THE NUTRITIVE VALUE OF CORN SILAGES CONTAINING CHEMICAL ADDITIVES AS MEASURED BY GROWTH AND MILK PRODUCTION OF DAIRY ANIMALS

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ABSTRACT

THE NUTRITIVE VALUE OF CORN SILAGES CONTAINING CHEMICAL ADDITIVES AS MEASURED BY GROWTH AND MILK PRODUCTION OF DAIRY ANIMALS

by William G. Schmutz

The nutritive value of corn silage containing urea, diammonium phosphate, calcium carbonate and dicalcium phosphate additives was studied over a two year period. The fermentation pattern and feeding value of thirteen silages were determined.

The initial and final pH values for two untreated silages were 5.1, 3.6; and 5.4, 3.6, respectively. There was a slight increase in these values for a single additive regardless of whether the additive was urea, diammonium phosphate or calcium carbonate. Additive combinations increased the pH more than single additives ($P < 0.01$). No significant differences in pH were observed among silages containing either urea or calcium carbonate.

Urea and diammonium phosphate additions increased the crude protein equivalent of the treated silages ($P < 0.01$ and $P < 0.05$ for both additives). In general, the crude protein equivalent of the treated silages increased in proportion to the level of urea added to the silages. The percent of the theoretical crude protein recovered ranged from 85 to 89 percent, while the percent of N.P.N. (non-protein nitrogen) lost ranged from 32 to 45 percent.

All additives resulted in increased organic acid production compared to the control silage. The range of acetate and lactate production expressed on a dry matter basis was 1.08 to 2.28 and 8.42 to 13.06 percent, respectively. Chemical combinations increased lactate production in both years (probability 0.05 and 0.10) and acetate production in the 1964-65 silages ($P < 0.05$), while silages with added calcium contained greater amounts of acetate and lactate in the 1964-65 silages (probability of 0.05 and 0.10) and lactate in the 1963-64 silages ($P \gtrsim 0.10$).

Calcium carbonate or diammonium phosphate additions increased the ash content, while added N.P.N. compounds increased the crude protein equivalent of the treated silages.

In growth trials, heifers made adequate live body weight gains when fed treated corn silages. In the first trial, differences between two 0.5 percent urea silages with different calcium compounds were not significant. In a second trial, heifers receiving the silages containing 0.5 percent calcium carbonate either alone or in combination with 0.5 or 0.75 percent urea made lower gains per day than heifers receiving either the untreated control silage or the 0.5 or 0.75 percent urea silages. This difference was significant (probability range of 0.05 to 0.01) for the 0.5 percent calcium carbonate and the 0.5 percent calcium carbonate plus 0.75 percent urea silages. Those heifers receiving the silages with urea serving as the only chemical additive made slightly better gains (probability range of 0.05 to 0.01) as the levels of urea increased.

In lactation studies, animals receiving the silages containing 1.0 percent diammonium phosphate consumed less (probability range of 0.05 to 0.01) silage dry matter per day, dry matter per hundred pounds of body weight, total dry matter, and total digestible nutrients (T.D.N.) per day and produced less 4.0 percent fat corrected milk (F.C.M.) per day. This depression in intake did not occur when 0.5 percent calcium carbonate was used either alone or in combination with diammonium phosphate. In a second lactation study, silage containing 0.75 percent urea followed a similar pattern as the 1.0 percent diammonium phosphate silage in the previous study except that 0.5 percent calcium carbonate did not improve performance when added in combination with 0.75 percent urea. In this study, cows consuming the 0.5 percent urea silages produced the most 4.0 percent F.C.M. per day.

In digestibility studies, there was a slight, but non-significant depression in apparent digestibility of dry matter, ash, and protein in the silages containing urea. No definite trends were noted in the biological values of silage proteins and definite conclusions could not be formed. The loss of silage dry matter during storage averaged 8.6 to 11.0 percent.

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INTRODUCTION

Moir (1965) compared the physiology of ruminant-like animals and concluded that because of their type of digestion, plant evolution has favored those animal species which are able to consume and utilize forages, and specifically the plant constituent, cellulose. Because of this advantage which ruminants have over other animal species, the development of methods to improve the utilization of forages has become of predominant interest. While the use of pasture represents the most economical forage for ruminant animals, its use as a year-around crop is limited by climate. Green forage crops preserved as silage provide a source of highly nutritious roughage during the times when pasture is either not available or of poor quality. Of all silage crops, the corn plant represents the most nutritious forage from the standpoint of expected total digestible nutrients harvested per acre.

While the corn plant is highly nutritious, it is low in such constituents as protein and calcium. In recent years much research has been devoted to increasing these constituents in corn silage in efforts to improve its feeding value. Such non-protein-nitrogen compounds as urea, biuret, and diammonium phosphate have been ensiled or fed with corn silage to supplement the total nitrogen content, while limestone or calcium carbonate have been used to increase the calcium content as well as to permit increased chemical fermentation. Research, thus far, has shown considerable feeding value from the addition of urea to corn silage, while results from other added compounds, either non-protein-nitrogen or mineral, are still questionable. If one considers that, in the year 1964, 3,685,000 tons of corn silage were produced in the state of Michigan, this represents a potential market for 36,850,000 pounds (10 lbs. per ton) of urea which could be added to this silage to improve the total nitrogen content (Michigan Agricultural Statistics, 1965). However, the most desirable level of urea to be added to corn silage is still an unanswered question.

The purpose of the investigation described in this thesis was to more accurately determine the optimal urea level in corn silage, and explore the use of other compounds. Data are presented on the chemical and nutritive value of corn silages ensiled with additions of calcium carbonate, urea and diammonium phosphate, both separately and in different combinations.

REVIEW OF LITERATURE

Much of the recent research dealing with corn silage has been devoted to means of improving its nutritive qualities as a feed for livestock. The question of using chemical additives as a means of improving total nitrogen content or prolonging fermentation processes has been of predominant interest.

Nutritive Value of Corn Silage

Corn silage has been used as a roughage source for most domesticated ruminants for maintenance, growth or lactation. The potential value of corn silage must be considered depending upon whether it forms the complete or partial roughage source in these rations.

Relative Feeding Value for Growth and Fattening

Stadler (1930) stated the following about corn silage: "Corn is the preeminent silage crop, because of its heavy yield of nutritious and palatable forage, because when it is ensiled it undergoes changes of the most desirable kind, and because it is a standard and adapted crop over a large part of the country." Nevens (1936) also emphasized that corn preserved as silage had more feeding value than corn crops utilized in other ways.

Corn silage has been extensively used as a source of roughage for growth, fattening, and wintering rations. Eckles (1918) over a period of several years examined various rations for wintering dairy heifers. Legume hay, grass hay, grain mixtures and corn silage were tested alone or in combination. The data show that only fair results could be expected from feeding silage alone and generally about two pounds of concentrates per head should be fed, of which one-half was a high-protein feed. The range of corn silage intakes was from 17 to 21.4 pounds per day with an average daily gain of 0.71 pound compared with 0.77 pound for normal growth. Eckles cited the low protein content of corn silage and the inability of the animal to consume enough feed as limiting factors. Converse and Wiseman (1952) grew normal dairy heifers from birth through at least one lactation on milk (to 6 months of age), and a 25 percent crude protein grain mixture and corn silage as indicated by body weights and wither heights.

Corn silage has been and is now extensively used in beef fattening rations. Livesay _et_ _al_. (1940) studied the value of stover silage (ears removed), normal silage, and ear silage when fed to yearling steers and young bred cows. Sixteen yearling steers divided into two lots were fed as follows: Lot (1): For the first 70 days of the 126 day experimental period: 20 pounds of normal corn silage, 4.0 pounds mixed hay, and 1.5 pounds cottonseed meal. For the remaining 56 days, 20 pounds of ear silage replaced the normal silage. In the second lot, an identical ration was fed for the full 126 day period, except stover silage replaced ear and normal silage on an equal dry matter basis. The results of this experiment indicated that the normal silage dry matter was only slightly superior to stover silage dry matter; however, when the dry matter in 20 pounds of ear silage was compared with an equal amount of stover silage dry matter, the ear silage produced marked increases in gains. In a second experiment, similar results were obtained with young bred cows except that the normal silage dry matter was superior to the stover silage dry matter. Hammes et al. (1964) have also reported good gains for fattening beef cattle with corn silage rations. The gains were not significantly depressed when steers were fed limited cottonseed meal plus corn silage as 80 to 100 percent of the forage dry matter intake compared with steers fed a conventional high grain fattening ration.

In the growth of dairy heifers, Camburn et al. (1942) conducted two 120 day trials in which the following treatments were used: (a) sun cured timothy hay, (b) corn silage, and (c) timothy molasses silage and (d) artificially dried timothy hay. Some grain mixtures were fed, but not over 3.0 pounds daily. In the second trial corn silage was the superior roughage; however, the authors concluded that poor quality silage prevented this effect in the first trial. Miller and Morrison (1950) wintered beef cows on mixed hay fed alone (U.S. No. 2 mixed legume and timothy hay, 30-50 percent legumes) or a ration of mixed hay and corn silage. The average daily gains for four trials for the mixed hay and the mixed hay plus corn silage treatments were 0.34 and 0.35 pound, respectively. However, Martz et al. (1964) used four groups of ten Guernsey heifers to study the comparative value of corn silage, oat hay and orchardgrass hay when supplemented with energy, protein, minerals and vitamins in a 118 day feeding period. In this trial, the group receiving free choice corn silage consumed more energy and gained significantly faster than the remaining three groups. The average daily gains for the groups receiving free choice corn silage, corn silage plus free choice oat hay, free choice oat hay, and free choice orchardgrass hay were 1.34, 0.84, 0.69, and 0.93 pounds, respectively, while the total digestible nutrients per animal per day for the same groups were 10.92, 10.25, 10.73, and 10.63 pounds, respectively. All groups received between two and four pounds of either a special supplement or a herd ration. Branaman and Davis (1942) reported that a molasses treated legume silage produced better gains than either corn silage or legume hay when these roughages were full fed as part of a fattening ration. However, the quality of the corn silage used in this study was thought to be inferior because of insect infestation and drought.

Harshbarger et al. (1956) compared rye silage in the pre-bloom and early dough stage of development with corn silage in a heifer growth trial. The silage consumed per animal for the early dough rye silage (28.1 percent dry matter), corn silage (29.9 percent dry matter), and the pre-bloom rye silage (19.5 percent dry matter) was 20.9, 25.0, and 27.2 pounds, respectively, while the average daily gains for the 112 day period were 1.02, 1.70 and 1.21 pounds per day, respectively. A grain mixture at a level of three to four pounds per day was fed at different periods during the trial.

Relative Feeding Value for Lactation

While the feeding value of corn silage has been recognized for many years, an extensive amount of research pertains to its value when added to control rations or when used to partially replace another roughage. Carroll (1924) studied the effects of adding corn silage to a basal ration of ad libitum alfalfa hay and a low rate of grain feeding. Grain and ad libitum hay were fed as the control ration. The reversal method of feeding was used with four experimental periods and two lots of seven cows. The actual silage consumption for both years of the experiment was only 24.6 pounds per day. However, 1.9 percent more milk and 3.9 percent more butterfat were produced on the silage ration than on the non-silage ration, while the weight gains on these same rations were 11.5 and 9.5 pounds per cow, respectively. In this study 2.49 to 2.95 tons of corn silage replaced one ton of alfalfa hay. Huffman and Duncan (1954b) indicated that 100 pounds of corn silage was equal to 22 to 27 pounds of hay and contained 13 to 17.4 pounds of grain. Similar results to those of Carroll (1924) had been reported from the Indiana Experiment Station by Fairchild and Wilbur (1925). These workers found that milk production of cows receiving no silage decreased an average of 16.3 percent in each 28 day period of the experiment, whereas the production of those receiving silage remained approximately the same or increased slightly. Greater weight gains were also made on the silage ration. Converse (1928) fed nine cows on similar rations to the two previously mentioned studies at approximately 106 percent of the Savage Total Digestible Nutrient Requirement and reported that 2.8 percent more milk and 4.2 percent more butterfat were produced on the non-silage ration. However, the hay and grain ration contained more digestible protein than the silage ration.

