the drier silages.

Correlation coefficients between average daily gain and silage quality measurements showed a negative correlation with 30-day acetic acid, 10-day pH, and 60-day pH, and a positive correlation with 60-day lactic acid.

Fermentation losses in the silage averaged three to six percent regardless of the moisture level.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

One of the big problems facing the corn grower and the livestock feeder is harvesting his crop. In the corn belt states and especially in the northern sections of the country, the weather interferes with the corn harvest. A method for preserving the nutritive value of corn when harvested before full maturity is needed. This can be accomplished by artificial drying; however, the cost is prohibitive. In the last five to ten years, experimental work has been undertaken at several state universities and experiment stations on the ensiling of high-moisture corn as a method of harvesting and storing. The following advantages have been given: (1) Corn may be stored even though the moisture is too high for cribbing; (2) Corn may be harvested at the convenience of the farmer; (3) Increased yields may be obtained due to less shattering during harvesting. Similar advantages that could be stated are a minimum of operations and equipment, lower cost, rodent free storage, simplified mechanical feeding, and if moist corn is utilized, it permits timely cultivation of the soil for the ensuing crop.

The previous work dealing with high-moisture corn has been mainly on the nutritive value of this fermented product as it pertains to the feeding of beef cattle, sheep, swine, and to a lesser extent, dairy cattle. Only a small fragment of the work has dealt with the actual fermentation processes which ear corn undergoes when it is ensiled.

The data presented in this manuscript deal with some of the chemical processes and transformations that occur in this ensiled product along with some of the bacterial populations and species that are present in the silage. Finally, data will be presented on feeding trials to illustrate the nutritive value of the ensiled product.

REVIEW OF LITERATURE

It was stated in the introduction that a large volume of the experimental work dealing with high-moisture corn concerns the nutritive value of this product when fed to species of animals other than dairy cattle. Few studies have included chemical or bacteriological data on the ensiled product. Most of these studies have included additives in the silages such as calcium carbonate, limestone, tetraalkylammonium stearate, yeasts, and 3-nitro-4-hydroxyphenylarsonic acid. From this collection of data much has been learned.

Nutritive Value of High-Moisture vs. Low-Moisture Corn in Different Species

High-moisture corn has been utilized to the greatest extent by the portion of farmers that deal mainly in a meat product since the consumption of corn normally leads to an increase in body fat. Since this is the case, a large volume of the work is from experiments using animals normally used for meat and meat products.

Beef Cattle

Most of the research on high moisture corn has been done in the past five to ten years. However, Rusk and Snapp (1924) were possibly the very first to see the value of harvesting and storing soft corn as an ensiled product. Starting as early as 1916, they conducted six experiments involving the use of ear corn silage. In all but one of these six experiments, the cattle made satisfactory gains on all forms of soft corn. The most extensive study was consummated in the fall of 1924 when the Illinois experiment station fed four forms of soft corn, namely: shocked corn, standing corn pastured in the field, broken ear corn (mature corn), and ear corn silage. The soft corn ranged in moisture from 37 to 45 percent. Since the 80-day experiment was to be conducted under adverse weather conditions, 72 western-bred Hereford steers weighing approximately 1,000 pounds each were used. Alfalfa hay and linseed meal were included in the rations. One group fed ear corn silage also received oats. The authors report that while satisfactory gains were made by all lots of cattle, the mature corn produced the most rapid gains. They felt that this difference was due to a larger consumption of dry matter rather than to any difference in the quality of the dry matter. When the corn was calculated on an equivalent moisture basis, the cattle fed soft corn made the best showing with the exception of the ones fed soft corn standing in the field. Further, Rusk and Snapp (1924) reported that the largest gains produced per acre were made by steers receiving ear corn silage, leading them to conclude that the use of ear corn silage is the most economical method of utilizing soft corn.

Hansen *et al*. (1959a, b) fed beef cattle high-moisture shelled corn stored at 24, 29, and 36 percent moisture with a control group receiving corn at 14.5 percent moisture. Using 44 yearling beef heifers, results showed that the corn at 24 and 29 percent was equal to dry corn in feeding value. Heifers fed 36 percent moisture shelled corn consumed about two pounds less (14.5 percent moisture basis) per day thus resulting in slower and less efficient gains. The feed per one hundred pounds of weight gain for the 18, 24, 29, and 36 percent moisture shelled corn groups were 686, 684, 681, and 740 pounds, respectively, while the average daily gains for these groups were 1.89, 1.90, 1.91, and 1.51 pounds per day, respectively.

Beeson (1958) compared ground ear corn at 32 percent moisture and 18 percent moisture dry corn in the first of two feeding trials and ground ear corn at 33 percent moisture and 16 percent moisture dry corn in his second feeding trial using steers and heifers. In his first trial, four groups of ten steers averaging 952 pounds were used. Two groups were given 100 mg. of Terramycin in their rations daily. The average daily gains for the two groups receiving dry corn and those receiving high-moisture corn were 2.34 and 2.52 pounds per day, respectively. This difference was not statistically significant. There was a 12 to 15 percent savings in pounds of corn per pound of gain for those steers receiving high-moisture corn. In the second trial there was no significant difference in daily gains; but the heifers fed high-moisture corn required 10 percent less corn to produce a pound of gain. Beeson (1958) also found that the daily dry matter consumption of ground ear corn silage was less than dry corn.

Klosterman et al. (1961a) attempted to increase the organic acid content in ear corn silage by adding 1.0 percent high calcium, ground limestone, and water to alternating loads of corn. Untreated ear corn was ensiled in the same silo using a plastic sheet to separate the individual silages. These two silages were fed to nine groups of seven Hereford steers randomly assigned into weight groups. Three lots were fed the limestone-water treated high-moisture ear corn silage, three lots the untreated high-moisture corn silage, and three lots the dry corn. All lots were fed salt and minerals, good quality clover-timothy mixed hay and soybean oil meal. The corn was full-fed according to appetite. During the 224-day trial, the average daily gains for the treated ear corn silage groups, the control ear corn silage groups, and the dry corn groups were 2.07, 1.81, and 1.88 pounds per day, respectively. When the three forms of corn were converted to an equal dry matter basis, each group of animals consumed an average of 10.2, 9.7, and 11.2 pounds per day, respectively. Therefore, the steers fed the treated ear corn silage required less feed per unit of gain. These results were in general agreement with the results of Beeson (1958).

Klosterman et al. (1961b) compared high-moisture ground ear corn treated with 0.5 percent high calcium ground limestone, 0.5 percent urea, and additional water to yield a moisture content of 48 percent, with untreated ear corn silage at 43 percent moisture. Soybean oil meal at two levels, 0.75 and 1.5 pounds, were fed with the treated and untreated silages. The daily gain of steers fed the treated silage was 0.12 pounds more per head than the cattle fed the untreated silage in a 195-day feeding trial. When the two levels of soybean oil meal were considered, the two groups of steers receiving the treated silage plus 0.75 pounds of soybean oil meal gained an average of 2.2 pounds per day while the steers fed the control silage plus 0.75 pound of soybean oil meal averaged 2.0 pounds per day. When 1.5 pounds of soybean oil meal was fed with the treated and control silages, there was little difference in the average daily gains for the four groups which were 2.06, 2.13, 2.12, and 2.03 pounds per day, respectively. The author felt that the results indicated that additions of urea, limestone, and water to ear corn silage increased the organic acids in the silage, and that urea may replace a part of the protein supplement needed.

Beeson et al. (1958) also studied the use of plant proteins and urea in feeding experiments with high- and low-moisture corn. Linseed meal and soybean meal were used as sources of protein in the "Purdue Supplement A." Five percent urea was also studied as a replacement in the supplement. They reported that beef heifers fed regular crib corn at 24 percent moisture gained slightly more than heifers fed ensiled high-moisture corn at 37 percent moisture, though the differences were not significant. On an equivalent moisture basis, the heifers on the ensiled high-moisture corn required 4 percent less feed per unit gain and consumed 1.0 pound less per head daily. The substitution of linseed meal for an equivalent amount of soybean meal did not give a consistent effect on rate of gain, while the substitution of 5 percent urea for either soybean or linseed meal on an equivalent basis resulted in gains equal to soybean or linseed meal as the principal source of protein in the supplement. In this study, urea was not a direct additive in the silage, but was fed with the silages, thus increasing its utilization as a protein source since there was no chance of its degradation in the fermentation processes. Van Arsdell et al. (1953) reports similar results when corn silage was supplemented with soybean oil meal and urea.

Supplemental protein sources have not been the only compounds used to increase the value of high-moisture corn. Stilbestrol, "Dynafac" (20 percent tetra alkylammonium stearate plus 80 percent bone meal), "3-nitro" (4-hydroxyphenylarsonic acid), antibiotics, and Torula yeast have been fed with high-moisture corn to study their bactericidal and gain-stimulating properties.

Culbertson et al. (1957) used seventy-two 800-pound yearling steers in a 119-day study to determine the nutritive value of high-moisture corn. Six pens of six steers each received full feed of low-moisture (14.5 percent) corn, and six pens received a full feed of high-moisture (31 percent) ground ear corn. In addition, the steers received 3 pounds of alfalfa hay and one pound of supplement per animal daily. The supplement varied only with respect to the presence or absence of Stilbestrol, "Dynafac," and "3-Nitro." The feeding results showed that the six lots of cattle receiving high-moisture corn made almost as much daily gain on 10 percent less corn (14 percent moisture basis) as the six similar lots of cattle receiving low-moisture corn. The average daily gains for the low-moisture and high-moisture groups were 3.05 and

2.98 pounds per day, respectively, while the total feed per 100 pounds gain on a 14 percent moisture basis was 889 and 819 pounds, respectively. This resulted in an 8 percent savings in feed costs in favor of high-moisture corn. High-moisture corn plus Stilbestrol resulted in a savings of 16 percent in feed costs. "Dynafac" and "3-Nitro" failed to stimulate live-weight gains or reduce feed costs.

Beeson et al. (1957) in an experiment closely related to that of Culbertson et al. (1957) compared high-moisture (32.5 percent) and low-moisture (15.5 percent) corn with additions of 0.10 pound of Torula yeast and one gram of "Dynafac" per heifer per day. "Purdue Supplement A," hay, and minerals were fed. "Dynafac" and Torula yeast did not significantly increase daily gains, but the 32.5 percent moisture corn improved feed efficiency when fed in addition to the "Dynafac". When "Dynafac" was fed with low-moisture corn, the reverse was true. It was also shown that on the same moisture basis the heifers on the 32.5 percent moisture corn required 10 percent less corn and consumed less dry matter to produce a pound of gain. These results are in general agreement with the results of (Culbertson et al., 1957; Beeson, 1958; and Klosterman et al., 1961a).

Further information on the nutritive value of high-moisture corn has been gained with the use of antibiotics

(Beeson *et al.*, 1956). Terramycin was fed with 32 percent moisture corn and regular dry corn at 18 percent moisture in a study to analyze the nutritive value of these three. The steers fed the high moisture corn gained somewhat faster (0.13 to 0.23 pounds per day); but this increase was not significant. Also, these cattle required 12 to 15 percent less corn to produce a pound of gain. Terramycin did not improve the daily gains or feed efficiency on these high energy rations.

Sheep

Cline *et al.* (1960) used dry matter digestibility and nitrogen retention to measure the feeding value of high-moisture ground ear corn as compared to high-moisture shelled corn and field-dried shelled corn. An equivalent amount of cobs was added to the latter two forms of corn. These rations were fed to three groups of lambs (Hampshire-Suffolk X Western) averaging 83 pounds with each ration containing the same dry matter content. The apparent digestion coefficients in dry matter, percent nitrogen, and in nitrogen retention were lowest for the three groups of lambs on the high-moisture ground ear corn. The lambs fed the field-dried shelled corn were the high group, and the ensiled shelled corn group was intermediate. There was no significant difference in the apparent digestibility and nitrogen retention among the lambs receiving the field-dried shelled corn and those receiving ensiled high-moisture shelled corn. Hansen et al. (1959a, b) found similar results with shelled corn stored at different moisture levels.

Benjamin and Jordan (1960), also using feeder lambs, conducted three trials in which shelled corn and ground ear corn were stored using three methods of storage: (1) ensiling, (2) drying and ensiling, (3) drying only. When these products were fed to 175 feeder lambs, neither the shelled corn nor the ground ear corn, when ensiled, increased in nutritive value for feeder lambs. Gains were less with the ear corn ration than with the shelled corn ration. It was also reported that within a main treatment neither drying nor ensiling was found to have a significant effect on average daily gains, and ensiling corn which had been previously dried and then re-wetted to 35 percent moisture did not cause a significant change in the nutritive value.

In a current report from the Missouri Agricultural Experiment Station, Ross and Rea (1959) used 64 ewe and 56 wether lambs in comparing the feeding value and yield of corn from the same field when harvested at 27.5 percent and 15.5 percent moisture. There were no significant differences in gains of the lambs fed high moisture or dry corn, but the wethers on the 27.5 percent moisture in the apparent digestibility and nitrogen retention among the lambs receiving the field-dried shelled corn and those receiving ensiled high-moisture shelled corn. Hansen et al. (1959a, b) found similar results with shelled corn stored at different moisture levels.

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Swine

Beeson and Conrad (1958) fed low-moisture shelled corn (12 to 19 percent moisture) and ensiled high-moisture shelled corn (26 to 32 percent moisture) to Duroc weanling pigs averaging 32 to 40 pounds. In two of the three feeding trials, pigs fed the high-moisture shelled corn gained from 3.0 to 4.9 percent faster but required 8 percent more feed on an equivalent moisture basis per 100 pounds of gain than pigs fed low-moisture shelled corn. In the third trial, both low- and high-moisture corn groups gained the same, but after 70 days on experiment, the high-moisture corn fed pigs had required 14 percent more corn on an equivalent moisture basis. The authors concluded that there was no improvement in the nutritional value of the corn from ensiling it at a higher moisture. Hansen et al. (1959a, b) fed shelled corn at 25, 30, and 35 percent moisture to swine and found that the three moisture levels were inferior to dry corn.

Dairy Cattle

Zogg et al. (1961) compared shelled corn harvested at 22, 26, and 32 percent moisture in various combinations with oat, corn, and sorghum silages. Nine Brown Swiss and 18 Holstein cows were used in a combination split-plot and switch-back design. There were no significant differences between cows of varying productive capacity in the amount of dry matter consumed, but when grouped according to the silage fed, the cows fed oat silage consumed less dry matter than did the cows on either corn or sorghum silage. This relationship held true when the cows were fed silages with rations containing 22, 26, and 32 percent moisture corn. Generally, the cattle on the 32 percent moisture corn started at a lower rate of milk production, but their persistency was greater throughout the trial. The average decline in F.C.M. (4 percent fat-corrected milk) per cow during the

5-week experimental period for the 32, 26, and 22 percent high-moisture corn was 11, 15, and 16 pounds, respectively. When the entire 21-week trial was considered, the F.C.M. production for the 22, 26, and 32 percent moisture corn groups was 801.1, 838.5, and 871.9 pounds per day, respectively; while the weight changes for these groups were -54, -36, and +3 pounds per cow per period. Hansen et al. (1959a, b), in a similar study, presented results stating that shelled corn at 25, 30, and 35 percent moisture was not superior to dry corn for milk production.

Lassiter et al. (1960) stored high-moisture corn grain and ear corn in a two-year study. In 1957 ground shelled corn was stored at 26 and 40 percent moisture and ear corn at 36 percent moisture. In 1958, ground ear corn, ground shelled corn, and unground shelled corn were stored at 32 percent moisture. The corn was harvested at 40 percent moisture and dried to the desired moisture level before grinding. Dried corn, used as a control, was dried to 14 percent moisture.

When these forms of high-moisture corn were fed to milking cows, the performance of all groups was quite satisfactory, and the feeding value of the high-moisture corn was comparable to that of dry corn. In 1957, the high-moisture and dry corn gave better results than the 40 percent ground shelled corn. The cows on the shelled corn produced less total 4 percent F.C.M. and showed a greater decline in 4 percent F.C.M. as well as less gain in body weight. From these results, the authors concluded that based on a dry matter content, the feeding value of the soft corn appeared to be equal to, but not greater than, that of dry corn. These results on nutritive value for milk production and weight gains correspond to the results of Zogg et al. (1961) who found a greater nutritive value for 26 and 32 percent moisture shelled corn than for lower moisture soft corn.

Hansen et al. (1959a) stored shelled corn at 25, 30, and 35 percent moisture when 24 Holstein heifers were studied. Corn at 14.0 percent moisture was used as a control group. The average daily gain and feed efficiency (pounds of D.M. per pound of gain) for the 14, 25, 30, and 35 percent moisture corn groups were 1.66, 1.37, 1.49, and 1.44 pounds per day and 8.7, 10.5, 9.7, and 9.9 pounds of dry matter per pound of gain, respectively.

The authors felt that the growth response obtained from these heifers did not indicate that high-moisture shelled corn was superior in feeding value to regular dry corn. In another report, Hansen et al. (1959b), similar conclusions were presented.

The studies of Zogg et al. (1961) and Lassiter et al. (1960) represent the only studies in which any form of high-moisture corn was fed to lactating dairy animals. The studies of Pratt and Rogers (1956) are concerned with the nutritive value of high-moisture corn when fed to growing dairy heifers. Corn ensiled at 54 percent dry matter and containing 5.1 percent protein was used in three different feeding trials. In their first trial eight Jerseys averaging about 750 pounds were fed mixed hay, grass-legume silage, and six pounds of ear corn silage. During a 12-week trial these heifers gained 1.12 pounds per day. In their second trial, seven yearling Holsteins and Jerseys averaging 763 pounds were fed 5 pounds of ear corn silage plus grass silage, soybean oil meal, and hay to appetite for 129 days. A control group was fed similarly except they received 3 pounds of grain equal in dry matter content to the 5 pounds of ear corn silage. The heifers on the ear corn silage gained as much as the control group in this trial. Similar results were obtained in a third trial.

One report by Cabell _et_ _al_. (1962) was found in which rats were used. Nine different types of high-moisture corn from four farms located in the corn belt were taken representing three types of silos: (1) gas tight, (2) concrete stave, (3) wood stave. A good sample and a poor sample were taken from each silo and dried for 24 hours. The dried samples were ground and mixed into diets containing equal amounts of nitrogen. Weanling rats were fed the diets in a 21-day assay test. The mean weight gain for rats on a crib-dried control corn was 72.4 grams as compared to 75.8, 73.6, and 78.4 grams for good samples of high-moisture corn from gas tight, concrete stave, and wood stave silos, respectively. There was no significant loss from the different types of silos. The poor samples all produced lower weight gains than the corresponding good samples; and the poor sample from the gas tight silo was significantly lower.

In all the studies with beef cattle, the rate of gain was not significantly greater for either high- or low-moisture corn; but it has been clearly brought out by Beeson _et al_. (1956), Beeson _et al_. (1957), Culbertson _et al_. (1957), Beeson _et al_. (1958), Beeson (1958), and Klosterman _et al_. (1961a) that cattle require from 4 to 15 percent less feed per unit of gain when fed high-moisture corn. Studies with sheep show similar results. With swine, gains are somewhat variable but in all cases less efficient with high-moisture shelled corn. Lactating dairy cows appear to make efficient use of high-moisture corn ; and a moisture range of 25-35 percent is the optimum range for production. Dairy heifers gain equally well when fed high-moisture corn or dry corn.

Urea, Calcium Carbonate, Calcium Phosphate, and Phosphoric Acid as Silage Additives: The Nutritive Value of Additives in Silage Urea

Urea as a protein sparing agent in livestock feeds has been studied by a multitude of researchers. Since the addition of urea to soft corn silage is a minor subject in this thesis, a short review of the more pertinent studies will be given.

I. The Utilization of Non-Protein Nitrogen Sources

Dyer (1961) states that with increased grain feeding resulting in a decreased roughage consumption, protein could be a limiting nutrient in livestock rations. Urea offers one of the best ways of increasing protein intake under these conditions. Reid (1953) reviewed the current research dealing with urea utilization and its effect as a protein-sparing compound.

Two factors in the composition of the ration, available carbohydrate and level of protein, affect the optimum utilization of urea. Mills et al. (1942) studied the presence of available starch on the utilization of urea using a three-week adjustment period, six rations, and a fistulated animal. The rations were as follows: (1) Timothy hay, (2) Timothy hay (10 pounds) plus 4 pounds corn starch, (3) Ration 2 plus 150 grams of urea, (4) Timothy hay (10 pounds) plus 150 grams of urea, (5) Timothy hay (10 pounds) plus 4 pounds starch plus 0.4 pounds casein, (6) Ration 5 plus 150 grams urea. The ration of Timothy hay, starch, and urea produced a 57 percent increase in protein utilization, but when casein was added to this ration, the utilization of urea was markedly reduced suggesting that casein is preferred over urea as a nitrogen source by the rumen microbial population. Gallup et al. (1953a), Gallup et al. (1953b), and Reid (1953) make similar reference to the value of starch for optimum utilization of urea.

The level of protein in the ration also affects the efficiency of urea breakdown. Wegner et al. (1941) used a fistulated heifer fed corn silage, Timothy hay, and a basal grain mix varying only in the levels of urea and linseed oil meal. When the level of protein in the concentrates was increased to 24 percent, the protein content in the rumen increased; however, when the level of protein of the rumen contents became greater than 12 percent, the rate of conversion of urea to protein decreased, showing that there is an optimum protein level for the most efficient use of urea. Johnson et al. (1942) and Reid (1953) report similar results.

While the two factors previously reported will give optimum utilization of urea, Reid (1954) states that in a number of experiments in which urea provided from

40 to 70 percent of the nitrogen needed by calves, four months or older, the body weight gains were 82 to 88 percent of that of calves fed rations with an equivalent amount of nitrogen in the form of high protein feeds. Thus, in most cases urea is somewhat inferior to conventional protein supplements as a source of nitrogen for growth. Bartlett and Cotton (1938), using seven to seventeen month old calves, showed similar results when a urea supplemented diet was compared to a normal protein diet. Frye _et_ _al_. (1954) fed a 12.5 percent crude protein concentrate in which urea and ammoniated molasses replaced 30 percent of the cottonseed meal to 24 Holstein and nine Jersey heifers averaging 22-30 months in age. Twenty-five pounds of corn and soybean silage and three pounds of chopped grass hay were included in the ration. Preliminary analysis of the results indicated that urea and ammoniated molasses are comparable in feeding value to cottonseed meal. Baker (1944a) used 72 yearling steers to compare soybean oil meal and urea either singly or in combination in a basal ration of corn silage, ground shelled corn, calcium carbonate, steamed bone meal and salt. The highest level of urea that was fed was 0.172 pound per head daily. They felt that the urea nitrogen was apparently utilized since the average daily gains for the different groups were not significantly different.

In a second study, Baker (1944b) found that additions of urea increased the gains of 84 steer calves, but the nitrogen of urea was not as well utilized as the nitrogen from soybean oil meal.

In the past ten years, studies have been made dealing with the effects of varying the levels of urea in the ration. Gallup et al. (1953a, b) conducted beef cattle fattening trials using pellets in which urea provided 25, 50, and 85 percent of the nitrogen. Results for eight years and 210 calves showed that the 25 and 50 percent pellets produced gains equal to those produced by the common plant proteins. The 85 percent pellets were unsatisfactory. With sheep, the authors found that ewes made very good use of urea nitrogen, but in lamb-fattening rations, the nitrogen of urea was not satisfactory. These results correspond to the results of Hart et al. (1938), who compared urea, ammonium bicarbonate, and casein in a basal ration of 5.38 to 6.0 percent protein. Urea at 1.4 pounds per 100 pounds of ration supported growth of calves equal to casein at 11 pounds per 100 pounds of ration. The calves fed urea at 4.3 pounds per 100 pounds of ration did not grow as well. Lassiter et al. (1958) fed 25 percent protein supplements containing 3, 5, and 7 percent urea with corncobs as the sole roughage. With increasing levels of urea, the rate of gain and feed efficiency decreased significantly. The authors felt that this decrease may have been due to a decrease in sulfur content with increasing levels of urea. Thomas _et al._ (1951), as cited by Lassiter _et al._ (1958) and Jones and Haag (1946), have established this fact.

Harris and Mitchell (1941a) studied maintenance levels when using urea and casein. They found that nitrogen equilibrium could be maintained on 20 mg. of urea nitrogen and 161 mg. of casein nitrogen per kilogram body weight, and the biological values of urea and casein at nitrogen equilibrium were 62 and 79, respectively. The biological values decreased with increasing level of intake. These results correspond to those of Harris _et al._ (1943), who found that the biological values of urea and soybean oil meal fed at 12.4 and 13.8 percent protein equivalent were 34 and 60, respectively. In a second study, Harris and Mitchell (1941b) added urea at 8, 11, and 15 percent of protein equivalent to a basal ration of silage and carbohydrate supplement. The biological values of the rations at the 8, 11, and 15 percent level were 74, 60, and 44, respectively, which agree with their first work (Harris and Mitchell, 1941a) for decreasing biological values with increasing intake. Further, they report that the 11 and 15 percent rations produced a greater rate of gain than the 8 percent urea ration.