While corn silage has been shown to have considerable nutritional value for lactating cows, the belief that an unidentified grain factor or factors was present in the silage has been reported from the Michigan Experiment Station. Huffman and Duncan (1954a) studied milk production when a portion of the total digestible nutrients in an all-hay ration was replaced with corn silage. Nine trials using eight Holstein cows were conducted in which the cows were fed an all-hay ration until a plateau resulted in milk production. At this point, corn silage replaced part of the hay, on an equal total digestible nutrient basis, so that approximately 36 pounds of hay were consumed per day in the depletion period, and 15 pounds in the experimental period. Silage was consumed at a rate of approximately 55 pounds per day. Within the first 15 days of the experimental period, milk production was increased from 18 to 23 pounds, however, total digestible nutrient consumption was slightly less in the experimental period as compared to the depletion period as well as a decline in body weight. The authors concluded that a pound of total digestible nutrients in a corn silage-hay ration was of more value than an equal amount of total digestible nutrients from an all-hay ration. These authors postulated that the grain of the silage contributed an unidentified grain factor or factors necessary to balance the all roughage diet. Similar evidence for the unidentified grain factors has also been reported by Huffman and Duncan (1954b), and Dunn *et al.* (1954). Huffman and Duncan (1954b) also suggested that previous efforts failed to show an increase in milk production from the grain in corn silage because of the large amounts of grain included in the rations. Dunn *et al.* (1955) compared corn silage and recombined corn silage (grainless corn silage plus dried ground ear corn recombined with the grainless corn silage at the approximate levels of regular corn silage) for milk production. The fat-corrected milk (F.C.M.) produced, body weight gains and amount of digestible protein ingested were similar for both silage feeding periods which indicated that the grain in corn silage was of the same nutritive value as corn and cob meal.

Other factors which may effect the value of corn silage in dairy cattle rations are the stage of maturity of the corn plant at ensiling time and the optimum level of corn silage feeding. Bryant et al. (1965) compared milk and medium hard dough corn silages supplemented with either cottonseed meal or alfalfa-orchardgrass hay plus grain. Milk production, persistency of production and silage consumption were higher for the more mature silage. Similar results have been reported by Huber et al. (1963) and Huber et al. (1965).

The optimum level of silage feeding has been studied by Pratt and White (1930). Timothy hay (ad libitum) and grain (1:3 grain-milk ratio) were included in a ration with corn silage fed at a daily rate of 36 and 18 pounds. Four percent F.C.M. for the high and low silage groups was 22.08 and 21.84 pounds per day, respectively, while total group dry matter consumption was 9,370 and 8,901 pounds, respectively. The low silage group lost more weight but produced more milk per unit of dry matter than the high silage group. However, Brown et al. (1965) reported that cows fed corn silage as the only roughage for a complete lactation produced as much milk and milk fat as similar cows fed alfalfa hay or a combination of silage and hay. Roughage dry matter consumption increased as the level of hay in the ration increased from 0 to 100 percent.

Converse and Wiseman (1952) reported an increase in milk production for cows fed a grain mixture (grain to 4 percent F.C.M. ratio of 1:1.2 to 1:2.1) and corn silage (17.2 to 36.5 pounds of silage per day) compared with cows fed a grain, hay, pasture ration. Some of the cows receiving corn silage had been raised from early life on a grain-silage ration.

While corn silage has gained considerable merit as a roughage for cattle rations, most of the research in the past fifty years pertains to its animal productivity value when compared with other grass or legume silage crops or dry roughages. Reed and Fitch (1913) compared corn silage and two sorghum silages (kafir and cane sorghum) for milk production when fed with grain (according to production) and hay. In a reversal type design, cows fed corn silage produced more milk but gained less weight than when fed either of the two sorghum silages. In a similar report, Cunningham and Kenney (1917) observed that kafir silage was about equal to corn silage but corn silage was superior to sweet sorghum silage. In another experiment, these three silages proved about equal for maintenance of beef calves. Cunningham and Reed (1927) using honeydrip sorghum silage and La Master and Morrow (1929) using sweet sorghum silage reported similar results. Cunningham and Reed (1927) reported little difference in the weight gain of cows when fed the two silages. In all of these studies, the silages were fed with either hay and a grain mixture or a simple grain mixture.

Owen _et_ _al_. (1957), Owen _et_ _al_. (1959), Haenlein and Richards (1961), Lance _et_ _al_. (1964), and Rahman and Leighton (1965) reported increased milk production for cows fed corn silage as compared to some specie or type of sorghum silage. Owen et al. (1957) and Lance et al. (1964) observed that cows fed corn silage consumed significantly more silage or silage dry matter than those fed sorghum silage, whereas Owen et al. (1959), Haenlein and Richards (1961) and Rahman and Leighton (1965) found almost no differences in dry matter consumption between the two silages. Body weight changes were also variable. Owen et al. (1957) reported highly significant body weight changes in favor of the cows receiving corn silage, whereas Haenlein and Richards (1961) and Rahman and Leighton (1965) reported greater weight gains with sorghum silage. Lance et al. (1964) found that cows fed sorghum silage gained significantly more body weight than those fed corn silage in one experiment, but the differences were not statistically significant in a second experiment. Owen et al. (1959) reported that corn silage produced 0.7 pound body weight gain per day, Axtell sorghum silage, 0.7 pound per day, and a forage sorghum hybrid (RS 303F) 0.6 pound per day, respectively. Browning et al. (1961) used a switchback design with 18 lactating cows and 28 day periods to compare corn, an intermediate forage type grain sorghum and a combined grain sorghum silages. Silage was fed ad libitum along with 0.5 pound of alfalfa hay per 100 pounds of body weight and a grain mixture. The dry matter consumption per 100 pounds of body weight was highest for the sorghum silages. The average persistency values for cows fed corn silage, intermediate and combined grain sorghum silages were 80.5, 78.0 and 117.5 percent, respectively. Brannon et al. (1965) compared Tracy and Sart Sorghum silage harvested in the soft dough stage with corn silage harvested in the soft dough stage. Cows fed the Sart and Tracy sorghum silages produced 97 and 98 percent as much milk as the corn silage groups with a lower average silage dry matter consumption. However, when cows were fed corn silage and Tracy sorghum silage ensiled in the milk or hard dough stage, both sorghum silage groups produced slightly more milk and consumed more silage than the corn silage group.

Corn silage has also been compared with clover hays and silages. Clark (1913) compared two rations in which grain, clover and alfalfa hay were compared with grain, clover and alfalfa hay and corn silage harvested in the milk stage. Little difference was noted between the clover hay or corn silage in cost of production, and production of milk or fat. Greater live-weight gains were made on the corn silage ration. Atheson and Anderson (1935) compared sweet clover silage and corn silage in rations for milk production and found that the two silages were comparable in productive value even though less total digestible nutrients and digestible crude protein were consumed per 100 pounds of 4.0 percent milk on the clover silage. In an Arizona study (1917), no difference was observed in milk and fat production of cows fed either 20 pounds of alfalfa hay plus 35 pounds of corn silage or 30 pounds of alfalfa hay. Foster and Meeks (1920) in a similar study found that milk production was 4.0 percent greater on an alfalfa ration than on an alfalfa hay-corn silage ration.

Hinton and Wylie (1940) treated first cut alfalfa silage and first cut Lespedeza sericea silage with a molasses-phosphoric acid mixture and compared these silages with corn silage. The moisture content in both legume silages was adjusted to 70 percent, and both silages were fed with ad libitum ground alfalfa hay and 10 pounds of a grain mixture. The milk and fat yields for the corn silage, lespedeza silage, and alfalfa silage were 12,599, 555.5; 11,740, 506.5; and 13,277, 566.8 pounds, respectively, over a period of 120 days. However, Hegsted et al. (1939) comparing A.I.V. alfalfa silage, molasses alfalfa silage and corn silage found that milk production was equally satisfactory for rations containing these silages. Waugh et al. (1943) also observed little difference between a molasses treated alfalfa-bromegrass silage and corn silage in F.C.M. and fat production per day (27.9, 1.13 and 27.3, 1.12 pounds, respectively). However, cows fed the corn silage gained slightly more weight than those fed the alfalfa-bromegrass silage. Camburn et al. (1942) in comparing rations containing corn silage or grass silage reported that more 4.0 percent milk equivalent was produced on the corn silage than on grass silage, but in all cases cows receiving corn silage consumed more digestible nutrients. Pounds of milk produced per pound of total digestible nutrients on the corn and grass silage were 1.87 and 1.81, respectively.

Corn silage has also been compared with other crops such as oats, vetch, sunflowers, ryegrass, and Bermuda-grass. King (1944) compared corn silage, molasses oat-silage, and phosphoric acid-oat silage when fed to milking cows. The average 4.0 percent F.C.M. production per day and the average decline in production during the 18 week experiment for these groups were 37.6, 5.0; 36.6, 7.7; and 33.5, 8.7 pounds and percent, respectively. The intake of total digestible nutrients and live weight gains were also highest for the corn silage group; however, 4.0 percent F.C.M. produced per pound of TDN was highest for the

molasses oat silage group. Lassiter _et al._ (1958) compared corn silage and oat silage for milk production and found that oat silage was superior to corn silage when 63 percent of the total roughage was supplied as oat silage. However, when the proportion of the total roughage intake supplied by silage was increased to 77 percent, corn silage was superior. Jones (1922) reported that cows fed oat and vetch silage produced more milk and fat than cows fed corn silage but that sunflower silage was inferior to corn silage when fed with a hay and grain ration. In a report from the California Experiment Station (1922) undesirable silage from the standpoint of consumption was produced when sunflowers were cut at an early stage of growth and compared with corn silage. However, Atkeson (1935) found that sunflower silage was about equal to corn silage for milk production when fed with alfalfa hay and a grain mixture at a 1:2.5 or 1:3.0 ratio. Sunflower silage was more efficiently used for milk production, but corn silage was more palatable and the cows showed a preference for the corn silage.

Arnold and Crockett (1964) compared boot stage ryegrass silage and early dent stage corn silage in milking trials in which the silages were fed with alfalfa hay at a rate of 0.5 pound per 100 pounds body weight and concentrates at a ratio of 1:3. The average daily pounds of 4.0 percent milk per cow fed corn silage or ryegrass silage for two different years were 26.8, and 28.2 pounds for 1962, 25.3, and 26.3 pounds for 1963, respectively, while the silage dry matter intake per 100 pounds of body weight for these silages was 1.23, 1.40, and 1.57, and 1.51 pounds, respectively.

In other experiments in which corn silage was compared with other forages, Bender et al. (1937) found that grass silage would replace hay or corn silage without altering the production level, whereas Woll and Voorhies (1917) reported that similar amounts of milk were produced when Indian corn silage, Sudan grass silage, or sweet sorghum silage were used as supplements in a ration of alfalfa hay, with or without grain. However, the sorghum silage was more efficiently utilized (returns per 100 pounds dry matter) than the corn silage, while the corn silage was better in this respect than Sudan grass silage. Zogg et al. (1961) fed 27 lactating cows either corn silage and hay, oat silage and hay, or sorghum silage and hay with high moisture corn at three levels of moisture (22, 26, and 32 percent). When these were fed with a soybean oil meal-mineral mixture, significantly less dry matter was consumed by cows receiving oat silage as compared with those fed the corn or sorghum silages. The oat silage was higher in moisture content than the other silages which may have accounted for the differences in intake. Cows fed the sorghum or oat silage were not as persistent in milk production as the cows fed corn silage. Significantly less milk was produced by the oat silage group as compared to the other two groups.

Miller et al. (1965) fed Coastal Bermudagrass pellets, corn silage, or a 50:50 Bermudagrass-corn silage mixture ad libitum to groups of six cows in an eight week experiment. These rations were fed with long Coastal Bermudagrass hay at three pounds per day and concentrates at a 1:3 ratio of F.C.M. established from the standardization period. The adjusted milk production averages for the last week of the experiment for cows fed pellets, silage or the 50:50 combination were 27.5, 29.3, and 34.3 pounds per cow per day, respectively. In the same order the forage dry matter intakes were 29.0, 23.7 and 31.5 pounds per day. The increased dry matter consumption of the 50:50 combination was statistically significant.

Digestibility of Corn Silage

Schneider (1947) in comparing the composition and digestibilities of many feeds found throughout the world reported the average digestibility coefficients of regular corn silage for organic matter, crude protein, crude fiber, nitrogen-free extract, and ether extract as 72, 49, 72, 74 and 79 percent for cattle, while for sheep these values were 70, 53, 65, 76 and 82 percent, respectively. Huffman and Duncan (1960) studied corn silages over a 17 year period. Digestibility coefficients were determined on eight of these silages, in which the silage intakes when fed to cattle ranged from 31 to 49 pounds per day. The digestibility coefficients for dry matter, organic matter, protein, ether extract, crude fiber and nitrogen-free extract were 66.8, 67.8, 52.8, 73.7, 60.8 and 73.4 percent, respectively. Bryant et al. (1965) in comparing corn silages harvested at different stages of maturity reported dry matter digestibility coefficients of 66.7 and 68.6 percent for immature (milk) and mature (medium hard dough) silages, respectively. Huber et al. (1965) reported the coefficients of apparent digestibility of a hard dough silage for crude protein, fiber, nitrogen-free extract and ether extract to be 54.8, 63.7, 70.4, and 79.5 percent, respectively. Cattle, fed ad libitum silage and supplemental soybean meal, were used as experimental subjects. Hammes et al. (1964) studied high silage rations for beef steers when full fed and found that the apparent digestion coefficients for dry matter, crude protein, ether extract, crude fiber and nitrogen-free extract were 68.1, 55.6, 77.9, 57.0 and 75.4 percent, respectively, with a total digestible nutrient content of 70.6 percent. Data for the digestion of stover silage, normal corn silage and ear silage have been reported by Livesay et al. (1940) using steers, while Dunn et al. (1955) have presented data for both regular corn silage and recombined corn silage using dairy cows.

The Use of Chemical Compounds to Improve the Nutritive Value of Corn Silage

Urea and Other Non-Protein-Nitrogen Compounds

The corn plant is comparatively low in crude protein content. Morrison (1957) stated that the analysis of 237 samples of well-eared, well-matured corn silages gave an average crude protein value of 2.3 percent of the fresh material. The same value was quoted by the National Research Council (1958). Thus the low protein content of the corn plant might be altered by crop fertilization or by feeding a protein supplement. Bender and Prince (1934) could not improve the protein percentage of the corn plant with nitrogen fertilization up to 450 pounds per acre. Generally, the yield was increased which resulted in an increased yield of total protein. Harshbarger et al. (1954) increased the protein content of the leaf-stalk fraction of corn silages with fertilizer, but the crops were grown on soils which were low in plant food.

Since fertilization has not produced consistent and dependable increases in the nitrogen content of the corn plant or silage made therefrom, the addition of protein supplements has been necessary for this purpose. The addition of protein supplements is expensive when considered on the basis of the price per pound of protein. Since ruminants have the ability to utilize the nitrogen from non-protein-nitrogen compounds, these supplements which are more economical, must be considered. Palatability problems may result when non-protein-nitrogen compounds are incorporated into the feed at the time of feeding, so that the use of these compounds at the time of ensiling warrants further study. Urea is probably the most commonly used compound for this purpose. Bentley _et al._ (1955) ensiled corn silage with 17, 20 and 25 pounds of urea per ton. In addition, 20 pounds of urea and 2.0 pounds of dicalcium phosphate were added to one silage. The crude protein (dry basis) for a control, control plus 17 pounds of urea per ton; control, control plus 25 pounds of urea per ton; control, control plus 20 pounds of urea per ton; and control plus 20 pounds of urea and 2.0 pounds of dicalcium phosphate per ton was 9.3, 15.1; 8.9, 19.9; 8.2, 14.6; and 13.4 percent, respectively. Brooks _et al._ (1965) added supplements to fresh corn fodder or corn silage. Those with supplements containing limestone and urea ensiled with these forages had higher crude protein values. Wise _et al._ (1944) ensiled corn silage with the addition of 5.0 gallon of a urea solution (2.0 pounds of crystals per gallon, 46 percent nitrogen) per ton of silage and found that crude protein of the treated and untreated silages was 10.79 and 7.48 percent, respectively. Increases in crude protein content have also been reported by Gorb and Lebedinskij (1961) using 0.65 percent urea; by Goode (1955) using 0.5 percent urea per ton, by Palamaru et al. (1961) using 0.5 percent urea, and by Klosterman et al. (1961). Klosterman et al. (1962) and Klosterman et al. (1963) suggested that urea added to corn silage could replace a portion of the protein supplement when fed to cattle. Hoffman and Fix (1965) reported that in a series of 70 maize silage samples, in which approximately 4.0 kilograms of urea per ton were added, the crude protein content averaged 1.99 percent with a range of 0.84 to 3.26 percent on a fresh basis.

Urea has also been added to sorghum silage to increase crude protein content. Means (1945) compared an untreated sorghum silage with sorghum silage treated with 10 pounds of urea per ton and found that the urea silage contained approximately 41 percent more crude protein and 10 percent less moisture than the non-treated silage. Davis et al. (1944) treated sweet sorghum with urea in a water solution at a rate of 0, 10, 30 and 50 pounds of urea per ton. Crude protein determinations revealed migration of nitrogen within the silos, but very little of the urea was changed from its original form from the time of ensiling until after the silage was removed from the silo.

Hydrogen Ion Concentration and Acid Production in Urea Treated Silages

In further attempts to improve the nutritive value of corn silages, chemical compounds, such as calcium carbonate, high calcium and dolomitic limestone, and urea, have been ensiled with forage to prolong fermentation. These compounds, because of their chemical action, stimulate the total acid production within the silage and specifically lactic and acetic acids. Barnett (1954) emphasized the fact that the aim in silage production was to stimulate lactic acid production to such a point as to inhibit other bacterial activity and preserve the crop. Watson and Nash (1960) stated that "The percentage of lactic acid in silage varies somewhat but in good silage samples will range between 1 and 2 percent of the weight of the fresh silage. If conservation is to be efficient the lactic acid should reach the neighborhood of 1 percent and should always exceed in amount the volatile acids." It was also noted that acetic acid should generally range from 0.5 to 0.9 percent of the fresh material. Barnett (1954) also stated that lactic acid should be at a concentration of 1 to 1.5 percent of the fresh material in normal silage.

While limestone and calcium carbonate have been shown to stimulate acid production, non-protein-nitrogen compounds, which are generally added to improve the nitrogen content of corn silage, also acts to prolong acid production. Klosterman et al. (1963) reported that urea was not as strong an adjunct as either limestone or calcium carbonate; however, Karr et al. (1964) indicated that this compound altered the fermentation to some extent. Cullison (1944) added urea to sweet sorghum as it entered the silo at an approximate rate of 10 pounds per ton. An untreated silage was also prepared. The results indicated that the treated silage had more total titratable acids, but the untreated silage a lower pH. Bentley et al. (1955) ensiled corn silage with various levels of urea. The pH values for a control corn silage, control plus 25 pounds of urea, control corn silage, control plus 20 pounds of urea, and a control plus 20 pounds of urea and 2.0 pounds of dicalcium phosphate were 4.70, 7.60, 3.70, 4.05 and 3.95, respectively.

Klosterman et al. (1963) reported that the pH for a control, 0.5 percent urea, and 1.0 percent urea whole plant corn silage was 3.8, 4.1 and 4.4, respectively. The percent acetic and lactic acid on a dry matter basis for these same silages were 1.51, 8.33; 1.90, 8.71; and 1.71, 12.00, respectively.

Relative Feeding Value

Urea has probably been used more extensively than any other non-protein-nitrogen compound as a nitrogen extender in sheep, beef, and dairy cattle rations. Reid (1953) reviewed the research which has been conducted on the utilization of urea when included in ruminant rations as well as the many factors influencing the utilization of this compound. Owen (1941) has also partially reviewed some of the research up to the period of 1941. More recently McLaren (1964) reviewed the metabolism of nitrogenous and non-protein-nitrogen compounds in ruminants. While an extensive amount of research has been done on the nutritive value of urea when added in its original form to a ration, the addition of urea to low protein silages has been extensively studied in recent years. Woodward and Shepherd (1944) ensiled corn silage with 10 pounds of urea per ton of fresh forages. This was fed to a group of cows along with low protein concentrates and hay in a 100 day single reversal experiment. A second group of cows was fed similarly, but in this case urea was mixed into the concentrates instead of including it in the ensilage. Palatability was slightly impaired with moderate additions of urea and became a greater problem with heavier additions to either silage or grain. Wise et al. (1944) observed lower intake when corn silage containing 5.0 gallons of a urea solution per ton of silage (2.0 pounds of crystals per gallon, 46 percent nitrogen) was fed to two groups of 11 cows in a double reversal experiment. Silage served as the sole source of roughage and grain was adjusted to the production of all cows. The daily silage consumption for cows fed the treated and untreated silage was 52.5 pounds (15.5 pounds dry matter) and 60.0 pounds (16.9 pounds dry matter) per cow, respectively. However, other reports indicated only slight intake problems from adding urea to corn silage at the rate of 10 pounds per ton (Hillman, 1964 and Woodward and Shepherd, 1944).

Milk production from cows fed urea treated silages has also been reported by Wise et al. (1944) and Woodward and Shepherd (1944). Wise et al. (1944) reported the average pounds of 4.0 percent F.C.M. for cows receiving the treated and untreated silages were 24.7 and 24.5 while the average total weight gains per cow were 43 and 56 pounds, respectively. Milk production was similar even though cows fed the treated silage consumed less silage dry matter than those fed the untreated silage (15.5 vs. 16.9 pounds per day). Woodward and Shepherd (1944) reported that production was maintained regardless of whether the urea was incorporated into the silage or into the concentrates. However, Sobczak (1961) found that milk production was 3.06 and 8.44 percent less when cows were fed rye and maize silages with urea than when fed a control maize silage in a Latin-square designed experiment. Opletalova and Lizal (1963) reported similar decreases in milk production with maize silage containing either 0.5 or 1.0 percent urea.

Hoffman and Fix (1965) reported on a series of silages in which approximately 4.0 kilograms of urea were added per ton of silage. When a control ration with a protein to starch equivalent ratio wider than 1:7.6 was fed, the urea improved both daily milk yield by 1.4 kilograms and fat by 47 grams. With a narrower ratio this effect was not apparent.

Huber et al. (1965a) conducted two twelve week trials with 40 lactating cows in which ad libitum corn silage was supplemented on an equal nitrogen basis with one of the following rations: (1) 15 percent crude protein concentrate mixture (1 pound per 3.5 pounds of milk), (2) soybean oil meal or cottonseed oil meal (fed at different experiment stations, Blacksburg or Middlebury), (3) soybean oil meal plus urea and cottonseed meal plus urea, and (4) urea. In the first trial at the Blacksburg station, the silage dry matter intakes for these four supplements were 1.78, 2.31, 2.30, and 2.30 pound per 100 pound of body weight per day, respectively, while the milk yields were 51.3, 48.7, 43.6, and 36.0 pounds, respectively. The persistency of production expressed as a percent of the standardization period followed similar trends. Milk yields and silage consumption were highest for the third group at the Middlebury station.

Urea has also been added to other high energy silages such as sorghum. Davis et al. (1944) ensiled sweet sorghum in four pilot silos each containing about one ton of silage. Urea, in a water solution, was mixed at a rate of 0, 10, 30, and 50 pounds of urea per ton of sorghum silage. Palatability observations revealed that the cows ate the 0 and 10 pounds of urea per ton silage equally well followed by the 30 pounds per ton silage. Complete refusal of the 50 pounds per ton silage was observed until free ammonia had disappeared. Hastings (1944a) and Hastings (1944b) noted that ammonia was released from soybean silage after two days when urea was mixed with this silage. Urease activity was found in silage samples after seven days under ordinary temperatures. There was no case of feed refusals, "off feed," or digestive disorders from ingredients containing 50 to 60 pounds of urea per ton. A feeding trial was conducted in a herd of Holsteins with one group (7 cows) of the herd serving as a test group and another group (15 cows) as controls. Urea was added to the concentrate mixture to supply 17, 21 and 25 percent of the total ration nitrogen for three successive months of the trial. During the remainder of the trial urea supplied 29 percent of the total nitrogen. During the experiment no significant differences were observed between groups in milk production, milk composition or body weight gains. Reid (1953) in his review of the research in which urea had been utilized in ruminant rations stated the following: "The results of long-time experiments with appreciable numbers of cows demonstrate that from the standpoint of milk yield and maintenance of body weight there is no significant difference between the value of urea nitrogen (fed at levels up to 27% of the required nitrogen) and the nitrogen of high-protein supplements."