Nitrogen balance studies have been used as a tool to study the value of urea. Harris _et_ _al_. (1943) used two rations, one with a low-protein content and a second supplemented with urea or soybean oil meal with a protein equivalent of 12 or 14 percent to study nitrogen balance. They found that the average percent of nitrogen stored for urea and soybean oil meal was 2.0 percent and 31.4 percent, respectively. The poor performance of urea was attributed to the fact that it may have been fed at a level above its maximum for conversion into protein. Fingerling _et_ _al_. (1937), as cited by Benesch (1941), found similar but not as drastic results with gluten and urea.

II. The Value of Urea in Silage

Since urea has been considered by many as a protein-sparing agent, an attempt to increase its usage has resulted in the additions of urea in silage. Various results have been reported.

Davis _et_ _al_. (1944) used a water solution of urea at concentrations of 0, 10, 30, and 50 pounds per ton as an additive in sorghum silage. Crude protein determinations showed that some nitrogen had migrated, but any loss was slight. Free ammonia was noticed at the highest concentrations of urea. The pH for the control and 50 pound urea silages were 3.5 and 7.6, respectively. When these silages were fed to cattle, the 0 and 30 pound urea silages were consumed equally well with complete refusal of the silage containing 50 pounds urea per ton until all free ammonia was released. Means (1945) compared urea-treated and untreated sorghum silage by ensiling sorghum with 10 pounds urea per ton. Three lots of beef cows and three lots of yearling heifers were used in a 77-day feeding trial in which three different rations were fed. They were: (1) Standard Ration--30 pounds of untreated sorghum silage, 1 pound of cottonseed meal and 5 pounds of Johnson grass hay; (2) 35 pounds untreated silage plus 5 pounds of Johnson grass hay; (3) 35 pounds of urea-treated silage plus 5 pounds of hay. In all three rations the heifers received five pounds less than the cows. The average gain or loss for lots one, two, and three for the beef cows was plus 9, minus 99, plus 13 pounds, respectively, showing the superiority of the treated silage. With heifers the standard ration produced the best gains but the treated silage was still superior to the untreated silage-hay ration. Cullison (1944), using beef breeding cows, reported similar results.

Woodward and Shepherd (1944) ensiled corn silage with the addition of 10 pounds urea per ton silage. This was fed to milking cows with a low protein concentrate and hay. A second group was fed similarly except the urea was mixed with the concentrates. Neither method of feeding had a significant effect since both groups maintained milk production exceptionally well. In both methods of feeding, increasing additions of urea impaired palatability. Wise et al. (1944) using the same ensiling procedure as Woodward and Shepherd (1944) found that silage with urea had a slight caramelized odor and a brownish color. The crude protein for the treated and untreated silages were 10.79 and 7.48 percent, while the pH's for these silages were 4.3 and 3.6, respectively. When the silages were fed to milking cows, the results were similar to those reported by Woodward and Shepherd (1944). Bentley et al. (1955) also reported an increase in crude protein with urea additions to green chopped corn silage at rates of 17, 20, and 25 pounds per ton. When they expressed the increase in crude protein as a percent of the amount of crude protein added as urea, these percentages for the 17, 20, and 25 pounds per ton urea levels were 94%, 112%, and 82%, respectively.

Bentley et al. (1955) found that urea-treated corn silages were quite palatable to both steers and lambs and compared quite favorably to corn silage and soybean oil meal in feeding value. In contrast, Archibald and Parsons (1945) found urea in silage to be unsatisfactory because of the urea conversion to ammonia thereby causing the silage to have an objectionable odor. Hall et al.

(1954), comparing urea-treated and untreated sweet potato vine silage, reported that the urea silage had good odor and color.

III. Calcium Phosphate and Calcium Carbonate

Only a limited amount of research has been done with calcium phosphate and calcium carbonate as additives in livestock feed. Colovas et al. (1958) used twelve dairy heifers between 18 and 24 months of age to determine the effect of pulverized limestone and dicalcium phosphate on the nutritive value of dairy feeds. In two different trials, the heifers were fed Ladino clover-bromegrass, Timothy, or grass-legume silage with limestone and dicalcium phosphate fed at 50 and 100 gram levels with the silage daily. A 16 percent crude protein concentrate mixture was fed the second year. In the first trial, 100 grams of pulverized limestone depressed the digestibility of the protein and energy in the silages. Fifty grams did not show a significant effect. In their second trial, 2 percent limestone decreased the digestibility of both the protein and energy. Two percent dicalcium phosphate had no appreciable effect. With 1.0 percent limestone the digestibility of energy was significantly depressed. When 2.0 percent dicalcium phosphate was added along with 2.0 percent limestone, it minimized the depressing effect of the limestone, thus leading the authors to suggest that calcium depresses the digestibilities of both protein and energy, whereas phosphorus increased the digestibility of the protein.

Klosterman et al. (1961) ensiled corn silage with 0.5 percent high-calcium ground limestone (36.66% calcium and 0.29% magnesium) and 0.5 percent urea. High-moisture ground ear corn was ensiled with 1.0 percent high-calcium limestone and 6.0 percent water. In both trials cattle gained significantly faster and required less feed with the treated as opposed to control silages. In both treated silages there was a vast increase in lactic acid over the control silage; 78 percent for the corn silage (dry basis) and 125 percent increase for the high-moisture ear corn. In a previous paper, they found a 100 percent increase in acid production with 1.0 percent calcium carbonate, and a 40 percent increase with 1.0 percent dolomitic limestone (Klosterman et al., 1960a). Sani (1912), as cited by Watson (1939), treated green fodder with 6.75 pounds per ton mono-calcium phosphate. The treated silage retained a green color and had a smell of esters with a high retention of digestible protein.

IV. Phosphoric Acid

Inorganic and organic acids have been used in silage fermentation to increase the acidity of the silage just as soon after ensiling as possible. Most of the research deals with the use of hydrochloric, sulfuric, and other acids for this purpose. Less work has been done with phosphoric acid *per se*. Virtanen (1933), as cited by Watson (1939), reports several experiments in which hydrochloric, phosphoric, and lactic acids were used. Hydrochloric acid was superior to the latter two in depressing the pH to 3.6. In a later experiment, Stone *et al*. (1943) reported that phosphoric acid at 16 pounds per ton produced a satisfactory silage if the ensilage was not too low in fermentable sugars. Two years later, Hayden *et al*. (1945) varied the amounts of phosphoric acid in nine lots of silage. The acid depressed the average pH as well as molasses. In general, the lots were graded as "good," but when fed to milking cows the phosphoric acid treated alfalfa silage was not equal to corn silage in feeding value in equal protein rations. Herman *et al*. (1941) ensiled barley with molasses (60 pounds per ton) and phosphoric acid (eight pounds of 75 percent phosphoric acid per ton) and found no significant difference between these two silages for milk production. Archibald and Parsons (1945) found that phosphoric acid treated silage was unpalatable and inferior to other silages with other preservatives.

In dealing in the area of additives, the results appear to be quite variable depending upon which study is cited and the conditions of the experiment. With urea, it could be concluded that it is slightly inferior or just equal to the common plant protein supplements in feeding value. Calcium carbonate and calcium phosphate pose a different problem. The value of these additives appears to depend on the form and the level in which it is used in the silage. Phosphoric acid, while it depresses pH, is much like urea in that treated silages are slightly inferior or just equal to untreated silages in feeding value.

Silage Fermentation: The Chemistry and Bacteriology of Different Types of Silage

Since silage has become a major portion of the average livestock ration, researchers have attempted to study the chemical and bacteriological changes occurring within an ensiled mass. Russell (1908) reported that the general chemical changes known to occur in silage are the conversion of sugars to carbon dioxide and water, the production of acetic, butyric, and lactic acids, and the production of non-protein material from protein.

Most of the recent studies dealing with the chemistry of silages are concerned with the production of the volatile and non-volatile acids and the time of most active fermentation. Esten and Mason (1912) concluded that the most important part of corn silage fermentation begins soon after the crop is ensiled, and for the most part, completed within a few days. Similar results were reported by Bender *et al*. (1941) and Hall *et al*. (1954).

Acid Production

Barnett (1954) states that acetic acid is a normal constituent of good quality silage and its production is initiated earlier than lactic acid. Butyric acid, which results from microbial action on lactic acid, is usually produced some time after the beginning of fermentation. Irvin *et al*. (1956) determined the organic acids in orchard-grass and alfalfa silages during the first 40-60 days of fermentation. They report that the acid content of the fresh material placed in the silos was usually under 1.0 percent on a dry matter basis with acetic acid predominating. In poor quality silages, butyric acid was present after five to eight days, while lactic acid increased during the first five days and then decreased. In good quality silages, acetic acid increased rapidly for the first two days and then increased slowly for the next 40-60 days. Lactic acid increased to as much as 8 to 10 percent in the first eight to twelve days. There was no detectable butyric acid present and propionic, formic, and succinic acids occurred only in small amounts. Langston *et al*. (1958) showed similar results with orchard-grass and alfalfa silages. They reported lactic acid concentrations of about 9 percent and acetic acid about 2 percent. Succinic acid increased only slightly. Kempton and San Clemente (1959) report similar acid productions from thirteen grass silages in Michigan.

In an earlier report by Sherman and Bechdel (1918), the acid production in dry corn stover with added water was similar to that of ordinary corn silage. Acid formation in the dry corn stover silage and the ordinary corn silage for the first and twelfth weeks was 0.16, 3.15, 0.87, and 2.24 percent of air dry material, respectively.

Dobrogosz and Stone (1957) studied alfalfa silage treated with 0, 8, and 12 pounds of metabisulfite per ton. They concluded that the utilization of sugar and production of acids in the silages were inversely correlated with the amount of bisulfite added to the silage. Klosterman _et al_. (1960b) analyzed the organic acid production in whole plant corn ensiled in large glass jars with various neutralizing materials. These materials consisted of 0.5 percent low magnesium limestone plus 0.5 percent urea, 0.5 percent urea, and 1.0 percent urea. The acidity of these silages as determined by pH was 4.30, 4.10, and 4.40, respectively, while the acetic acid content for the three silages was 2.13, 1.92, and 1.71 percent on a dry matter basis, respectively. Lactic acid content was 12.05, 8.71, and 12.00 percent, respectively.

In a later report, Klosterman *et al*. (1961a) treated corn silage with 0.5 percent high calcium ground limestone and 0.5 percent urea. Likewise, they treated ear corn silage with 6.0 percent additional water and 1.0 percent high calcium ground limestone. When these silages were compared to control whole plant and ear corn silages, the treatments had little effect on pH, but they did increase the lactic and acetic acid content.

Bacterial Populations and Sequences in Silages

When silage studies were first undertaken, two schools of thought were advanced as to the cause of the fermentation and the changes that occur in the ensiled mass: (1) the action of plant enzymes and (2) bacterial action. Since that time, bacterial action has gained prominence as the agent initiating the chemical changes occurring in silages. The majority of the recent research deals with the types of organisms present in silage and their sequence changes.

Kroulik *et al*. (1955a) reported that there are many variations in the microbial populations on green plants, but that microorganisms tend to increase with the maturity of the plants. The predominating microorganisms on green plants consisted of "pigmented, aerobic, nonspore-forming, rod-shaped bacteria." Coliforms were also present in large numbers and very few of the bacteria from fresh green plants were similar to those found in silage. None of the microorganisms were typical of lactobacilli found in silage. Allen et al. (1937) and Gibson et al. (1958) both reported that obligate anaerobes, which are of particular significance in silage, are present only in small numbers in fresh grass.

Sherman and Bechdel (1918) state that bacterial counts from dry corn stover silage increased during the first week followed by a continued decrease thereafter. Rods and cocci appeared to be in equal numbers during the first two weeks. As fermentation proceeded the rods became more predominant until toward the end of fermentation practically all the bacteria were rods. The results of Kempton and San Clemente (1959) and Langston and Bouma (1960c) correspond to these results. Hunter (1918), using grass silage, reported similar results over the first two weeks of fermentation and observed that yeast cells increased for the first two to three days followed by a gradual decline in numbers. In a second report, Kroulik et al. (1955b) concluded that the numbers of bacteria increase rapidly in high-moisture ensiled forage and reach a maximum in five days, thereafter decreasing very rapidly. Coliforms after an increase up to two days storage also decreased rapidly. In wilted silage, the bacteria increased at a much slower rate reaching a maximum at nine days and remained at this level over 16 days before a decrease occurred.

There is a definite sequence in which the different types of organisms develop in the silage and this sequence is associated with the quality of the ensiled product. Langston _et al_. (1958) grouped 30 silages according to quality and found that rods were much more predominant in good and intermediate quality silages than in poor silages. Regardless of the quality, there was an overall increase in rods with a decrease in cocci as fermentation progressed. The authors also noticed a higher initial percentage of cocci in the better quality forages. Langston and Bouma (1960a, b, c) show quite similar results. They further state that cocci will persist over a longer period of time in poor forages possibly because of low acid conditions. Isolates revealed that cocci occurred early in forage fermentation but were lost when higher acid producing lactobacilli appeared. Pediococci appeared both early and late in the fermentation process. Lactobacilli usually did not become predominant until after the cocci reached high numbers and produced considerable amounts of acids.

Allen and Harrison (1936) substantiated the belief that lactobacilli play an active role in the advanced stages of fermentation. They reported that the majority of lactobacilli from six different types of grass silage were strains of Streptobacterium plantarum which is the same as Lactobacillus plantarum. In a later report, Allen et al. (1937) ensiled grass silage in 3 by 5 feet pilot silos. L. plantarum was the predominant type of lactobacilli and after seventeen days 1 x 10^9 per gram were grown from the lower half of the silage. When grass silage was ensiled in large test tubes, lactobacilli were found to be present on fresh grass at about 1 x 10^6 per gram, but after 24 hours they had increased to approximately 1 x 10^9 per gram. Stone et al. (1943) made similar conclusions from studying 38 different alfalfa silages over a five-year period. In all cases, the majority of organisms after the first few days of fermentation were members of the genus Lactobacillus. The report of Cunningham and Smith (1940) is in agreement with the results of Stone et al. (1943); while Langston and Bouma (1960c) state that Pediococcus, Lactobacillus brevis and Lactobacillus plantarum accounted for 70 percent of the total strains cultured from alfalfa and orchard grass silages. Gibson et al. (1958), working with perennial rye grass at controlled temperatures, reported lactobacillus, streptococcus, leuconostoc, pediococcus, clostridium, and bacillus developing extensively in most of the silages. Anderson (1956) stated that excess water with packing tends to favor the development of lactobacilli.

Yeasts

The presence of yeasts indicates the presence of air in the silage. High-moisture corn grain silage appears to be one type of silage in which yeasts may be predominant. Zogg *et al*. (1961), working with shelled corn at 22, 26, and 32 percent moisture, found a predominance of yeasts rather than molds when samples were taken within a foot of the top of the silo. In another report, Benjamin and Jordan (1960) reported that the number of aerobic bacteria, yeasts, and molds was higher in an ensiled corn (30 percent moisture) than in a dried ensiled corn (15 percent moisture). Hall *et al*. (1954) presented results showing that yeast counts were much lower when new barrels of silage were opened each time rather than sampling from a previous sampled barrel. Experimental error expressed as a coefficient of variation was as high as 50 percent for samples taken within a barrel of silage.

Heat Production

Chemical reactions occurring in silage produce heat in amounts depending upon the ensiled material and the conditions of the experiment. Heat greater than 100° F. results in "tobacco" brown silage with excessive dry matter losses, while "cold" fermentations sometimes produce undesirable amounts of butyric acid according to Briggs *et al*.

(1959). Temperatures as low as 75 degrees F. may be characteristic of this type of fermentation. Benne and Wacasey (1960) expressed similar conclusions when they reported that temperatures of 80° to 100° F. favor the growth of lactic acid bacteria.

Temperature in a silo will vary depending upon the level where it is recorded. Hunter (1917) reported average temperature limits in the center of the silo ranging from 30 to 40 degrees C. and noted a difference in heat production at the top and center of the silo depending on the oxygen content. Allen *et al*. (1937) recorded peak temperatures of 102° and 92° F. for the top and bottom of a silo. Sherman and Bechdel (1918), working with ensiled dry corn stover with additional water, recorded a maximum temperature reading of 57.7 degrees F. from the average of four resistance bulbs after 73 days of fermentation. These results are similar to the results of Hall *et al*. (1954) with sweet potato vine silage. Kempton and San Clemente (1959) reported silage temperatures at different depths three weeks after ensiling. In two well-preserved silages the highest temperatures were 131° F. and 111° F. In one silo containing spoiled silage, the highest temperature was 114° F. and in an overheated silage the highest recording was 138° F. Only one study has been conducted in which temperatures were recorded in high-moisture corn. Lassiter *et al*. (1960) stored high-moisture corn in two different years. In 1957, ground shelled corn at 26 percent moisture, ground shelled corn at 40 percent moisture, and ground ear corn at 36 percent moisture were ensiled. The 26 percent ground shelled corn produced the highest temperature followed by 40 percent ground shelled and 36 percent ground ear corn. All forms of corn reached peak temperatures of about 78° to 95° F. at approximately eight to ten days. In 1958, 32 percent moisture ground ear corn and 32 percent shelled and ground shelled corn were stored. The 32 percent ground ear corn produced the highest temperature followed in descending order by the 32 percent ground shelled corn and the 32 percent shelled corn. Esten and Mason (1912) stored corn silage at controlled temperatures of 40°, 50°, and 70° F. They report that the percent acids in terms of lactic and acetic were 0.57, 1.18, and 1.89 percent per gram of silage, respectively, for these temperatures.

Silage fermentation has been extensively studied. The production of organic acids is a principle process in fermentation and the types and levels of different acids determine the quality of the silage produced. High levels of lactic and acetic acids are a sign of intermediate to good quality silage while high levels of butyric with decreasing levels of lactic acid are characteristic of poor quality silage.

Cocci and rods appear to be the predominant types of bacteria in silages. Cocci appear to decrease in numbers and rods increase as the fermentation proceeds and acid concentration increases. The number of yeasts will vary depending on the type of substrate and the presence of air either entering or trapped in the silage. The optimum silage temperature is generally between 80° and 100° F., but it may vary depending upon the level in the silo at which it is recorded.

EXPERIMENTAL PROCEDURE

The experiments in this study cover a period of two years' work with high moisture ground ear corn.

Trial I

In October, 1960, twelve 5 by 7 foot experimental concrete stave silos with a capacity of approximately 2 tons each were constructed. On October 31 and November 1, 1960, ear corn was harvested at approximately 25 percent moisture using a standard corn picker. The corn was ground through a power take off burr-mill set so that all kernels were broken. Additional water was added at the silo to bring the final moisture content to the desired level. In Trial I, urea at 20 pounds per ton, 85 percent phosphoric acid at 0.75 and 1.5 percent, 1.0 percent monobasic calcium phosphate, 0.75 percent calcium carbonate, and soybean oil meal at 125 pounds per ton were added to the corn in different combinations at the burr-mill.

The following regime was used:

Silo 1: 28 percent moisture ear corn
Silo 2: 28 percent moisture ear corn plus 20 pounds urea per ton
Silo 3: 28 percent moisture ear corn plus 20 pounds urea per ton plus 0.75 percent phosphoric acid
Silo 4: 28 percent moisture ear corn plus 20 pounds urea per ton plus 1.5 percent of an 85 percent phosphoric acid solution

Silo 5: 28 percent moisture ear corn plus 20 pounds urea per ton plus 0.75 percent calcium carbonate
Silo 6: 35 percent moisture ear corn
Silo 7: 35 percent moisture ear corn plus 20 pounds urea per ton
Silo 8: 35 percent ear corn plus 20 pounds urea per ton plus 0.75 percent of an 85 percent phosphoric acid solution
Silo 9: 35 percent moisture ear corn plus 20 pounds urea per ton plus 1.5 percent of an 85 percent phosphoric acid solution
Silo 10: 35 percent moisture ear corn plus 20 pounds urea per ton plus one percent monobasic calcium phosphate
Silo 11: 28 percent moisture ear corn plus 20 pounds urea per ton plus one percent monobasic calcium phosphate
Silo 12: 28 percent moisture ear corn plus 125 pounds soybean oil meal per ton.

When the silos were filled, the silages were leveled and packed. The silos were covered with black, plastic sheets and the side of the cover was tied in place.

The silages were allowed to ferment for 60 days. During this period samples were removed on the 0, 5, 10, 20, 30, 45, and 60th day with a Seedburo corn probe. Each sampling day the plastic covers were removed and the samples were taken from the top 4 to 5 feet of silage near the center of the silo. The samples were stored in polyethylene bags at minus 1-3° F. until chemical analyses were completed. The determinations of Kjeldahl-N, Ammonical-N, pH, moisture content, urea, organic acids, and ethanol content were completed in the laboratory.

Two feeding experiments were conducted using eight of the twelve original silos. Before feeding, 6 to 12 inches of top spoilage were removed from each silo. Twenty Holstein heifers ranging in weight from 315 to 900 pounds were fed the silages in silos 1, 6, 10, and 12 in a 46-day trial. The heifers were assigned to five groups of four heifers each on an equal weight basis following a 7-day pre-trial period in which a dry corn plus soybean oil meal mixture (12.8 percent crude protein), five pounds mixed grass hay, salt, and dicalcium phosphate were fed. The silages were fed according to appetite along with 5.0 pounds of mixed grass hay, 1.0 ounce dicalcium phosphate, and 1.0 ounce trace mineralized salt. Soybean oil meal was also fed in order that all heifers were offered a similar amount of protein. A control group was fed similarly except they were fed dry corn to appetite. Feed consumptions were kept on each heifer with weigh-backs recorded every other day. Weights were recorded for three consecutive days at fourteen-day intervals throughout the trial.

Silages number 3, 4, 8, and 9 were fed in a second 30-day growth experiment. Twenty Holstein heifers weighing 400 to 1000 pounds were allotted into five groups on an equal weight basis. The feeding regime was the same as used in the first experiment. The remaining four silages, 2, 5, 7, and 11, had an objectionable ammonia odor and were not used.

Trial II

Purchased dry ear corn from the previous year's crop was ground through the same burr-mill that was used in Trial I on May 11, 12, and 13, 1961. Eight of the original twelve silos were used in this trial. Duplicate silages were studied at 30 and 45 percent moisture with and without additions of 1.0 percent monocalcium phosphate. Urea and calcium phosphate were added with the corn at the burr-mill. Water was added to the ground ear corn at the silos to obtain the approximate moisture content. The silages were packed and covered with large sheets of black plastic. The following regime was used:

Silo 1: 30 percent moisture ear corn plus 15 pounds of urea per ton
Silo 2: 30 percent moisture ear corn plus 15 pounds of urea per ton
Silo 3: 45 percent moisture ear corn plus 15 pounds of urea per ton
Silo 4: 45 percent moisture ear corn plus 15 pounds of urea per ton
Silo 5: 30 percent moisture ear corn plus 15 pounds of urea per ton plus one percent monocalcium phosphate
Silo 6: 30 percent moisture ear corn plus 15 pounds of urea per ton plus one percent monocalcium phosphate
Silo 7: 45 percent moisture ear corn plus 15 pounds of urea per ton plus one percent monocalcium phosphate
Silo 8: 45 percent moisture ear corn plus 15 pounds of urea per ton plus one percent monocalcium phosphate

The sampling and the analyses were handled the same as in Trial I.

Following 60 days of fermentation, the eight silages were used in a 21-day growth trial. Fifty-four heifers weighing 310 to 880 pounds were allotted into nine groups of six heifers each on an equal weight basis following a two-week preliminary period during which dry corn was fed. Top spoilage was removed from each silo. Each of the eight silages was fed to one of the eight groups of heifers with a ninth group fed dry corn as a control. The silages were fed according to appetite with 5.0 pounds of hay, 1.0 ounce dicalcium phosphate, and 1.0 ounce trace mineralized salt. Soybean oil meal (average of 1.4 lb./day) was also fed so that each heifer was on an equal protein basis. Feed offered and rejections were recorded for each heifer. Heifer weights were taken once each week and for three days at the termination of the trial.

Trial III

Following the first two trials in which water was added to dry corn to obtain the desired moisture content, a third trial was conducted in which corn was harvested from one field at the desired moisture levels. The previous year, hay was raised in this field with no fertilization. "Michigan 300" hybrid corn was planted in the field after fertilization with 400 pounds of 8-32-16 and approximately eight tons of manure per acre.

Six 10 by 6.5 foot concrete-stave silos were constructed. The corn for the first two silos was picked on September 19 and 20, 1961, using a two-row corn picker. On September 19, two loads of corn were picked and covered with tarpaulins until the following morning when the first two silos were filled. The corn was ground with a burr-mill as in Trial I and Trial II. In this trial, the corn was put into a grain wagon and each load was weighed before it was transported by a grain augar into the silos where it was packed after each load.

Four copper-constantan thermocouples were used in two silos and three in the remaining four silos. An attempt was made to place these thermocouples so that the temperature could be recorded from the bottom, middle, and upper third of each silo. A Leeds and Northrup potentiometer was used to indicate the temperatures. After each silo was filled it was covered with black plastic and weighted down with silo staves. Tarpaulins were used to prevent the entrance of additional water. The middle two silos were filled on October 4, and the final two silos on October 26, 1961, so ground ear corn was ensiled at three moistures, 40, 34, and 24 percent. The same sampling schedule and chemical analyses were used as in Trials I and II. Samples were removed from the silos through 1½ inch holes bored through the doors and closed with rubber stoppers. Bacteriological studies were also included using the same samples.