Besides being fed to lactating animals, urea silage has also been utilized in wintering, growing and fattening rations for cattle and sheep. Cullison (1944) added urea to sweet sorghum at an approximate rate of 10 pounds per ton. This was compared with an untreated silage as a feed for wintering two groups of 15 Hereford and Angus cows for a 78 day period. The rations fed were 5 pounds of

Johnsongrass hay plus 35 pounds of either treated or untreated silage. The average loss in weight per head for the treated and untreated silage rations during the feeding period was 0 and 47 pounds, respectively. The treated silage was reported to be more palatable than the untreated silage. Goode (1955) performed a similar experiment with corn silage treated with 10 pounds of commercial urea. Mature cows were fed urea treated and untreated silages as a wintering ration with and without soybean oil meal. No significant differences in the gains of these cows were observed and all gains were negative. In another experiment four lots of steers and heifers were fed the following wintering rations: (1) corn silage plus 0.5 pound soybean oil meal, (2) urea-corn silage plus 0.5 pound soybean oil meal, (3) corn silage, (4) urea treated corn silage. The silages were fed to appetite and after 81 days the average daily gains were 1.12, 0.91, 0.76, and 0.65 pounds, respectively. From these results the suggestion was made that corn silage with 10 pounds of urea per ton lowered the feeding value. Bentley _et al_. (1955) ensiled corn silage with 17 and 25 pounds of urea per ton. These silages were used in growth studies with a limited number of animals. While gains were slightly lower for animals fed the treated silages, more of the treated silages was eaten per day than the untreated silages. Grain rations with and without urea were also fed to these steers. In a third feeding trial, larger numbers of steers were used with five rations consisting of corn silage plus (1) ground ear corn, (2) ear corn plus urea, (3) ear corn plus soybean oil meal, (4) urea treated silage (20 pounds of urea per ton) plus ground ear corn, and (5) urea-phosphate silage (20 pounds urea plus

2.0 pounds dicalcium phosphate per ton) plus ground ear corn. The average daily gains of animals fed these silages were 1.62, 1.73, 1.87, 1.82, and 1.83 pounds, respectively, in a 112 day trial. From these data the authors suggested that 20 pounds of urea per ton of corn silage could be ensiled for fattening cattle. Similar recommendations were reported by Bentley et al. (1956a). Gorb and Lebedinskij (1961) using young bulls reported that maize silage with 0.65 percent urea was superior to a control maize silage, but inferior to a silage of equal parts maize and soybean. Lebedinskij (1960) also using bull calves in a 90 day trial fed the following rations: (1) basal: cereal meal, hay, sugar beets, and 16.06 kilograms of maize silage, (2) basal ration with 15.22 kilograms maize silage and 0.65 percent urea, (3) basal ration with 15.50 kilgrams of maize silage and soya mixture in equal parts. These three rations supplied 533, 710, and 667 grams of digestible protein and produced average daily gains of 755, 833, and 890 grams, respectively. The feed units and kilograms of digestible protein per kilogram of gain were 8.90 (0.73); 7.53 (0.90); and 7.19 (0.81).

Harvey et al. (1962) compared the value of urea (10 pounds per ton), limestone (10 pounds per ton) and sodium metabisulfite (8 pounds per ton) when added to corn silage and fed to 57 Angus and Hereford beef calves in a 104 day experiment. The silages were fed at a rate of 14.4 pounds in a ration of rolled shelled corn, linseed oil meal, alfalfa-brome hay, and free choice minerals. The average daily gains for the control, sodium metabisulfite, limestone and urea silages were 1.76, 1.72, 1.71, and 1.59 pounds, respectively. The pounds of feed per 100 pounds of gain were 1274, 1298, 1305 and 1400 pounds, respectively. In a similar report (Harvey *et al.*, 1963), the average daily gains for groups fed the control, limestone (10 pounds per ton), urea (10 pounds per ton) and sodium metabisulfite (8 pounds per ton) silages were 1.48, 1.48, 1.45, and 1.42 pounds, respectively. In the same order the pounds of feed per 100 pounds gain were 1462, 1469, 1518, and 1550 pounds, respectively.

Klosterman *et al.* (1964) prepared a complete corn silage composed of the entire plant from one area and added ears from an equal area. Urea at 20 pounds, pulverized limestone at 10 pounds and dicalcium phosphate at 2.0 pounds per ton were added to the complete silage. This silage was fed to two lots of seven steers with four other lots receiving control corn silage plus ear corn at levels to equal the energy content of the complete corn silage. Soybean meal or a urea-grain mixture were also fed to duplicate lots to approximate the crude protein found in the complete silage. The average daily gains for the groups fed the complete silage, regular silage plus corn and soybean meal and regular silage plus corn and urea for the 126 day trial were 2.32, 2.44 and 1.98 pounds, respectively. Significantly less dry matter per unit of gain was required by those steers consuming the complete silage. In a similar experiment, Harvey *et al.* (1964) compared corn silages prepared in the following manner: (1) regular corn silage; (2) corn silage plus 1.0 percent urea; (3) corn silage plus 24.4 percent shelled corn and 4.7 percent soybean meal; and (4) corn silage plus 29.0 percent ground shelled corn and 0.7 percent urea. These were all added at ensiling time in addition to 8 pounds of

sodium metabisulfite. The average daily gains for treatments one through four were 1.61, 1.59, 1.63, and 1.55 pounds, respectively.

Means (1945) treated sorghum silage with 10 pounds of urea per ton at the time of ensiling. This was compared with an untreated silage for wintering mature beef cows and in rations for long yearling heifers. Using three lots of ten cows each and three lots of ten heifers each, a 77 day experiment was conducted. In the experiment with mature cows, the following rations were used: (1) 30 pounds untreated silage, 1.0 pound cottonseed meal, 5.0 pounds Johnsongrass hay; (2) 35 pounds untreated silage and 5.0 pounds Johnsongrass hay (3) 35 pounds urea treated silage and 5.0 pounds Johnsongrass hay. The average weight change for cows in each group was 9, -99, and 13 pounds, respectively. In the heifer experiment less silage was fed, but similar results were obtained. The standard ration of 25 pounds of untreated silage, cottonseed meal, and Johnsongrass hay produced better gains than the treated silage, but the treated silage was superior to the untreated silage-hay ration.

In rations for fattening cattle, Van Arsdell _et al._ (1953a) and Van Arsdell _et al._ (1953b) fed four lots of eight steers each corn silage and one of four supplements mixed with the silage. The four supplements were: (1) similar to Purdue Supplement A (soybean oil meal, molasses, minerals, and vitamins); (2) a soybean supplement containing minerals; (3) a corn-soybean supplement with molasses and minerals; (4) a corn-urea-soybean supplement with minerals (urea forming 8.4 percent of the supplement). Over a 146 day period, the average daily gains for the four supplements were 2.33, 2.18, 2.07

and 2.37 pounds, respectively. Those fed the urea supplement ate less silage per 100 pounds of gain and had the lowest cost per unit of gain. The amount of supplement fed per animal per day for lots 1 through 3, and lot 4 was 3.5 and 3.82 pounds, respectively.

In an extensive study on the evaluation of biuret and urea, Karr *et al.* (1965a) ensiled the following mixtures for metabolism and feeding experiments with lambs: (1) basal (chopped corn plant, ground yellow corn, calcium carbonate, and trace mineralized salt), (2) basal plus 20 pounds of urea, (3) basal plus 23.5 pounds of pure biuret. Calcium carbonate was added at a level of 10 pounds per ton to all silages. Besides these ensiled mixtures, other groups of lambs were fed a regular silage plus similar concentrate mixtures added at feeding time. In this experiment the basal concentrate added at feeding time was adjusted with soybean meal substituting for part of the corn to equalize the nitrogen content of all diets. Both the non-protein-nitrogen compounds (urea and biuret values combined) increased gains by 26 percent and reduced the amount of feed required per pound of gain by 1.35 pounds when added to the basal diet. Significant increases in gains were not found when concentrate mixtures containing the non-protein-nitrogen compounds were added at ensiling time compared to feeding time, but feed requirements were reduced.

Digestibility and Balance Studies

McLaren (1964) reported that nitrogen utilization from non-protein nitrogen (urea) compounds increased with time on that diet up to 50 days. Karr _et al._ (1965b) and Campbell _et al._ (1963) also found a better utilization of non-protein-nitrogen compounds with longer adaptation periods. In both reports a longer adaptation period was necessary for biuret than for urea. Johnson and McClure (1964) reported that an adaptation for biuret occurred only when apparent digestibilities were considered. This was not the case when either nitrogen retention or biological value were taken into account. This phenomenon was not observed in the case of urea.

Digestibility of urea-corn silages.--Bentley _et al._ (1955) performed digestibility studies using wether lambs in which the following feed mixtures were studied: (A) corn silage, (B) corn-urea silage, (C) corn silage plus soybean oil meal, (D) corn silage plus ground corn-urea, (E) corn silage plus corn urea silage, (F) corn silage plus ground corn-urea, (G) corn silage plus yellow corn plus soybean oil meal. The treated corn silages contained 25 pounds of urea per ton. The coefficients of apparent digestibility of dry matter and crude protein for these silages were 74.4, 60.5; 73.4, 77.7; 75.0, 80.3; 74.8, 79.9; 75.3, 67.4; 75.1, 71.2; 77.7, and 72.9 percent, respectively. Karr _et al._ (1965a) conducted three metabolism trials with lambs and reported increased dry matter digestibility from adding urea and biuret to a basal silage. However, this increase was significant in only one of three trials. No real improvement in urea utilization was noted with time on diet, but with added urea, dry matter digestibility increased with time. There was an indication that the utilization of biuret improved with time. When the concentrate mixtures were added at ensiling time rather than feeding time, there was a highly significant increase in dry matter digestibility, nitrogen digestibility, and daily nitrogen retention. Gorb and Lebedinskij (1961) reported that urea (0.65 percent) added to maize silage improved both protein and crude fiber digestibility. Likewise, Lebedinskij (1960) reported that when either maize silage and 0.65 percent urea or a soya mixture were added to a basal ration, the digestibility coefficients were higher for those calves getting urea or the soya mixture for dry matter, organic matter, protein and fiber.

Nitrogen balance and biological value.--The major criteria for nutritive value of a protein or nitrogen source is the nitrogen retained in the body from this source. Urea has been evaluated alone and in combination with true protein sources in its ability to promote nitrogen retention. From the measurement of nitrogen retention has come the expression of the nutritive value of a protein or nitrogen source called the "Biological Value." However, this expression may be misleading as far as ruminant nutrition is concerned. Annison and Lewis (1959) in their Methuen Series Monograph, "Metabolism in the Rumen," make the following statement as to the contribution of a protein to the nutrition of a ruminant. "A proportion of the dietary protein reaches the duodenum unchanged and its nutritive value is the same as in monogastric animals; the portion that is converted to microbial protein in the rumen must be assessed in terms of the value of that protein; and the nitrogen of the nucleic acid fraction of the bacteria is probably not available to the host animal. With good quality ingested proteins, the degree of protein synthesis in the rumen may only slightly modify the nutritive value. On the other hand, a protein that is deficient in certain amino acids may be more effectively utilized because of synthesis of microbial protein." Reid (1953) indicated many of the factors involved in efficient non-protein nitrogen utilization.

The value of urea and other non-protein-nitrogen sources has been assessed in this respect both when incorporated into silages or used in protein supplements added to the ration at feeding time.

Nehring (1937) conducted metabolism trials with wethers in which a simple nitrogen-bearing compound and potato flakes replaced one-third of a basal hay ration. Equivalent total nitrogen contents were attained. Data from nitrogen balance experiments indicated positive results from the presence of the amides in the diet. A transition from negative to positive balances occurred with ammonium acetate producing the best results and urea somewhat less favorable results. Nehring and Schramm (1937), added 15 pounds of urea to mixtures of either dried beet slices or wheat bran and molasses. When these were used as supplements to a basal hay ration, wethers fed 150 grams of supplement and 600 grams of hay daily increased in nitrogen retention 2.0 to 3.0 grams and 1.0 gram, respectively, over that of an 800 gram hay ration. Harris and Mitchell (1941a) and Harris and Mitchell (1941b) performed several experiments in evaluating urea as a source of nitrogen for maintenance and growth in ruminants. In their first experiment these authors observed that fecal nitrogen increased when lambs were switched from a low nitrogen ration to either casein or urea supplemented rations. Nitrogen equilibrium was maintained in the sheep on 202 milligrams of urea nitrogen and 161 milligrams of casein nitrogen per day per kilogram of body weight. The biological value of urea nitrogen was 62 and casein nitrogen 79 at the point of nitrogen equilibrium. In evaluating urea for growth, Harris and Mitchell (1941b) used 23 wether lambs which received a basal ration of corn silage, limestone, salt, and fortified cod liver oil during a preliminary period. This ration would not support growth or nitrogen equilibrium. Urea was added to bring the protein equivalent from an average of 5.35 percent to 8, 11 or 15 percent on a dry basis. The percent nitrogen in the form of urea was 34, 50, and 62 percent, respectively. A carbohydrate supplement was also added to the urea rations during the growth period. The 11 percent ration was superior to the 8 percent ration in promoting growth and nitrogen balance, however, the 11 and 15 percent rations were not significantly different in growth promoting abilities. The biological value of the basal (5.35 percent crude protein), 8, 11, and 15 percent protein equivalent rations was 82, 74, 60, and 44, respectively.