A 57-day growth trial was conducted 45 to 60 days after ensiling using 35 Holstein heifers weighing 500 to 1,000 pounds. These heifers were assigned to seven equal weight groups of five heifers each after being fed dry corn for seven days. The experimental silages were fed for an additional ten-day preliminary period. Each group received one of the silages and one group was fed dry corn as a control. Three-day body weights were taken at the beginning and the end of the trial and every fourteen days during the trial. The feeding regime for hay, minerals, and soybean oil meal was the same as in the previous growth studies. Feed intakes and refusals were recorded for each heifer and sampled weekly for dry matter determinations.

Chemical Analyses

Moisture, pH, Ammonical Nitrogen, Crude Protein

Moisture was determined by drying in a hot air oven at 100°-105° C. for 24 hours. A Beckman pH meter with an external glass electrode was used to determine hydrogen ion activity. Ammonical-Nitrogen and crude protein equivalents were analyzed by procedures outlined by the Association of Official Agricultural Chemists and adapted for high-moisture corn.

Urea Determinations

The ion exchange resin method described by Hawk *et al.* (1954) was attempted with some modifications. This method was unsuccessful and the procedure described by Brown (1959) was used with modifications. Two g. of high-moisture corn and ten ml. of distilled water were mixed, in a twenty-five ml. erlenmeyer flask, and held for two hours at room temperature. One ml. of extract from the unknown samples plus the standards and a water blank were pipetted into 10 by 150 mm. test tubes. A urea solution (107 mg. of urea in water in a 100 ml. volumetric flask) was used as a standard. Seven ml. of water were added to each test tube followed by one ml. each of a one percent zinc sulfate solution and a 0.5N sodium hydroxide solution. After the addition of the above solutions, the contents in the tubes were mixed thoroughly and allowed to sit for a period of 15 minutes after which they were centrifuged at 2500G. for 20 minutes. After centrifugation, 2 ml. aliquots of each filtrate were put into test tubes and 2 ml. of p-dimethylaminobenzaldehyde sulfuric acid color reagent were added to each sample followed by thorough mixing.

After 10 minutes, the optical density was read in a Beckman "B" Spectrophotometer at a wave length of 430 Mu.

Volatile Fatty Acids

Fifty or one-hundred grams of silage were mixed with an equal volume of 0.6N sulfuric acid and stored at 37°-39° F. for at least three days. The liquid portion of these samples was extracted and centrifuged for ten minutes at 2000G. The supernatants were removed and stored under refrigeration. Organic acids were determined by the method of Wiseman and Irvin (1957).

Ethyl Alcohol

The supernatant used in the volatile fatty acid determinations was also used to analyze for ethanol content. The procedure described by Kent-Jones *et al.* (1954) was followed with modifications. Using 50 ml. erlenmeyer flasks, 5 ml. of potassium dichromate (0.2129 grams potassium dichromate per liter of water) was mixed with 5 ml. concentrated sulfuric acid, and allowed to cool to room temperature. Paper clips were attached to the base of rubber stoppers and a strip of filter paper was attached to the paper clip. One-tenth ml. of the supernatant was absorbed on the filter paper, and this was placed inside the erlenmeyer flask for four hours in a 37° C. water bath. Following the four-hour period, the potassium dichromate-sulfuric acid solution was titrated to a faint pink against a water blank and a 0.05 percent ethanol standard. The final titrating solution consisted of 35 ml. of a 50 percent sulfuric acid solution to which 15 ml. of a methyl orange solution and 1.0 ml. of a ferrous sulfate solution (1.25 grams ferrous sulfate in 15 ml. water plus 3 ml. concentrated sulfuric acid made up to 25 ml.) was added.

The ethanol content on part of the samples was determined using a Cenco gas chromotography unit with a one millivolt recording potentiometer with a ten foot Carbowax-600 column on a sensitivity setting of three. One hundred microliters of each sample were injected into the unit with a micro-syringe. A time period of 45 minutes was required for each sample with the unit set at 7 pounds helium and at a temperature of 117°-118° C. Ethanol at 0.25, 0.5, and 1 percent were used as standards for identification of the unknowns and for plotting standard curves by the peak area method.

The methods of Kent-Jones _et_ _al_. (1954) and the gas chromotography unit proved to be in close agreement.

Bacteriological Procedure

In Trial III, bacteriological samples were taken with a Pennsylvania hay borer on the 0, 5, 10, 20, 30, 45, and 60th day of fermentation. The samples were placed in clear plastic bags and were immediately transported to the laboratory for plating and microscopic examination. The 0-day samples from silos 3, 4, 5, and 6 were placed in a cooler over night and plated the following day. All other samples were plated within 4 hours after sampling.

One gram of silage was placed into 125 ml. sterile erlenmeyer flasks along with 99 ml. sterile distilled water. These were shaken manually twelve to fifteen times in a 12-inch arc to dislodge any bacteria attached to the corn. Nine ml. of Azide Dextrose Broth (Baltimore Biological Laboratory No. 11499), which had been autoclaved at 115° C. with 15 pounds pressure for 15 minutes, was distributed into sterile disposable plastic test tubes, 17 by 100mm (Falcon Plastics, No. T17100C). One ml. of the original 10^2 dilution was pipetted into the first tube and subsequent dilutions were made thereafter. The tubes were stored at 32° C. for 48 hours with an inspection for growth at 24 hours. Following the 48-hour growth period, a microscopical examination was conducted on the growth in the azide tubes. This procedure yielded higher cultural counts than plating on nutrient agar.

Lactobacilli were plated from the 10^2 dilution used for total counts and additional dilutions were made with

9.9 ml. sterile distilled water in the sterile plastic test tubes. Lactobacillus-Selective Medium (LBS medium, Baltimore Biological Laboratory, No. 106646) was prepared in liter quantities and used as prescribed. Dilutions of 10^6, 10^7, 10^8, and 10^9 were prepared and pour plates made from these dilutions. The plates were incubated at 32 degrees C. for 48 hours. Inspections for growth were made at 24-hour intervals with final counts at 48 hours.

Yeast and mold growth was determined following the same procedure as was used for Lactobacilli. Autoclaved Potato Dextrose Agar (Difco Laboratories, No. 0013-01) was employed as the growth media with approximately 1.6 ml. of a 10 percent tartaric acid solution per 100 ml. of medium to inhibit bacterial growth. Plates were prepared from dilutions of 10^3, 10^4, and 10^5 with incubation at 32 degrees C. for 48 hours and growth inspections at 24 hours. Occasionally, longer periods of growth were required before total counts could be made.

Anaerobic growth was determined with the use of two media, Fluid Thioglycollate Medium (Difco Laboratories, No. 0256-01) and Brewer Anaerobic Agar (Difco Laboratories, No. 0433-02) with 0.5 percent glucose following the same procedures as were followed for Lactobacilli, yeasts, and molds. Plates from dilutions of 10^6, 10^7, 10^8, and 10^9

were poured and allowed to solidify. Anaerobic conditions were produced by the use of a Brewer's Anaerobic jar. Oxygen in the jar was removed by evacuation of air and replacement with natural gas. Remaining oxygen was removed via the action of an electrically heated catalyst. The jars were left at room temperature for 48 to 72 hours before total counts were made.

RESULTS

Chemical and Bacteriological Studies

pH

The results are given in Table I. Urea was a constant additive in all but three silages in Trials I and II. Its effect upon silage pH is presented in Graph I. The silages containing 20 pounds of urea per ton had an initial pH of 4.7, but following 60-day fermentation the pH had risen to 7.4. The initial and 60-day values for silages containing 15 pounds of urea were 6.0 and 5.1, respectively, while these values for the silages containing 0 pounds of urea were 6.3 and 5.2, respectively.

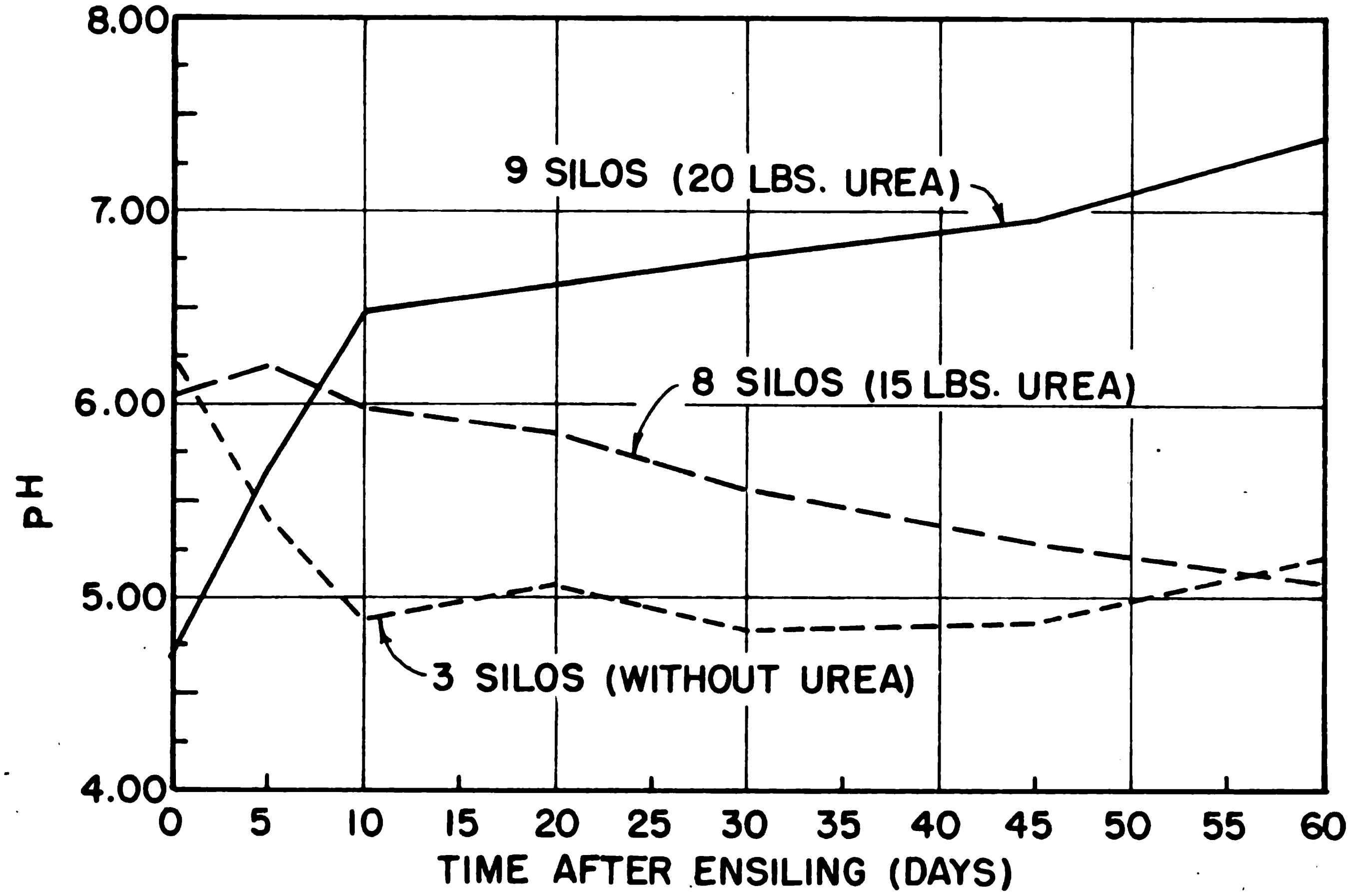
The effect of other additives on pH was also followed. Phosphoric acid was added to study its pH depressing effect. The initial average pH in Trial I for four silages containing phosphoric acid was 3.2 but after 60-day fermentation, the pH had risen to 6.9. The two silages containing 1.5 percent phosphoric acid (silos 4 and 9) did have a lower pH than the silages with 0.75 percent phosphoric acid (silos 3 and 8). When moisture content was considered along with phosphoric acid, the 35 percent moisture silage (silos 8 and 9) had a lower pH throughout than the 28 percent moisture silage (silos 3 and 4). The initial pH was 6.5 and the 60-day pH was 8.3 for silage

TABLE I. pH OF EAR CORN SILAGE

	Silo Number											
	1	2	3	4	5	6	7	8	9	10	11	12
<u>Trial I</u>												
Mean pH[a]	5.40	7.59	6.58	5.08	7.58	4.68	7.70	6.40	4.37	5.57	6.35	5.57
60-day pH	5.33	8.55	7.88	6.05	8.31	4.69	8.45	7.82	5.71	6.09	7.52	5.67
<u>Trial II</u>												
Mean pH[a]	6.53	6.73	6.01	4.56	5.87	5.86	4.85	5.30				
60-day pH	6.65	5.50	4.95	4.18	4.72	5.62	4.32	4.70				
<u>Trial III</u>												
Mean pH[a]	4.12	4.15	4.20	4.63	5.60	5.72						
60-day pH	4.15	4.09	4.06	5.83	5.48[b]	5.75[b]						

[a]Each entry is mean of 0, 5, 10, 20, 30, 45, and 60-day samples.
[b]48-day values.