Chalupa et al. (1964) fed a low nitrogen (0.23 percent nitrogen on a dry matter basis) semipurified diet to steers (267 kilogram) in which urea was used to supply 0, 46 or 92 percent of the nitrogen requirement and corn gluten meal the remaining percentage. The calorie to nitrogen ratios were similar for all diets. Fecal nitrogen values were significantly increased and urinary nitrogen excretion increased by urea. The nitrogen retained in grams per day, percent biological value, and net protein utilization for the rations containing 0 percent urea plus 92 percent corn gluten meal, 46 percent

urea plus 46 percent corn gluten meal, and 92 percent urea plus 0 percent corn gluten meal were 19.6 $\pm$ 1.96, 56.5 $\pm$ 3.69, 51.2 $\pm$ 2.66; 13.6 $\pm$ 4.57, 50.6 $\pm$ 5.28, 44.44 $\pm$ 5.16; and 1.2 $\pm$ 1.37, 36.8 $\pm$ 3.79, 30.7 $\pm$ 2.67, respectively. These differences were significant. The percent of urinary nitrogen in the form of urea, ammonia and creatine significantly increased with increasing amounts of urea in the ration. Lassiter *et al.* (1958a) also reported lower nitrogen balance for animals receiving rations in which urea supplied 30, 50 and 70 percent of the total nitrogen when compared to a ration containing no added urea. When fed to Holstein cows the balance in grams per cow per day was 47.1, 55.2, 52.5 and 60.2 grams, respectively. Similar balance values were observed when rations supplying 30, 50, and 70 percent of the total nitrogen as urea were fed to dairy heifers (Lassiter *et al.*, 1958b). This was difficult to explain since rate of gain and feed efficiency decreased significantly as level of urea increased. However, the sulfur content of the rations was not equalized. In a third study, Lassiter *et al.* (1958c) gains were improved with equalized sulfur in the rations.

Dinning *et al.* (1949) used two pelleted protein supplements (urea supplying 0, 25 and 50 percent of the total nitrogen) for maintenance, wintering and fattening rations for steers and lambs. In only a few cases did the percent crude protein exceed 12 percent for the rations of prairie hay and the pellet supplements of varying amounts of hominy feed, blackstrap molasses, urea and cottonseed meal. Nitrogen retention in both steers and lambs increased with increasing additional nitrogen supplied by urea. The supplement containing 50 percent urea nitrogen was as efficient in promoting nitrogen retention as the supplement with 25 percent urea nitrogen. Lambs appeared to be more efficient in utilizing urea nitrogen and appeared to tolerate higher percentages of urea in the rations than steers. Urea increased the total-nitrogen in the urine, but did not significantly change fecal nitrogen excretion. Hamilton et al. (1948) used nitrogen balance as the criterion to measure the utilization of nitrogen from urea and feed proteins. Using growing lambs and a paired-feeding procedure with a single reversal of rations, the nitrogen from a ration with a 16.2 percent protein equivalent (63 percent from urea) was less efficiently utilized than that of a ration with 11.4 percent protein equivalent (46 percent from urea). The nitrogen balance was lower and the biological value significantly reduced in the 63 percent urea ration. It was also shown that urea nitrogen is as well utilized as the same amount of nitrogen from dried skimmilk, dried skimmilk plus cystine, gluten feed, casein or cystine plus casein. However the nitrogen from linseed oil meal was more efficiently utilized. The conclusion was made that urea is a satisfactory nitrogen source for lambs provided that at least 25 percent of the food nitrogen is in the form of preformed protein and that the total protein equivalent of the ration is not greater than about 12 percent. Johnson et al. (1942) also found that urea additions to a low protein basal ration to give a crude protein equivalent of 12 percent induced a retention of nitrogen in lambs which was not increased by further additions of urea. It was concluded from their data that urea added to a low protein basal ration could not promote protein synthesis at a rapid enough rate for the nitrogen requirements of the lamb under the conditions of this experiment. However, the utilization of urea for metabolism was slightly higher than that of casein nitrogen, and compared favorably with that of soybean oil meal nitrogen.

The effect of kind of carbohydrate on urea utilization versus plant proteins was studied by Drori and Loosli (1961). Diets of poor quality timothy hay plus molasses were supplemented with either glucose, sodium sulfate and urea, or corn starch, sodium sulfate and urea, or soybean oil meal and corn with urea supplying 69 percent of the dietary nitrogen. The nitrogen retention for the glucose-urea, corn starch-urea, and soybean oil meal-corn diets was 2.3, 2.6, and 4.1 gram per day, respectively, while the biological value for these same diets was 42.9, 45.1 and 52.8 percent, respectively, with intakes being approximately 700 grams per day.

Working with young dairy calves, both Loosli and McCay (1943) and Brown _et al_. (1956) reported that calves fed urea supplemented rations made better gains than calves fed low protein basal rations. However, Loosli and McCay (1943) found that the urea fed calves were 75 to 90 percent of normal in weight and 95 percent of normal in height of withers and heart girth at four months of age. Both reports indicate that the urea fed calves were in positive nitrogen balance.

Johnson and McClure (1964) compared the utilization of urea, biuret and diammonium phosphate by four wether lambs fed rations consisting of 50:50 roughage-concentrate mixtures in a 4 x 4 Latin square designed experiment. The basal roughage--concentrate mixture (corn cobs, soybean flakes, shelled corn, and starch) was 6.8 percent crude

protein and the nitrogen supplemented rations 12.0 to 12.6 percent crude protein on a dry matter basis. Neither diammonium phosphate nor biuret appeared to be utilized as well as urea from the standpoint of digestibility or nitrogen retention.

Karr et al. (1965a) reported increased nitrogen retention in two experiments with biuret added to a basal silage mixture (chopped corn plant, ground yellow corn, calcium carbonate and trace mineralized salt), while urea additions produced lower retentions. Concentrate mixtures added at ensiling time versus feeding time, resulted in a highly significant improvement in daily nitrogen retention (urea and biuret values combined).

Diammonium Phosphate

Diammonium phosphate has been investigated from the standpoint of a nitrogen and phosphorus source in ruminant rations. There are no reports in the literature, as far as this writer knows, where diammonium phosphate has been added to an ensiled mass. Mainly urea and diammonium phosphate have been compared, physiologically and nutritionally, as supplements added to sheep and cattle rations.

Shaw et al. (1946) reported the following about diammonium phosphate: "At a level of 1% in the ration, it furnishes the equivalent of 1.31% protein and 0.23% phosphorus or approximately 30% more phosphorus than is supplied by an equal amount of bone meal." In their study 1.0 percent diammonium phosphate or 1.0 percent of a mixture of mono- and di-ammonium phosphate was added to grain mixtures for milking animals receiving mixed hay and grain. These additions did not effect the palatability of the rations in a 21 day test. "Fitting rations" containing 3.0 percent diammonium phosphate or 3.0 percent of a mixture of mono- and di-ammonium phosphate were fed to dry cows with the result that diammonium phosphate was more palatable than the mixture of the two phosphates. These authors recommended that diammonium phosphate could be fed in amounts not to exceed 1.0 percent of the concentrates. Cowman and Thomas (1962) also observed favorable results with these ammoniated phosphates for gains during a wintering period of 112 days and a fattening period of 168 days. However, in the fattening period a comparable lot of cattle fed soybean oil meal gained at a faster rate and more efficiently than the lot fed the ammoniated phosphates. Diammonium phosphate also proved to be an adequate phosphorus source. Lassiter _et al._ (1962) conducted palatability trials with nine Holstein cows in which alfalfa hay and a basal grain ration containing 1.0, 2.0 and 4.0 percent diammonium phosphate were fed. Incomplete eating or a slowness in grain consumption was noted for some cows when the grain ration contained diammonium phosphate at 2.0 percent or higher. In digestibility and nitrogen retention trials, the nitrogen digestibility of rations containing urea and soybean oil meal was similar, and in both cases higher than the diammonium phosphate rations. Similar trends were noted for nitrogen balance data. Oltjen _et al._ (1963) reported similar results as those of Lassiter _et al._ (1962) for nitrogen balance and palatability when fed to sheep, but diammonium phosphate did serve as a satisfactory source of phosphorus. However, Russell _et al._ (1961) observed no significant differences in nitrogen retention in lambs when urea or diammonium phosphate supplied

30 percent of the nitrogen. In contrast, Johnson and McClure (1964) observed that neither diammonium phosphate or biuret appeared to be utilized as well as urea from the standpoint of digestibility or nitrogen retention when these compounds were added to a 50:50 roughage-concentrate mixture and fed to lambs. Lassiter et al. (1962) concluded that diammonium phosphate nitrogen appeared to be utilized as well as soybean meal or urea nitrogen. In a growth study with heifers comparable growth rates were observed when either diammonium phosphate or urea supplied 35 percent of the nitrogen in the ration.

Diammonium phosphate has also been investigated from the standpoint of its effect upon rumen pH, blood ammonia-nitrogen (NH_3-N), and toxicity. Russell et al. (1961) and Russell et al. (1962) reported that larger amounts of diammonium phosphate were required to produce adverse effects or toxicity in lambs than urea. When urea and diammonium phosphate were infused into the lambs by a stomach tube on an equivalent nitrogen basis, urea caused a greater increase in rumen pH, and a highly significant increase in blood NH_3-N.

An interesting observation has been reported by Oltjen et al. (1963) concerning the reaction of diammonium phosphate when placed in either saliva or distilled water. They reported a release of ammonia when diammonium phosphate comes into contact with these liquids and as much as 30 and 10 percent of the nitrogen was lost in this form when diammonium phosphate reacted with either saliva or distilled water, respectively. Pelleting rations containing diammonium phosphate also resulted in large losses. In more recent research dealing with this observation, Reaves et al. (1965) determined the ammonia release from reagent diammonium phosphate, regular diammonium phosphate and stabilized diammonium phosphate in the presence of saliva. Stabilized diammonium phosphate produced less ammonia in two different incubations of different time lengths. When 1.5 and 3.0 percent stabilized diammonium phosphate and 3.0 percent regular diammonium phosphate were incorporated into a grain ration and fed with alfalfa hay against a control ration, the mean consumption was 8.89, 7.86, 8.26 and 9.23 pounds per day, respectively, for these rations.

Mineral Additives

The incorporation of limestone, calcium carbonate or dicalcium phosphate into corn silage has been the subject of several research reports as an attempt to prolong fermentation of the ensiled mass. These compounds also supply additional calcium to the calcium deficient corn silage. However, the major emphasis has been placed upon the chemical action of these compounds which, as an end result, will increase volatile and non-volatile fatty acid content of the silage which serve as potential energy sources for ruminant animals.

Hydrogen Ion Concentration and Acid Production in Corn Silage Treated with Mineral Additives

Calcium carbonate and limestone.--Calcium carbonate and different grades of limestone have been added to silages, since the calcium ion will form the salt of the organic acids. Simkins et al. (1964) added 13.6 pounds of calcium carbonate per ton of corn silage and compared the fermentation products with a control silage. The pH and total organic acid content for the control and treated silages were 3.73, 6.52 percent, and 3.92, 11.24 percent of the dry matter, respectively. These differences were statistically significant. Nicholson and Cunningham (1964) ensiled several grasses and legumes at varying dry matter percentages in glass jar silos with additions of 1.0 or 2.0 percent ground, high-calcium feed grade limestone. These additions resulted in higher organic acid content and pH with generally lower proportions of lactic acid and higher proportions of butyric and acetic acids. Immature corn silage was also ensiled with limestone additions which resulted in higher proportions of lactic acid, organic acid content, and pH. Byers _et al_. (1963) and Byers _et al_. (1964) ensiled corn silage treated with either 0 or 1.0 percent limestone. The pH of the control silage was 3.85 as compared to 4.20 for the limestone treated silage. The addition of limestone to the fresh crop at the time of ensiling produced a significant increase in acetic and lactic acids in the silage. The acetic and lactic acid content of the control and treated silages on a dry matter basis was 1.55, 3.16 and 5.36, 9.66 percent, respectively. Succinic acid was also increased by 18 percent in the treated silage.