GRAPH I



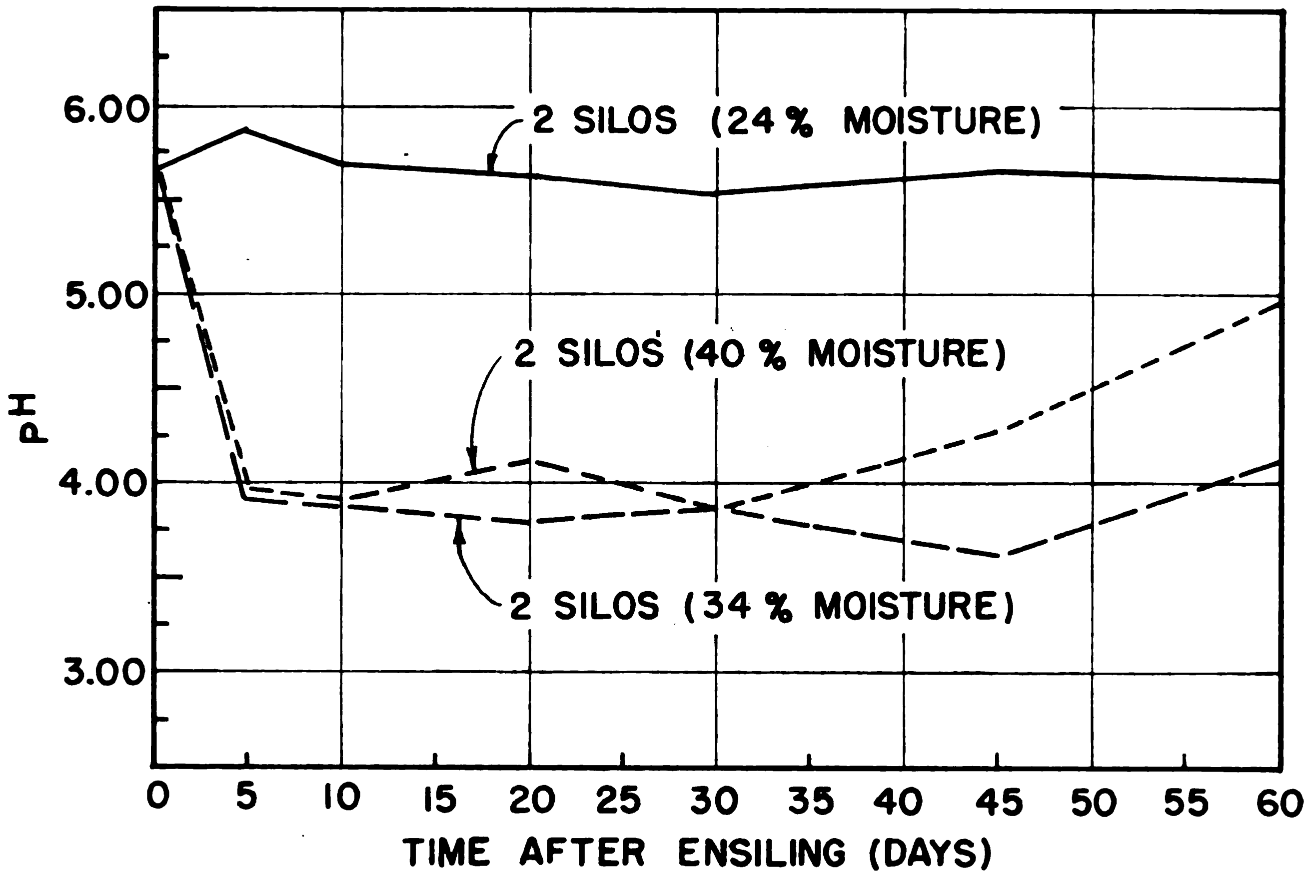
THE ACIDITY (pH) OF HIGH MOISTURE EAR CORN SILAGE WITH DIFFERENT LEVELS OF UREA.

number 5 which contained 0.75 percent calcium carbonate. These values are almost identical with silage number 2 which differed only in omission of the calcium carbonate. In Trial I, 1.0 percent monobasic calcium phosphate (silos 10 and 11) had a somewhat lower pH than control silages (silos 2 and 7) which were the same with the exception of monobasic calcium phosphate. In Trial II, with 15 pounds of added urea, the pH was lower at 45 percent moisture ($P < 0.01$) (silos 3, 4, 7, and 8) than at 30 percent moisture (silos 1, 2, 5, and 6). One percent monobasic calcium phosphate also depressed pH ($P < 0.01$) (silos 5, 6, 7, and 8). Moisture level has a profound effect on pH as can be seen in Graph II. With 24 percent moisture silages the initial pH was 5.7 with little depression observed since after 60 days the pH was 5.6. The 34 and 40 percent moisture silages had virtually the same initial pH as the 24 percent moisture silages, but a significantly ($P < 0.01$) lower pH was observed after 60 days of fermentation.

Organic Acids

The results are presented in Tables II and III. There was no distinct pattern for butyric and propionic acid production in individual silos. However, in all three trials there was a tendency for more butyric and propionic acid in the higher moisture silages (35-45

GRAPH II



THE ACIDITY (pH) OF HIGH MOISTURE EAR CORN SILAGE AT DIFFERENT LEVELS OF MOISTURE

TABLE II: BUTYRIC AND PROPIONIC ACIDS

	Silo Number											
	1	2	3	4	5	6	7	8	9	10	11	12
	uM/g											
<u>Trial I</u>												
30 day	12.3	5.2	13.4	11.5	16.3	13.7	31.5	20.7	28.3	22.8	20.4	14.5
60 day	14.2	.7	.7	9.2	11.0	1.0	14.6	9.6	15.7	2.0	17.9	0
<u>Trial II</u>												
30 day	0.5	3.5	32.0	0	0	0	5.9	0				
60 day	5.6	10.4	129.2	94.1	24.97	15.29	44.3	44.8				
<u>Trial III</u>												
30 day	5.4	15.1	0	5.5	0.7	4.7						
60 day	25.4	5.8	0	30.0	---	---						

TABLE III: EFFECTS OF MOISTURE ON ORGANIC ACID PRODUCTION

Moisture Level	ACETIC ACID Mean (uM/g)	s.d.[a]		LACTIC ACID[c] Mean (uM/g)	s.d.[a]	
Trial I						
a) 26-28%	47	19	(7)[b]	35	18	(7)
b) 30-35%	60	20	(5)	44	13	(5)
	(P < 0.10)			(P < 0.12)		
Trial II						
a) 23-30%	46	15	(4)	40	15	(4)
b) 40-45%	128	28	(4)	198	32	(4)
	(P < 0.01)			(P < 0.01)		
Trial III						
a) 24%	9	0.6	(2)	15	8	(2)
b) 34%	36[d]	24	(2)	124	17	(2)
c) 40%	54[d]	7	(2)	164	3	(2)
	(P < 0.01)			(P < 0.01)		

[a] Standard Deviation.
[b] Number of Silos.
[c] Lactic acid determined colorimeterically.
[d] 34 and 40 percent significantly higher than 24 percent moisture corn.

percent moisture). In Trial II, it was observed that 1.0 percent monobasic calcium phosphate reduced the concentration of butyric and propionic acid at the 45 percent moisture level but not at the 30 percent moisture level.

Lactic acid was increased and acetic acid decreased with additives of monobasic calcium phosphate. In Table III, it can be seen that increased moisture increased the acetic and lactic acid content. In Trial III the lactic acid production in silages at 40 percent moisture was higher ($P < 0.01$) than at the 34 percent moisture level.

Urea

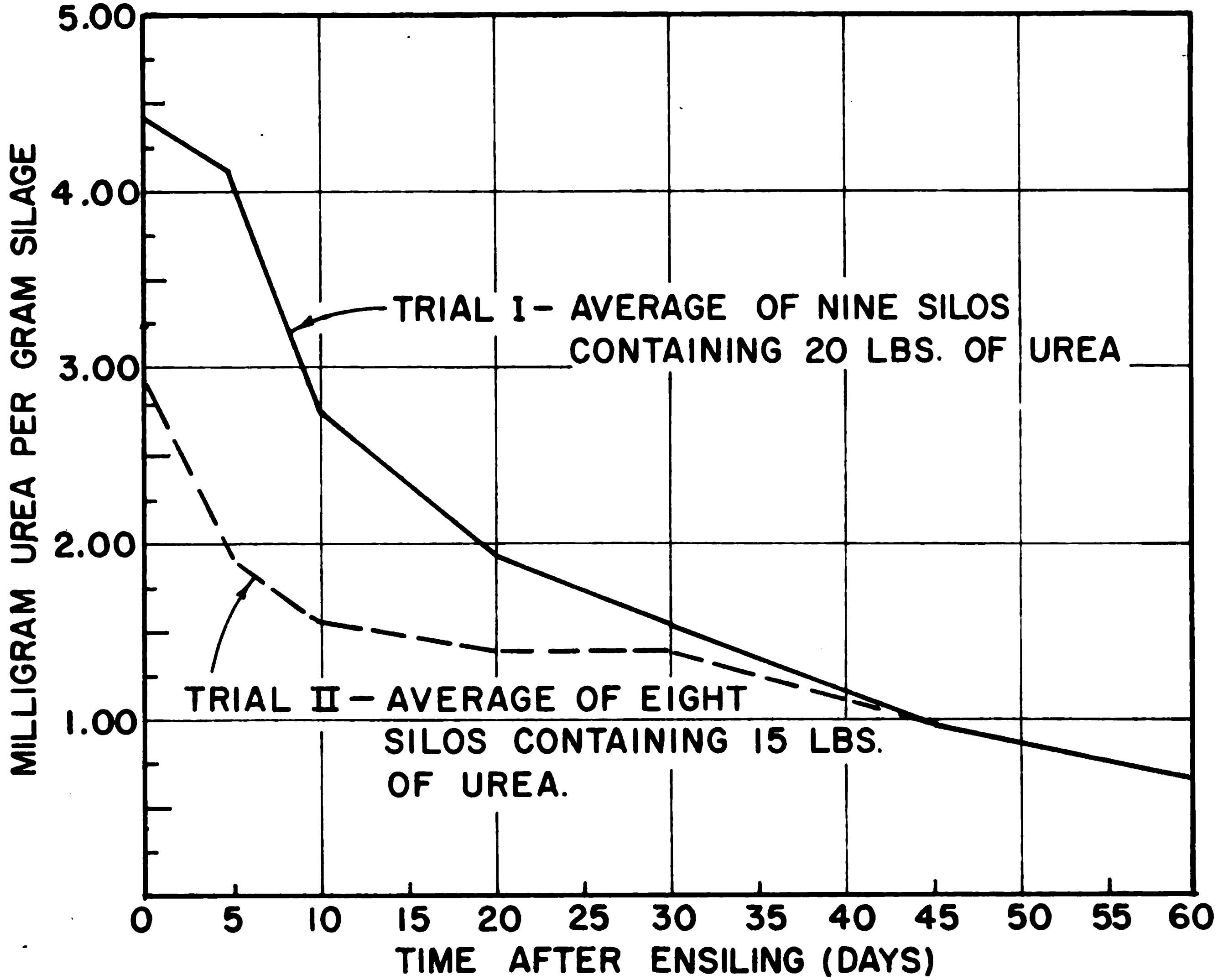
There was a gradual decrease in the amount of urea present in the silages as shown in Table IV and Graph III.

TABLE IV: EFFECT OF TIME ON UREA CONTENT
(Mean Values for all Silos with Urea)

Sampling Days	TRIAL I (20# urea/ton)[a]	TRIAL II (15# urea/ton)[a]
	mg/g	mg/g
0	4.4	2.9
5	4.1	1.9
10	2.7	1.6
20	1.9	1.4
30	1.5	1.3
45	0.9	1.0
60	---	0.65

[a]Values determined on wet basis.

GRAPH III



THE PRESENCE OF UREA IN HIGH-MOISTURE EAR CORN SILAGE DURING A 60 DAY FERMENTATION PERIOD.