Klosterman _et al_. (1962) ensiled ground ear corn and whole plant corn silages with and without 0.5 percent high calcium limestone and 0.5 percent urea. In another experiment whole plant and ground ear corn silage with 1.0 percent high calcium limestone were ensiled. These additions resulted in an increase in the organic acids. In an earlier report Klosterman _et al_. (1960a) revealed that in whole plant corn silage ensiled with 0.5 percent urea the lactic acid was increased 78 percent. In an ear corn silage with 1.0 percent high calcium limestone and 6.0 percent added water the lactic acid was 125 percent greater than a control silage. In a more extensive report, Klosterman et al. (1963) included research in which limestone and urea were used singly and in combination with whole plant and ear corn silages. Using glass jar silos, the pH for a control, 0.5 percent limestone, 1.0 percent limestone, and 1.0 percent dolomitic limestone whole plant corn silages was 3.8, 4.0, 4.2, 4.3, respectively. The percentages of acetic and lactic acid on a dry matter basis for these same silages were 1.51, 8.33; 1.59, 9.72; 1.99, 11.05 and 2.63, 11.90 percent, respectively. It was also noted that dolomitic limestone produced variable results as far as increasing the acid production, when compared to high calcium limestone.

However, urea did not increase the acid content as much as calcium carbonate or high calcium limestone. Karr et al. (1964) reported that whole plant silage plus ground corn, calcium carbonate and salt lowered the acetic acid, increased the lactic acid and increased the total organic acid production in glass jar silos. Karr et al. (1965a) reported similar results.

Feeding Trials with Silages Treated with Mineral Additives

The effects of adding these compounds to corn silage as a feed for dairy cattle has been the subject of study at several institutions. Byers et al. (1963) and Byers et al. (1964) reported on work in which 24 Holstein, Brown Swiss and Jersey cows were fed ad libitum corn silage treated with 0 and 1.0 percent limestone at the time of ensiling or added to the silage at feeding time in an attempt to evaluate these silages for milk production, milk fat percent and rumen volatile fatty acids. Alfalfa hay and a grain mixture were also fed at specific rates. There were no significant differences among groups in average daily F.C.M., milk fat percentage or dry matter intake corrected for body weight. There was a tendency for higher rumen propionic acid levels when the cows were fed the treated silage. Similar results were reported by Byers (1965). Simkins et al. (1964) and Simkins et al. (1965) reported little or no change in milk production from adding 13.6 pounds of calcium carbonate per ton of corn silage. However, the silage dry matter intake per 100 pounds of body weight was significantly higher for the control cows (1.91 lb.) than for the treated silage group (1.64 lb.). Similarly the greatest body weight gains were made by the control animals. There was also a significantly greater rumen concentration of total volatile fatty acids in cows receiving the treated silage, but the percent acetic, propionic and butyric acid were not different. Kesler et al. (1964) also reported a higher consumption of a control corn silage than a limestone treated silage (1.0% limestone). McCullough et al. (1964) reported decreased dry matter intake and milk production by cows fed silage treated with 1.0 percent calcium carbonate as compared with similar cows fed an untreated silage.

Limestone and calcium carbonate have also been used in rations for heifer growth. McCullough (1964) prepared NK300 sorghum silage with and without additions of 1.0 percent calcium carbonate and the enzyme cellulase. When these silages were fed to heifers, the silage dry matter intakes for the control, control plus 1.0 percent calcium carbonate and control plus 1.0 percent calcium carbonate and 2.0 percent enzyme were 11.06, 9.14 and 10.37 pounds, respectively. Nicholson and Cunningham (1964) and Megli et al. (1965) also reported reduced feed intake and gain with limestone additions to corn silage. Mohler et al. (1962) compared regular corn silage and corn silage treated with 0.5 percent limestone when fed to 72 beef calves with additional protein. The average daily gains for the regular corn silage and treated corn silage calves were 1.83 and 1.97 pounds, while the silage required per 100 pounds of gain was 1705 and 1794 pounds, respectively.

A considerable amount of our present information concerning the addition of adjuncts to silage has been performed at the Ohio Experiment Station. Klosterman et al. (1960) studied the additions of 1.0 percent dolomitic limestone to whole plant corn silage. Results of growth experiments indicated that steers fed the treated silages made gains about the same or slightly higher than those fed untreated silages. However, less silage dry matter was required per unit of gain with the treated silages.

Similar results have also been reported for limestone or limestone plus urea additions by Klosterman et al. (1961), Klosterman et al. (1962) and Klosterman et al. (1963).

Digestibility Studies with Mineral Additive Silages

The digestibility of silages which contained limestone or calcium carbonate was reported by McCullough (1964) and Klosterman <u>et al</u>. (1960). McCullough (1964) used NK 300 sorghum silage to study the effects of calcium carbonate and cellulase additions. The addition of calcium carbonate alone reduced dry matter digestibility as can be seen from the following silage treatments and their digestibility coefficients: control, 50.3 percent; control plus 1.0 percent calcium carbonate; 42.6 percent; and control plus 1.0 percent calcium carbonate plus 2.0 percent enzyme, 54.5 percent. Klosterman <u>et al</u>. (1960) used lambs to determine the digestibility of organic matter, cellulose, crude fiber, protein and ether extract of an untreated and treated (1.0 percent dolomitic limestone) whole corn silage. Values of 67.1, 67.4; 40.5, 42.6; 37.9, 41.0; 59.8, 60.0; 64.9, 67.5 percent, were found for the above constituents, respectively. In another experiment with ear corn silage and dry ear corn with and without dolomitic limestone, there was a significant depression in digestibility of ether extract in the ration containing dry ear corn plus added limestone. No depression was observed for the other constituents. Colovos <u>et al</u>. (1958) fed 12 dairy heifers either on an all roughage or a mixed ration with added pulverized limestone or dicalcium phosphate to determine the effects of the added calcium on the utilization of protein and energy. The roughages used were mixed grass hay or grass to grass-legume silages. In the first experiment 100 grams of limestone were fed per animal per day along with a grass-legume silage with a second group receiving no supplemental calcium. In a second experiment 0, 50 and 100 grams of limestone were fed with silage and in the third experiment hay and a concentrate mixture (16 percent crude protein) were fed plus either 2.0 percent limestone, 2.0 percent

limestone plus 2.0 percent dicalcium phosphate, 2.0 percent dicalcium phosphate, or 0 level minerals. Limestone depressed the digestibility of protein and energy, while dicalcium phosphate had no effect. When the two supplements were fed in combination there was a decrease in the depressing effects of limestone. It appeared that the added calcium depressed protein and energy digestibility while phosphorus additions increased protein digestibility.

Limestone Urea Combinations

Hydrogen Ion Concentration, Acid Production and Crude Protein Changes

Limestone-urea combinations have been evaluated as silage additives at several institutions within the past few years. In chemical studies Newland and Henderson (1965) reported increases in crude protein content when corn silage was ensiled with 10 pounds of limestone and 10 pounds of urea per ton as compared to untreated corn silage (3.19 vs. 2.48 percent). Klosterman *et al.* (1962) with similar treatments also indicated that urea could replace a portion of the supplemental proteins in the treated silages. These additions resulted in increased organic acids. In an earlier report, Klosterman *et al.* (1960a) reported a 78 percent increase in lactic acid in a whole plant corn silage ensiled with 0.5 percent high calcium ground limestone and 0.5 percent urea. Klosterman *et al.* (1963) reported that pH for a control and a 0.5 percent limestone plus 0.5 percent urea, whole plant corn silage was 3.8 and 4.3, respectively. The acetic and lactic acids on a dry matter basis for these same silages were 1.51, 8.33; and 2.13, 12.05 percent, respectively. In this same report, chemical data on silages containing 1.0 percent dicalcium phosphate, 1.0 percent limestone plus 0.5 percent urea and 0.5 percent limestone plus 1.0 percent urea were reported. The pH, acetic and lactic acids (percent on dry matter basis) for these silages were 3.8, 1.68, 8.51; 4.5, 3.22, 12.99; and 4.2, 2.33 and 11.06, respectively.

Feeding Studies with
Limestone-Urea Combinations

Newland and Henderson (1965) ensiled regular corn silage with additions of limestone and urea (10 pounds each per ton). These were fed to four lots of eight Hereford heifers comparing protein supplements with and without urea, mineral sources and vitamin supplementation. Heifers gained 8 percent faster, were more efficient and made cheaper gains when fed the limestone-urea corn silage. The urea containing protein supplement did not significantly depress animal performance when fed with the treated silage and overall the gains were more economical for the groups receiving urea. Klosterman _et al._ (1960a) reported similar results when whole plant silage was treated with 0.5 percent limestone and 0.5 percent urea and incorporated into a ration of alfalfa hay, soybean oil meal, minerals and a half feed of dry, ground ear corn. In another experiment, steers fed a treated silage gained somewhat less than another lot fed untreated silage. The reverse was true when 8 pounds of corn was fed. Increased feeding value was also reported by Klosterman _et al._ (1962) with addition of 0.5 percent urea and 0.5 percent high calcium limestone in both whole plant and ground ear corn silages.

Resumé

Corn silage, when properly supplemented, is obviously one of the better roughage sources for cattle from a production standpoint. Improvement in milk production or a good replacement value has been reported by Carroll (1924), Fairchild and Wilbur (1925), and Converse and Wiseman (1952). Corn silage may contain unidentified factors necessary to balance other roughages (Huffman and Duncan 1954a, Huffman and Duncan 1954b, and Dunn et al. 1954). While the subject of the optimum level of silage feeding is still under investigation, this level may range from light silage feeding, (Pratt and White, 1930), to the point where it serves as the sole roughage source (Brown et al., 1965), depending upon how it is supplemented. In growth experiments, corn silage when fed alone has not produced good results unless supplemented with grain or other roughages (Eckles, 1918); and Converse and Wiseman, (1952). When corn silage was compared with other roughage sources for milk production or growth, improvement in milk production in favor of corn silage as compared with sorghum silage was reported by Reed and Fitch (1913), Owen et al. (1957), Owen et al. (1961), and Rahmon and Leighton (1965). However, comparisons with other roughages are variable depending upon the experiment and roughage comparisons.

The additions of various chemical compounds to whole plant corn silage must be evaluated from the standpoint of the changes in the chemical fermentation and the result of this change on the feeding value and animal performance. Additions of urea to corn silage resulted in increased crude protein equivalent, (Bentley *et al*., 1955), (Wise *et al*., 1944), Gorb and Lebedinskij, 1961), (Goode, 1955), (Palamaru *et al*., 1961), (Klosterman *et al*., 1961, 1962, 1963), (Hoffman and Fix, 1965), and (Davis, 1944). Bentley *et al*., (1955), Cullison (1944) and Klosterman *et al*. (1963) also reported that urea prolonged volatile and non-volatile fatty acid production, but the pH of the treated silages has remained elevated when compared to control silages. In general, urea additions resulted in comparable to slightly less gains or milk production when fed to cattle and its value appears to be in its economy as a protein source.

While there are no reports in the literature concerning the addition of diammonium phosphate to corn silage, results when it was supplemented into the ration are again variable ranging from equal to poorer utilization than other non-protein-nitrogen sources.

Additions of either calcium carbonate or ground high calcium limestone stimulated total acid production in treated silages and elevated the pH, (Byers *et al*., 1963), (Byers *et al*., 1964), (Klosterman *et al*., 1960, 1962, 1963), and (Karr *et al*., 1964). For milk production, the addition of limestone or calcium carbonate does not appear to improve the silage performance, (Byers *et al*. 1963), (Byers *et al*. 1964), (Byers *et al*. 1965) and in some cases resulted in a depression of feed intake (Simkins *et al*. 1964), (Simkins *et al*. 1965). Improvements in animal gains have also been noted with additions of limestone or calcium carbonate, but results are still variable.

Limestone and urea combinations resulted in increased crude protein equivalent, (Newland and Henderson, 1965) acid production,

and pH values, (Klosterman *et al.*, 1960, 1962, 1963). Increased feeding value with this combination has been reported by Klosterman *et al.* (1960), Klosterman *et al.* (1962), and Newland and Henderson (1965).

EXPERIMENTAL PROCEDURE

The experimental data reported in this thesis covers a period of two years' work with whole plant corn silage (excluding roots).