In Trial I, an initial urea content of 4.4 mg/g was recorded with a decrease to only 0.9 mg/g after 45 days. In Trial II, the same picture developed with an initial level of 2.9 mg/g and a 60-day level of 0.65 mg/g. Regardless of the initial urea level, about 50 percent of the urea was broken down within 20 days and 80 percent within 60 days. There was a tendency for the two levels to become equalized at the end of the fermentation period. Ammonia in the silages tended to increase throughout the fermentation period but in general 90 to 100 percent of the urea could be accounted for as ammonia in the silages after 60 days of fermentation. One percent monobasic calcium phosphate decreased the breakdown of urea when compared to silages without this compound. In Trial I, the 45-day level of urea for silages with and without monobasic calcium phosphate was 2.14 and 0.60 milligrams per gram ($P < 0.01$). In Trial II, these values for the 60-day samples were 0.85 and 0.45 milligram per gram, respectively, thus illustrating the urea sparing effect of this compound.

Crude Protein

Sixty-day values were the only figures utilized since any effect on the protein content could best be observed at the termination of the fermentation period. The mean crude protein values are presented in Table V.

TABLE V: EFFECT OF MOISTURE AND UREA ON PROTEIN CONTENT (60-Day Values, Dry Matter Basis)

	PERCENT CRUDE PROTEIN	
	Mean	S.D.[a]
Trial I		
No urea (2)[c]	9.9	0.5
20 lbs. urea/ton (9)	13.6[d]	0.6
28% moisture corn	13.4	0.7
35% moisture corn	13.9[f]	0.5
Trial II		
30% moisture corn	9.9	0.7
45% moisture corn	11.1[g]	1.2
Trial III		
24%[b] moisture corn	10.6[e]	0.1
34% moisture corn	10.1	0.1
40% moisture corn	10.5[e]	0.1

[a]Standard Deviation.

[b]48-day value.

[c]Silos

[d]$P < 0.01$.

[e]$P < 0.05$.

[f]$P < 0.23$.

[g]$P < 0.25$.

The addition of urea (Trial I) increased ($P < 0.01$) the crude protein content. In this respect, the added urea could be accounted for in the increase in crude protein. In Trials I and II, there was a slight increase ($P < 0.23$), ($P < 0.25$) in crude protein with the higher moisture silages. In Trial III, the 24 and 40 percent moisture silages were significantly higher in crude protein than the 34 percent moisture silage so that no direct pattern developed.

Ethyl Alcohol

The results are presented in Table VI.

TABLE VI: MEAN ETHANOL CONTENT OF EAR CORN SILAGE

Days	Moisture Level						
	Trial I		Trial II		Trial III		
	28	35	30	45	24	34	40
	Mg%						
5	0.11	0.05[a]	----	----	0.02	0.24	0.22[b]
10	----	----	0.15	0.21	0.24	0.24	0.24
20	0.19	0.11[a]	----	----	0.07	0.20	0.23
30	0.04	0.04	0.11	0.20	0.12	0.23	0.23
45	----	----	----	----	----	0.22[b]	0.22
60	0.11[a]	0.13	0.08	0.20	----	0.08	0.22

[a]Mean of 4 silos.
[b]One value represented.

The average ethanol content for all trials was 0.2 percent. In Trials II and III, the lower moisture silages effectively decreased the ethanol content when compared to the higher moisture silages. In Trial I this pattern did not develop; possibly because the range in moisture was not as great as in the latter two trials. In

Trial III the ethanol content of the 24 percent moisture silages reached 0.2 percent in 10 days, but thereafter declined steadily. This decline was much more rapid than in other silages. The other treatments had no detectable effect on ethanol content.

Bacterial Counts

There were slight differences between moistures in sodium azide counts (azide dextrose broth) with the exception of 24 percent moisture silages where the counts were slightly lower. During the fermentation period total growth and lactobacilli growth was slower in the 24 percent moisture silages than in the 34 and 40 percent moisture silages. The lactobacilli counts present an interesting picture since it was observed that the 24 percent moisture silages were somewhat lower whereas the total counts were within the same log range when compared to the other moisture levels. In following the development of the cocci and rods, growth was observed at 24 and 48 hours during incubation of the azide dextrose tubes. In 40 percent moisture silages, cocci were present in larger numbers at 24 hours than the rods. Following this, the rods grew in larger numbers especially at the higher dilutions. As the silages became drier more cocci were present throughout the incubation period. It was interesting to note that in Silo 5 (24 percent moisture) more rods were growing at 24 hours than in the other 24 percent moisture silage (Silo 6). Lactic acid production in Silo 5 was slightly higher than in Silo 6.

Yeast counts increased steadily as moisture decreased (Table VII). Mold growth was also higher in the drier silages and was possibly due to less compaction at this moisture level. These results are supported by the total anaerobe counts which show a decrease in the 24 percent moisture silages. The anaerobes were mainly rods occurring singly or in pairs.

TABLE VII: LOGARITHM MICROBIAL COUNTS

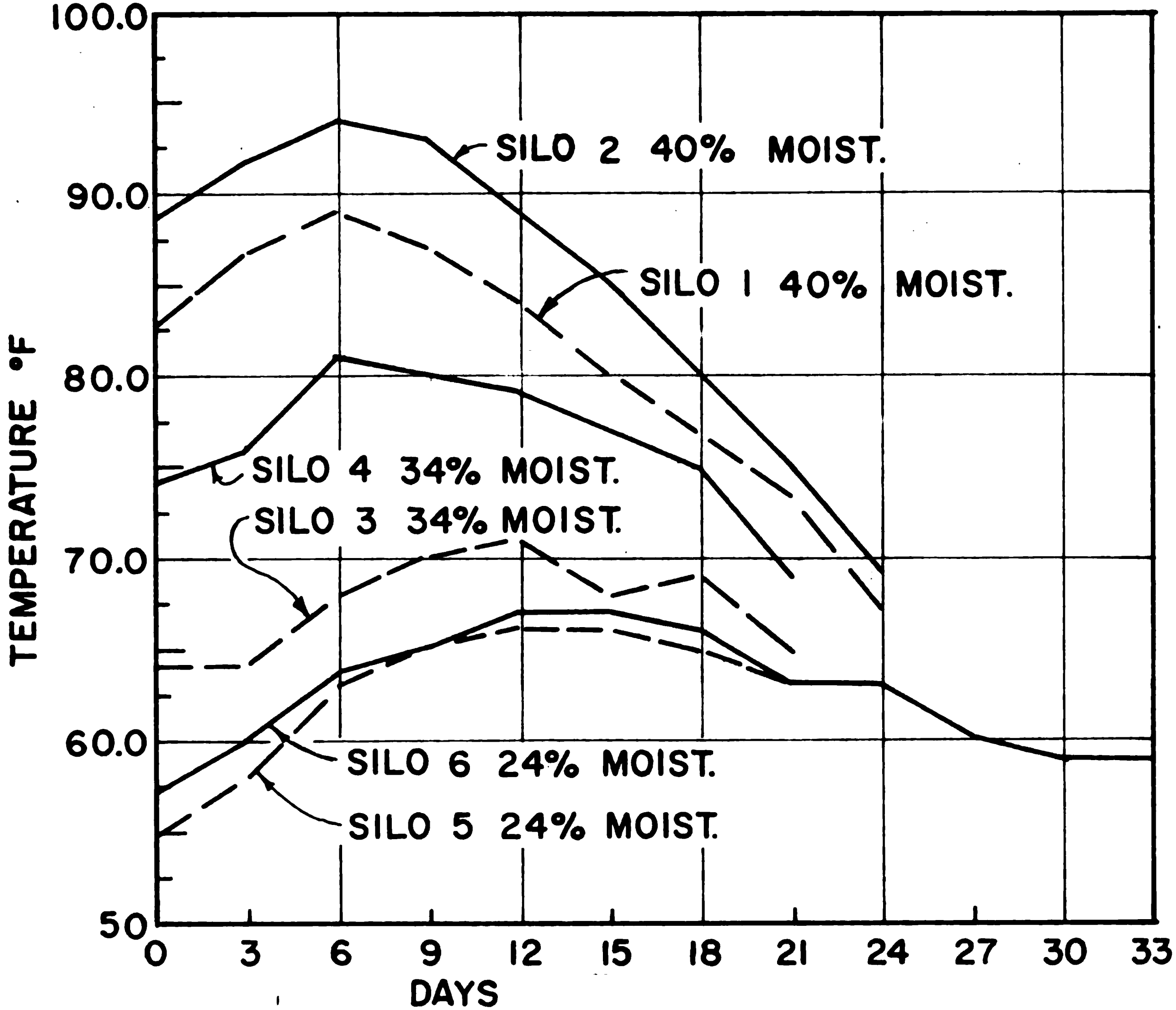
	Moisture		
	40%	34%	24%[b]
Total Counts[a]	8.8	8.8	8.0
L.B.S. (Lactobacilli)[a]	8.3	8.6	7.9
Yeasts[a]	6.2	7.9	8.4
Molds[a]	‹4.1	‹ 4.3	‹ 5.8
Anaerobes[a]	8.0	8.3	7.3

[a]Mean Log Counts of 45- and 60-day samples.
[b]Counts of 30- and 53-day samples.

Silage Temperatures

Silage temperatures at different moisture levels are presented in Graph IV. All of the silages reached a

GRAPH IV



THE EFFECT OF MOISTURE ON TEMPERATURE TRIAL III peak temperature within six to twelve days after ensiling. The higher moisture silages tended to attain the peak temperature earlier than the drier silages. The peak temperatures for the 40, 34, and 24 percent moisture silages were 92, 76, and 67 degrees F. while the actual increase in temperature from the zero day temperature for the three moisture levels was 6, 7, and 11 degrees F., respectively.

Animal Performance

Weight Gains. The results are presented in Table VIII. In the second growth study significantly better weight gains were produced with dry corn when compared with the 28 and 35 percent moisture silages. In all other studies, weight gains were not significantly different. The silages in Trial III, made from field picked corn, produced the best weight gains of any of the silages fed. In this trial, the 24 percent moisture silage produced the best weight gains though these gains were not significantly higher because of group variation. Maturity of the corn could be a factor in these silages. The abundance of different compounds plus the level of urea may have affected the gains in the feeding studies of Trial I and made a systematic analysis of results impossible. In Trial II, while there were

TABLE VIII: RESULTS OF HIGH-MOISTURE CORN FEEDING TRIALS

	Moisture	Number of Heifers	Average Daily Gains (lbs/day)	Feed Efficiency (lb DM/lb gain)	Feed Intake (lb DM/day)
Trial I					
Exp. I (46 days)	Control[a]	4	1.7	5.5	8.9
	28	8	1.6	6.2	8.9
	35	8	1.7	5.5	8.4
Exp. II (30 days)	Control[a]	4	2.6[d]	4.8	12.4
	28	8	1.6	9.0	11.5
	35	8	2.2	5.2	11.3
Trial II	Control[a]	6	2.3	5.5	12.7
	30	24	2.3	5.6	10.3
	45	24	2.2	3.8[d]	7.9[b]
Trial III	Control[a]	5	2.7	5.7	14.9
	24	10	2.9	5.7	16.4
	34	10	2.6	4.8[c]	12.0[b]
	40	10	2.5	4.9	11.5[b]

[a] Dry Corn.
[b] $P < 0.01$.
[c] $P < 0.25$.
[d] $P < 0.05$.

no significant differences in weight gains between different moisture contents, 1.0 percent monobasic calcium phosphate increased weight gains by 19 percent ($P < 0.12$) as shown in Table IX. In Trial I, Experiment I, silages with and without urea were fed. The average daily gains for these silages were 1.35 and 1.66, respectively.

TABLE IX: EFFECT OF MONOBASIC CALCIUM PHOSPHATE ON WEIGHT GAINS

Trial II	Number	Daily Gains (lbs/day)
No $CaH_4\ (PO_4)_2 \cdot H_2O$	24	2.06
1% $CaH_4\ (PO_4)_2 \cdot H_2O$	24	2.44

<u>Feed Efficiency</u>. In Trial I, there were no significant differences among silages. The feed efficiency of the 28 percent moisture silage of Experiment II appears as if it would be significantly higher, but the difference was primarily due to one animal. In Trials II and III, animals fed the wetter silages (34-45 percent moisture) required less ($P < 0.05$, $P < 0.25$) dry matter per pound of gain.

Feed Intake. Feed intake presented the same picture as feed efficiency. In Trials II and III, the heifers on the wetter silages ate less ($P < 0.01$) dry matter per day than heifers on the drier silage or the control ear corn. Further, there was a significant interaction ($P < 0.01$) between moisture and monocalcium phosphate in Trial III. There were no differences in feed consumption observed in the first two feeding studies of Trial I.

Correlations Between Animal Performance and Silage Quality Measurements

When the growth and chemical studies had been terminated, an attempt was made to correlate the data. The results are presented in Table X using 100-110 animals and 22 silages. There was a positive correlation with 60-day lactic acid and a negative correlation with 30-day acetic acid showing a difference for the two major acids found in silage.