Experiment I

During the period of September 6 to September 10, 1963, whole plant corn silage was harvested at approximately 27 percent dry matter with a two row corn chopper. The fresh material was transported to the Michigan State University dairy farm in self-unloading wagons where each load was weighed prior to ensiling. Two silos were filled at the same time by adding alternate loads to each silo. Approximately 35 tons of the fresh material were placed in each of four 10 x 40 foot silos, while approximately 63 tons were placed in each of two 10 x 40 foot silos. The chemical compounds studied were distributed on top of each load of fresh material on a fresh weight basis before it was blown into the silo. Mixing occurred as the materials passed from the wagons through the blower and into the silo. In the first experiment, urea ("cyrea," minimum nitrogen 42.0 percent), diammonium phosphate (21.21 percent nitrogen), calcium carbonate (38 percent calcium), and dicalcium phosphate (average percent calcium, 25.5 and minimum phosphorus, 21 percent) were added to the silage either singly or in combinations.

The following design was used:

Silo 3: Control corn silage.

Silo 4: Corn silage plus 0.5 percent urea per ton.

Silo 5: Corn silage plus 1.0 percent diammonium phosphate per ton.

Silo 6: Corn silage plus 0.5 percent calcium carbonate per ton.

Silo 7: Corn silage plus 0.5 percent calcium carbonate plus 0.5 percent urea per ton.

Silo 8 Bottom: Corn silage plus 0.5 percent calcium carbonate plus 1.0 percent diammonium phosphate per ton.

Silo 8 Top: Corn silage plus 0.75 percent dicalcium phosphate plus 0.5 percent urea per ton.

When two different silage mixtures were ensiled within the same silo, a sheet of black plastic separated the two silages. After a silo was filled, the ensiled material was leveled, packed, and covered with another sheet of black plastic.

Samples were removed for chemical analyses on the 0, 5, 10, and 20th day following ensiling which represents most of the fermentation period. Two inch holes were drilled into the silo doors to provide an entrance into the silage, and samples were removed with an auger. The samples were placed in polyethylene bags, tagged and stored at -2 to 3 degrees F. for future chemical analysis. The hydrogen ion concentration, moisture, total nitrogen, volatile and non-volatile, were determined on each of these samples. During the feeding experiments, samples were taken from the top one-half foot of the silage surface. These samples were preserved and analyzed in a similar manner as the fermentation samples. With the exception of the first heifer growth experiment, (1963-64 silages), these samples from each silo were composited for the determination of volatile and non-volatile fatty acids and proximate analysis. Supplementary feeds were also sampled and composited for proximate analysis.

Heifer Growth Trial

The silages were evaluated on the basis of animal performance in a heifer growth or a lactation study. In the heifer growth trial, two silages were fed; corn silage treated with 0.5 percent calcium carbonate plus 0.5 percent urea per ton (Silo 7) and corn silage treated with 0.75 percent dicalcium phosphate plus 0.5 percent urea per ton (Silo 8-T). Sixteen Jersey heifers weighing 500 to 770 pounds were allotted into two equal weight groups of eight animals each. One animal was injured during the experiment and was removed so that only fifteen animals completed the experiment. A mixture of the corn silages from the top of both silos 7 and 8 was fed for approximately one week immediately preceding the 87-day experimental period. A mixture of dicalcium phosphate and trace mineralized salt was fed at the daily rate of approximately 55 grams. All animals were weighed for three consecutive days and allotted into groups on the basis of average body weights. Subsequent weights were recorded at 30 day intervals and three day weights at the end of the trial. During the experimental period, each group was fed ad libitum silage from either silo 7 or 8 top plus approximately 55 grams of a 50-50 mixture of dicalcium phosphate and trace mineralized salt. The silage fed as well as orts were weighed and recorded daily for each heifer.

Samples of silage and orts were taken on Monday, Wednesday, and Friday of each week for dry matter determinations.

Lactation Study

In the lactation study, six silages from silos 3 to 8-B, page 52 were fed.

Thirty-six Holstein cows were divided into six outcome groups on the basis of milk production. Each cow within an outcome group was randomly allotted to one of the six treatment groups in a randomized block design. Ad libitum corn silage and grain at a grain to milk ratio of 1:3.5 were fed during an 18 day preliminary period. During the 90 day experimental period, the six silages were fed ad libitum. Based on the assumption that cows would consume approximately 80 pounds of silage, the rations were equalized in T.D.N. and crude protein by supplementing the 80 pounds of silage with either 2.0 pounds of soybean oil meal for the non-urea silages or 2.0 pounds of ground shelled corn for the urea silages. This level of silage intake and concentrate supplementation would theoretically supply enough T.D.N. and crude protein to support maintenance plus 30 pounds of milk testing 3.5 percent fat. The difference in production between this 30 pounds of milk and the average actual milk production within each outcome group was supported by feeding various levels of a 16.1 percent crude protein grain mixture consisting of 1470 pounds of ground shelled corn, 390 pounds of soybean oil meal, 100 pounds of molasses, 20 pounds of dicalcium phosphate, and 20 pounds of trace mineralized salt. Approximately one month after the beginning of the experiment

the cows were not consuming 80 pounds of silage. The grain supplementation level was recalculated on the basis of 70 pounds of silage and all rations adjusted accordingly. Grain changes were made at approximately 28-31 day intervals throughout the experiment according to the average milk production within an outcome group. Approximately 55 grams of a 50-50 mixture of dicalcium phosphate trace mineralized salt were also fed. All cows were weighed for three consecutive days immediately preceding and at 30-day intervals throughout the 90 day experimental period. Daily feed consumption was recorded for each cow and samples of silages and orts were taken three days each week for dry matter determinations. Samples of the different concentrates were also taken at various times throughout the experiment for dry matter determinations.

Daily milk weights were recorded for each cow and a composited sample taken twice weekly for both butterfat and solids-not-fat (SNF) analysis. During the first month of this experiment, the butterfat and SNF determinations were not made. The values for butterfat were taken from the monthly Dairy Herd Improvement Association testing sheet and averaged with the first butterfat test made during the experiment to obtain a value to use for the missing period. For the missing SNF value, the average of the second month's SNF values were used to replace this value for the first month of the experiment.

Experiment II

In a second experiment, calcium carbonate and optimum levels of urea additions to corn silage were studied. Whole plant corn silage (excluding roots) at approximately 29 percent dry matter was harvested and ensiled from September 1 to September 5, 1964 in a similar manner as that of Experiment I. Approximately 62.5 tons of the fresh material was ensiled in each of six 10 by 40 foot silos with calcium carbonate (ground high calcium limestone, minimum calcium 38 percent), or urea (minimum nitrogen 42 percent), added either singly or in combination as silage treatments.

The following treatment design was used:

Silo 3: Control corn silage.

Silo 4: Corn silage plus 0.5 percent urea per ton.

Silo 5: Corn silage plus 0.75 percent urea per ton.

Silo 6: Corn silage plus 0.5 percent calcium carbonate per ton.

Silo 7: Corn silage plus 0.5 percent urea plus 0.5 percent calcium carbonate.

Silo 8: Corn silage plus 0.75 percent urea plus 0.5 percent calcium carbonate per ton.

After each silo was filled, the ensiled material was leveled, packed, and covered with a sheet of black plastic plus additional fresh chopped corn. All sampling and chemical analysis for silage samples were the same as outlined in Experiment I.

The silages were evaluated in three animal performance experiments consisting of a heifer growth trial, a lactation study, and a digestion and nitrogen balance study.

Heifer Growth Trial

In the heifer growth trial, 42 Holstein and six Jersey heifers were brought into the barns from summer pasture on October 20, 1964. From October 21 to October 30, the heifers received hay and corn silage. From October 31 to November 11 a mixture of the experimental silages were fed ad libitum plus 55 grams of a 50-50 dicalcium phosphate-trace mineralized salt mixture. All heifers were weighed for three consecutive days at the beginning of the trial, twice weekly during the trial, and for two consecutive days at the end of the trial. The 42 Holstein heifers were divided into seven outcome groups of six heifers each on a weight basis. Each heifer in an outcome group was randomly assigned to a treatment group in a randomized block design. The remaining six Jersey heifers, regardless of weight, were randomly assigned to treatments. During the 70 day experimental period, each treatment group was fed one of the silages ad libitum, plus 55 grams of a 50-50 dicalcium phosphate trace mineralized salt mixture. The sampling of the silages for both dry matter determinations and chemical analyses was the same as in Experiment I.

Lactation Study

Thirty Holstein cows were used in a 90 day lactation trial to evaluate these silages as the sole roughage source for lactating dairy cows. The first group of 18 cows was allowed a 16 day preliminary period in which herd silage and later a mixture of the treated silages was fed ad libitum. Grain intakes were decreased during the preliminary period to increase silage consumption and to approximate grain levels to be fed during the experimental period. The cows were placed into outcome groups according to their expected production for a 120 day feeding trial, and randomly allotted to treatment groups. The following equation was used to predict the expected production:

$$P_{120} = P_p \left(\frac{f_p}{f_p + 120} - 1\right)$$

where P_{120} is the expected cumulative milk production for the 120 day experimental period, P_p is the cumulative milk production from parturition to the time of the experiment, f_p is a ratio factor (chosen for appropriate age, number of days in the preliminary period, and season of calving) for estimating 305 day production from the preliminary production and $f_p + 120$ is the ratio factor (chosen for appropriate age, season of calving, and number of days to the end of the 120 day experimental period) for estimating 305 day production from preliminary and 120 day experimental production.

A second group of 12 Holstein cows was placed on experiment approximately two months after the first group. These animals received similar treatment during a 14 day preliminary period as the first group of cows with the exception that two cows, 281 and 755, were on the preliminary regime for only three days. Two of the original 12 cows were not compatible with the remaining animals with respect to milk production and were replaced by these two animals.

During the experimental period, the cows were fed the various silages ad libitum according to treatment groups. In this experiment, it was assumed that each cow would consume 70 pounds of corn silage.

The T.D.N. and crude protein content of all silages was equalized by supplementing with 3.0 pounds of soybean oil meal (50% C.P.) and 5.0 pounds of shelled corn for the 0 percent urea silages, 2.0 pounds of soybean oil meal and 6.0 pounds of shelled corn for the 0.5 percent urea silages, and 8.0 pounds of shelled corn for the 0.75 percent urea silage. The above amounts of feed would theoretically support maintenance plus 39.0 pounds of milk testing 3.5 percent fat. Cows producing more than 39 pounds of milk were fed additional ground shelled corn and soybean oil meal according to calculated requirements (N.R.C., 1958). Grain changes were made at 30-day intervals during the experiment according to the mean persistency of each outcome group. However, the grain intake for any cow was never reduced below the point at which the silages were equalized for T.D.N. and crude protein. Approximately 55 grams of a dicalcium phosphate-trace mineralized salt mixture was fed daily. During the experiment the daily recording of feed consumption and milk production was the same as in the first experiment. Weekly analysis for butterfat and S.N.F. were conducted throughout the experimental period. Likewise, all feed sampling techniques and sample analysis were the same as in the first experiment.

Digestibility and Nitrogen Balance Study

Near the end of the lactation study, April 10, 1965, sixteen wether lambs weighing approximately 70-95 pounds were fed a regular herd corn silage ration plus additional ground shelled corn and a 50-50 dicalcium phosphate-trace mineralized salt mixture. On April 14, twelve of the original sixteen lambs were randomly assigned to the silage mixtures from silos 3, 4, 5, and 7. These silages were chopped in a hay chopper and stored in a walk-in refrigerator in order to improve the intake and prevent selection of silage particles by the lambs. During the 19 day preliminary period, the lambs were given 8.0 pounds of silage per day. The various silage treatments were equalized for T.D.N. and crude protein by supplementing the silages with 0.524 pound of cornstarch and 0.276 pound of soybean meal (50 percent C.P.) for the lambs receiving the 0 percent urea silage, 0.718 pound of cornstarch, and 0.082 pound of soybean meal for the lambs receiving the 0.5 percent urea silages, and 0.800 pound of cornstarch for the lambs receiving the 0.75 percent urea silage. The total feed offered to each lamb was equalized at 8.8 pounds per day.

Following a seven day change over period, eight of the twelve lambs from the first study were used in a second digestion trial and fed the remaining two silages from silos 6 and 8. The silages were fed at a rate of 8.0 pounds per day and were supplemented the same as the 0 and 0.5 percent urea silages fed in the first study equalizing the total feed offered, T.D.N. and crude protein.