Acreage Yields--Fermentation Loss

The third phase of this study pertains to factors in the storing and feeding of high-moisture corn that are not related to direct chemical reactions. Corn yields per acre were obtained in Trial III. The exact field area and yield were difficult to obtain because of an uneven field and limitations of the corn picker. The results are presented in Table XI.

TABLE X: CORRELATION COEFFICIENTS BETWEEN AVERAGE DAILY GAIN AND CHEMICAL COMPOSITION

Average Daily Gain vs. Silage Quality Measurements	Coefficients H.M.C.	Coefficients Gordon et al. (1961)[d]
1) 10-day pH	- 0.09	----
2) 60-day pH	- 0.13	- 0.56
3) 30-day Lactic Acid[a]	+ 0.03	+ 0.36
4) 60-day Lactic Acid[a]	+ 0.21	
5) 30-day Acetic Acid[a]	- 0.26	- 0.72
6) 60-day Acetic Acid[a]	+ 0.07	
7) Ammonical -N[b]	+ 0.18	- 0.89[c]
8) Lactobacilli (30-day)	- 0.27	----

[a]Dry matter basis.

[b]Wet basis.

[c]As percent of total nitrogen.

[d]Gordon et al., J. D. S., 44:1299:1961.

TABLE XI: THE EFFECT OF MOISTURE ON YIELD PER ACRE

Moisture percent	Dry Matter Yield (lb/acre)
24%	5,002
34%	4,724
40%	4,204

The fermentation loss from the silages in Trial III are presented in Table XII and reveal about a 5 percent loss in the silo when high-moisture ear corn is ensiled. It is interesting to note that as the moisture level decreased, the spoilage in the silage increased. Again, this may be a result of less compaction in the drier silages with the incorporation of air which provides a perfect media for the initiation of the spoiling processes.

TABLE XII: LOSSES IN HIGH-MOISTURE GROUND EAR CORN

	Moisture		
	40%[a]	34%[a]	24%[a]
Dry Matter Ensiled (lbs.)	12,192	13,226	15,006
Dry Matter Fed (lbs.)	11,995	11,584	13,374
Top Spoilage (dry matter)	532	913	1,146
Percent Recovery	103	94	97

[a]Mean value from 2 silos.

DISCUSSION

Since the objective was to study the physical and chemical effects of moisture level and different additive compounds on the feeding value and fermentation of ear corn silage, it was a necessity to study as many silages as possible and with as many additive combinations as possible. With the analyses of 26 silages, our objectives in part were obtained.

When urea was incorporated into the silage at 20 pounds per ton, there was a continual rise in pH. This increase could possibly be due to the neutralizing effect of ammonia from the breakdown of urea. At 15 pounds per ton, this effect on pH was not as drastic, especially when compared with the control silages. Klosterman _et al_. (1961a, b), ensiling the entire corn plant, found similar results of increasing pH with increasing levels of urea. In all cases, their pH values were lower than the values found with the ear corn silage in this work. Since Klosterman _et al_. (1961a, b) had found favorable results with limestone ($CaCO_3$), this compound was further investigated. The results were not favorable in this work which may have been due to the added urea. Further, Klosterman _et al_. (1961a, b) used a special grade of limestone which may have resulted in a different chemical picture.

The results with phosphoric acid did not improve animal performance or decrease ammonia odor possibly because of the level of urea combined with it in the silage. However, an indication of better results was observed with phosphoric acid at a concentration of 1.5 percent with the silage at 35 percent moisture. Further, research should be pursued on this mixture. One percent monobasic calcium phosphate produced favorable results at the lower level of urea (15 lb/ton). Monobasic calcium phosphate exhibits an acid reaction thereby depressing the initial pH. Higher moistures, which provide a suitable media for both chemical and bacteriological reactions, further depressed the pH.

Klosterman _et al._ (1961a) reported an increase in organic acids (acetic and lactic) with increased moisture and limestone. The results of the chemical analyses of organic acids in this study substantiate these findings, especially with the higher moisture levels. These data also showed an increased production of butyric and propionic acid with higher moisture although these results have not been reported elsewhere. One percent monobasic calcium phosphate increased the lactic acid content and decreased the acetic acid content. One possible theory on the mode of action of monobasic calcium phosphate is that it depresses the initial pH to a level where the first fermentation acid (acetic) is not produced. At lower pH's lactic acid production is stimulated, since lactic acid bacteria become the predominant organisms in this fermentation environment. Since more lactic acid is produced, a better silage results under these conditions. Further research is needed on this subject.

Acetic acid accounted for 1/3 to 2/3 of the total acid production in the silages of Trials I and II. Langston et al. (1962) working with aerated and sealed Orchardgrass and Alfalfa silages showed an increase in acetic acid content in aerated silages as compared to the content in sealed silages. Since in Trials I and II samples were removed from the top, the seal was removed each sampling time suggesting that these silages may have responded like aerated silages. In Trial III, where less acetic acid was produced, samples were removed through silo doors so that the seal remained intact resulting in less aeration and higher lactic acid production.

No reports on the breakdown of urea have been presented, but this study reveals a steady degradation of the compound throughout the fermentation period. A large percentage (75-99%) of the released ammonia was accounted for in the silage. The increase in crude protein can be accounted for from the added urea. These results correspond to those of Wise et al. (1944), Bentley et al.

(1955) and Gorb and Lebedinskij (1960) in that they report an increase in crude protein content with additions of urea.

Sherman and Bechdel (1918), Langston *et al*. (1958), and Langston and Bouma (1960a, b, c) reported a predominance of cocci in the early stages of the fermentation process followed by an increase in the higher and more active acid-producing rods with a subsequent decrease in cocci. A similar pattern of bacterial development was observed in the higher moisture silages. As the moisture level decreased more cocci were present throughout the fermentation. These results were not consistent in all observations. Since the lactic acid production in the 24 percent moisture silages was significantly lower than in the 34 and 40 percent moisture silages, this proposes two impressions about the bacterial counts in the 24 percent moisture silages: (1) the lower moisture level of the 24 percent moisture silages may have provided a growth media for the lower acid-producing cocci, and the higher acid-producing lactobacilli may not have been present in large enough numbers over a long period of time to grow and produce appreciable amounts of lactic acid; and (2) it is possible that at the lower moisture levels the species of lactobacilli present may have been different than those in the higher moisture silages.

Since ear corn silage exhibits a strong yeast smell, an attempt was made to plate these yeasts. Large numbers were present in all silages, but an increase was noticed in the drier silages. Zogg et al. (1961), working with shelled corn at different moisture levels, found a predominance of yeasts rather than molds when samples were taken within a foot of the top of the silo. The results of this study showed that yeasts were present throughout the silage since the samples were taken below one foot of the top. Entrapped air due to less compaction possibly enhanced yeast growth. Mold and anaerobe counts support this theory.

Silage temperatures in high-moisture corn have been reported by Lassiter et al. (1960) using various forms of soft corn at different moisture levels. The peak temperatures in their silages were attained in eight to ten days which corresponded to peak temperatures of six to twelve days in the present study. The peak temperature observed in the silages varied depending upon the moisture level. Some concern was raised over whether the silage was cooling off or actually heating, but outside temperature plus chemical data does not warrant concluding that the silages were cooling off during the fermentation period.

Animal performance has been reported by numerous researchers. Beeson et al. (1956), Beeson et al. (1957), Culbertson et al. (1957), Beeson et al. (1958), Beeson (1958), and Klosterman et al. (1961a) report that cattle require 4 to 15 percent less dry feed per unit of gain with ensiled high-moisture corn. Further, there was no significant difference for rate of gain between high and low-moisture corn. The data of this study warrant the same conclusions as to animal gains, but feed efficiency data were variable. These differences were possibly due to the various silage additives.

Dry matter yield per acre is an important consideration in the use of high-moisture corn. Ross and Rea (1959) report that higher dry matter yields per acre were obtained when corn was picked wet as compared to picking as number two corn. The data of this study are in direct disagreement with the results of Ross and Rea (1959). Difficulty in measuring the field area plus extreme wastage by the corn picker may have affected the results. Further research should be conducted on this problem.

The loss in dry matter during fermentation is another phase of silage making where the farmer is confronted with a problem. This loss can amount to 0-30 percent or higher depending upon crop quality, the physical features of the silo and the care, knowledge, and precision in ensiling the crop. At the present time only a small amount of research has included results of the dry matter losses occurring in the silo when high-moisture corn is ensiled. Klosterman _et al_. (1960b) report that the total dry matter losses between the amounts stored and amounts fed for limestone-water treated silage (46 percent moisture), untreated silage (40 percent moisture), and dry ear corn were 16.8, 16.5, and 12.6 percent of the amount stored, respectively. In this study losses in the silo including top spoilage were not over 6.0 percent. Further, Lassiter _et al_. (1960) reported that corn containing 25 to 35 percent moisture produced the least spoilage. The results in this study show just the reverse situation with these two moisture levels producing more spoilage than 40% moisture silage. This problem is not settled as can be seen from the conflicting results.

When the results of the chemical phase and the feeding phase were correlated, there was a direct relationship between the results in this study and the results of Gordon _et al_. (1961). This was true with the exception of ammonical-N, but there was a difference in the basis of calculation. On the basis of the correlation coefficients, it would appear that at the present there is still no direct chemical measurement with the exception of lactic acid and acetic acid to measure the nutritive value of silages. Ammonical-N and pH, the popular criteria for measuring silage quality, were of no value for predicting animal performance in this study.

SUMMARY

In a two-year study, high-moisture ground ear corn was ensiled at different moisture levels and with the addition of different chemical compounds. The chemical products from the resulting fermentation were studied using 26 different silages. Bacteriological and temperature studies were also conducted using six silages. Twenty-two of the twenty-six silages were utilized in growth studies using Holstein heifers to study the nutritive value of the fermented corn. Following the completion of the chemical, bacteriological, and growth studies, correlation coefficients were run in an attempt to correlate the chemical quality of the individual silages with animal performance.

The effect of urea upon the pH was noted as silages with 20 pounds of urea per ton increased in pH throughout the fermentation period. With 15 pounds of urea per ton, this effect was not noted. The silages containing 20, 15, and 0 lb. of added urea had an initial pH of 4.7, 6.0, and 6.3; but following 60 days fermentation the pH had changed to 7.4, 5.1, and 5.2. In a second trial there was a depression ($P < 0.01$) of pH with high moisture and with the addition of 1.0 percent monobasic calcium phosphate. The effect of moisture content was

studied in a third trial as 40 and 34 percent moisture silages depressed the pH ($P < 0.01$) whereas the opposite effect was noted with the 24 percent moisture silages.

There was no direct pattern for butyric and propionic acid production in individual silos, but there was a tendency for more butyric and propionic acid production in the higher moisture silages (34-45% moisture). One percent monobasic calcium phosphate reduced the concentration of these two acids at higher moisture levels. In all three trials acetic and lactic acid were significantly higher at the higher moisture levels. Lactic acid was increased and acetic acid decreased with the addition of 1.0 percent monobasic calcium phosphate.

In general, 50 percent of the urea was broken down within 20 days and 80 percent within 60 days. Monobasic calcium phosphate significantly depressed ($P < 0.01$) the rate of breakdown of urea in one of two trials. There was a significant increase ($P < 0.01$) in crude protein with additions of 20 pounds of urea. In two trials there were slight increases ($P < 0.23$), ($P < 0.25$) in crude protein with the higher moisture silages. This effect was not noted in a third trial.

The ethyl alcohol content of the silages was increased in the higher moisture silages. The average content was 0.2 percent.

The total microbial counts were within the same log range for 40, 34, and 24 percent moisture silages. Lactobacilli counts decreased in the 24 percent moisture silages. The mean log counts of Lactobacilli from the 45- and 60-day samples for 40, 34, and 24 percent moisture silage were 8.3, 8.6, and 7.9. Yeast counts increased and anaerobe counts decreased with decreasing moisture.

With the exception of one growth study, there were no significant differences in weight gains when ensiled ground ear corn (24-45% moisture) was compared to ground dry corn. One percent monobasic calcium phosphate increased gains by nineteen percent. In two growth studies, animals fed the wetter silages (34-45% moisture) required less ($P < 0.05$, $P < 0.25$) dry matter per pound of gain than heifers fed the drier silages. This same pattern developed with feed intake as the heifers fed the wetter silages consumed less ($P < 0.01$) dry matter per day than the heifers on the drier silages.

Correlation coefficients using average daily gain and silage quality measurements showed a negative correlation with 30-day acetic acid and a positive correlation with 60-day lactic acid and average daily gain. There was a negative correlation with both 10- and 60-day pH and average daily gain.

Fermentation loss in the silage averaged three to six percent regardless of the moisture level.

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