In both studies, the lambs were placed in digestion crates one day prior to the seven day total collection period. During the collection period, the supplemented silages plus a 50-50 dicalcium phosphate-mineralized salt mixture were fed daily with free access to water. Feed, orts and feces were weighed and recorded daily. The fecal material was collected in polyethylene bags cemented to the lambs with branding cement. The bags were emptied twice daily and the feces stored in a walk-in refrigerator with thymol as a preservative.

At the completion of the collection period, the amount of fecal material was weighed, mixed, sampled, and dried at approximately 80° C. for 72 hours. The dried samples were ground in a Wiley mill and stored until chemical analysis could be completed. Urine was collected under toluene with sulfuric acid as a preservative. Urine volume was determined once per day and approximately 5 to 10 percent by volume composited and frozen for nitrogen analysis. Complete proximate analysis was performed on feed, orts, and fecal samples. The weight of each lamb was determined before and after the collection period.

Computation of Data--Production Trials

All feed consumption data were computated on a dry matter basis. In the milk production trials, T.D.N. intake was calculated and feed utilization was expressed on a T.D.N. per pound of 4.0 percent milk basis. Net utilization was calculated as T.D.N. per pound of milk after correcting for body weight change (using the factor of 2.1 pounds of T.D.N. per pound of body weight change, Brody, 1945).

Milk production was expressed on a 4.0 percent fat-corrected basis (Gaines, 1928) using the following equation:

4% F.C.M. = .4 (pounds of milk production) + 15 (pounds of fat)

Milk and S.N.F. were computed on a 30-day basis and summed for the complete experimental period. Regression equations of Erb *et al.* (1960) and Erb (1963) were used in computing the S.N.F. data from the Golding Bead test.

The nitrogen balance data were computed using the method of

Mitchell (1924) and the factors of Harris and Mitchell (1941) for endogenous urinary nitrogen and metabolic fecal nitrogen.

Chemical Analysis

Moisture, pH, Total Nitrogen

Moisture was determined on silage samples with a hot air oven at 100-105° C. for 24 hours. Dry matter determinations for feed and orts samples were performed by drying in a hot air oven at approximately 80° C. for 72 hours. The hydrogen ion concentration was determined with a Beckman pH meter equipped with an external glass electrode. Nitrogen was determined by procedures outlined by the Association of Official Agricultural Chemists and adapted for corn silage. The total nitrogen values from each silage sample were multiplied by 6.25 to obtain the crude protein equivalent values.

Volatile Fatty Acids

Samples for both volatile and non-volatile fatty acids were prepared by mixing 100 grams of silage with 100 to 150 ml. of 0.4N sulfuric acid and stored at 38 to 39° F. for at least 72 hours. The liquid portion was extracted and centrifuged at 2000 R.P.M. The supernatants were removed, strained through two layers of cheese cloth and stored under refrigeration with Thymol as a preservative. The volatile fatty acids (acetic, propionic, and butyric) were determined with a Wilkens Hi-Fi Aerograph, Model 550 or 600, equipped with hydrogen flame detectors. The column materials were either 20 percent carbowax on chromosorb "W" or 10 percent FFAP on chromosorb "W" DMCS acid washed. The column temperature was approximately 135^{o} C. The non-volatile fatty acid, lactic, was determined by the Barker and Summerson (1941) method.

Analysis of Data

The data were analyzed according to the methods for completely randomized and randomized block designed experiments, (Li, 1964).

RESULTS

Chemical Data

pH

In Experiment I two silage treatments were fed to heifers: corn silage plus 0.5 percent calcium carbonate and 0.5 percent urea (silo 7), and corn silage plus 0.75 percent dicalcium phosphate and 0.5 percent urea (silo 8-T) (Table 1). Both treated silages were higher in pH than the control silage (silo 3). In the remaining silages of Experiment I, the single additive treated silages (silos 4, 5, and 6) showed similar trends to those of silos 7 and 8 when compared to the control silage (silo 3). Silo seven contained 0.5 percent calcium carbonate plus 0.5 percent urea. The final pH of this silage treatment was higher than the remaining silage treatments ($P < 0.01$). Diammonium phosphate (1.0 percent) and calcium carbonate (0.5 percent), when used as single additives to corn silage (silos 5 and 6), produced slight increases in pH as compared to the control silage. The ions of diammonium phosphate (NH_4^+ and $H\ PO_4^-$, $HPO_4^=$, etc.) ammonium and phosphate may have opposite effects upon pH of the silage. Calcium carbonate (0.5 percent) and diammonium phosphate (1.0 percent) were used in combination as a silage treatment (silo 8-B). The pH of the as fed samples of this silage was higher ($P < 0.01$) than all other silages fed during the lactation trial except the silage containing 0.5 percent calcium carbonate and 0.5 percent urea (silo 7). The

TABLE 1.--Effect of chemical additives on pH of corn silage

Silo:	3	4	5	6	7	8-T[g]	8-B[h]
Treatment:	None	0.5% Urea	1.0% DAP[i]	0.5% $CaCO_3$	0.5% Urea 0.5% $CaCO_3$	0.75% Dical[l] 0.5% Urea	0.5% $CaCO_3$ 1.0% DAP
<u>Experiment I</u> (1963-64)							
0 day	5.1	4.9	6.1	5.3	5.6	5.4	5.4
5 day	3.7	3.9	3.8	3.8	3.9	4.2	4.9
10 day	3.7	3.7	3.8	4.1	4.0	3.9	4.1
20 day	3.7	3.8	3.8	3.8	4.0	3.8	3.9
As fed[e]	3.6^{kad}	3.7^{kad}	3.7^{kad}	3.7^{kad}	4.1^{b}	--	3.9^{ac}
As fed[f]	--	--	--	--	4.6	4.4	--
Silo:	3	4	5	6	7	8	
Treatment:	None	0.5% Urea	0.75% Urea	0.5% $CaCO_3$	0.5% Urea 0.5% $CaCO_3$	0.75% Urea 0.5% $CaCO_3$	
<u>Experiment II</u> (1964-65)							
0 day	5.4	5.7	5.6	6.0	6.3	6.3	
5 day	3.7	3.9	3.8	4.0	4.0	3.9	
10 day	3.6	3.8	3.8	3.7	3.8	4.0	
20 day	3.7	3.8	3.7	3.8	4.0	3.9	
As fed[e]	3.7^{kad}	3.7^{ka}	3.7^{ka}	3.7^{ka}	3.8^{ac}	3.9^{b}	

[e]As fed = Average of samples taken during lactation feeding trial.
[f]As fed = Average of samples taken during heifer growth trial (analyzed separately).
[g]Top half of silo 8; [h]Bottom half of silo 8.
[i]DAP = Diammonium phosphate; [j]$CaCO_3$ = Calcium carbonate; [l]Dical = Dicalcium phosphate.
[k]Values with the same superscript represent a homogeneous group; b > a, c > d ($P < 0.01$).

standard error of the mean of the silage pH values for the first lactation trial was ± 0.042.

The silages studied in the second experiment were treated with different levels of urea with and without a second adjunct, calcium carbonate. The single additive treatments of 0.5 percent urea, 0.75 percent urea, and 0.5 percent calcium carbonate (silos 4, 5, and 6) influenced the silage pH values similarly to the single additive treatments of the first experiment. In silo 7, calcium carbonate and urea were both added at 0.5 percent per ton, while in silo 8 these two compounds were included in the silage at 0.5 percent and 0.75 percent, respectively. The pH of the 0.5 percent calcium carbonate plus 0.75 percent urea silage was higher than all other silage pH values ($P < 0.01$), while the 0.5 percent calcium carbonate plus 0.5 percent urea treated silage was significantly higher than only the control silage (silo 3). In this trial, the standard error of the treatment means was ± 0.029.

The pH values of similarly treated silages from Experiments I and II were combined to give weighted means and standard error of the means for each treatment. These values for the control, 0.5 percent urea, 0.5 percent calcium carbonate, and 0.5 percent calcium carbonate plus 0.5 percent urea silages were $3.64 \pm .024$, $3.71 \pm .024$, $3.72 \pm .024$, and $3.90 \pm .024$.

The greatest rate of decrease in pH occurred within the first five days indicating active microbial and chemical changes. While single additive treatments resulted in increased silage pH values, combination chemical treatments produced even greater increases in pH irrespective of sampling time (silos 7 and 8). Similar trends were noted for samples composited during the feeding trials. No significant differences were observed in pH of silages treated with calcium carbonate or urea in either Experiment I or II. When both of these compounds were added to the same silage, the urea-calcium carbonate combinations significantly increased pH in both experiments ($P < 0.05$).

Crude Protein Equivalent

The addition of either 0.5 percent urea, 0.75 percent urea, or 1.0 percent diammonium phosphate per ton increased the crude protein equivalent of the resulting silages (Table 2). In Experiment I, the only variable in the chemical treatments was the calcium source (calcium carbonate, silo 7, and dicalcium phosphate, silo 8-T). Each silage contained 0.5 percent urea so that the mean crude protein values for these silages were 11.89 and 11.83 percent, respectively. The remaining silages contained two different nitrogen sources, diammonium phosphate and urea, both added on an approximately equal nitrogen basis. The two silages containing no added nitrogen, control (silo 3) and 0.5 percent calcium carbonate (silo 6), had mean crude protein equivalent values of 9.34 and 8.88 percent, respectively. Silages containing 0.5 percent urea, (silos 4 and 7) had mean crude protein values of 13.81 and 12.12 percent, respectively, while similar values for the diammonium phosphate treated silages (silo 5 and 8) were 12.07 and 13.87 percent, respectively. Crude protein equivalent values for all nitrogen treated silages were higher ($P < 0.01$ or $P < 0.05$) than the untreated silages with a standard error of treatment means of ± 0.82.

TABLE 2.--Crude protein equivalent of experimental corn silages (dry matter basis)

Item	Silo Number						
	3	4	5	6	7	8-T	8-B
				Percent			
Experiment I							
Growth Trial							
Mean[a]					11.89	11.83	
As fed[b]					11.30	10.43	
Lactation							
Mean[a]	9.34[ldj]	13.81[ke]	12.07[ki]	8.88[ldj]	12.12[ki]	--	13.87[ke]
As fed[b]	9.60	13.38	12.65	8.75	12.45	--	11.87
Experiment II							
Growth & Lactation							
Mean[a]	10.10[dj]	13.33[ki]	14.88[ke]	9.82[dj]	14.86[ke]	15.91[ke]	
As fed[b]	10.37	13.08	15.14	9.83	13.07	14.55	

[a]Crude protein values represent the mean of four fermentation samples and composited feeding trial samples.

[b]Average crude protein value of composited feeding trial samples.

[kl]Values with the same superscript are a homogeneous group: $e > d$ ($P < 0.01$); $i > j$ ($P < 0.05$).

In the second experiment, a definite relationship was observed between the percent added urea and crude protein equivalent content of the silages. The average crude protein equivalent values for silages containing 0, 0.5, and 0.75 percent urea were 9.5, 13.1, and 15.4 percent, respectively. As in the first experiment, these differences between the treated and untreated silages were significant with a standard error for the treatment means of ± 0.97. When the values for similarly treated silages were combined for both years, the mean and standard error for the control, 0.5 percent urea, 0.5 percent calcium carbonate and 0.5 percent calcium carbonate plus 0.5 percent urea silages were 9.72 ± 0.64, 13.57 ± 0.64, 9.35 ± 0.64, and 13.49 ± 0.64 percent, respectively.

The average crude protein equivalent value (one composited sample per silo) for all silages treated with similar levels of urea and diammonium phosphate are presented in Table 3. Increases in the added nitrogen increased the corresponding crude protein equivalent values for these silages.

The percent loss of urea crude protein equivalent added as well as the percent of theoretical crude protein equivalent in each silage are also presented in Table 3. The average crude protein equivalent expressed as a percent of the theoretical crude protein equivalent for the 0.5 percent urea, 0.75 percent urea, and 1.0 percent diammonium phosphate silages were 86.7, 87.2 and 87.4 percent, respectively. The greatest loss in added urea crude protein equivalent occurred in the 0.5 percent urea and 1.0 percent diammonium phosphate silages, while the lowest occurred in the 0.75 percent urea silage. One-half percent urea and

1.0 percent diammonium phosphate represent equal amounts of added nitrogen. The average urea crude protein equivalent loss for all non-protein nitrogen treated silages was 37.9 percent.

TABLE 3.--Effect of urea and diammonium phosphate additions on silage crude protein equivalent content (dry matter basis)

Treatment	0% Urea	0.5% Urea	0.75% Urea	1.0% D.A.P.[a]
		Percent		
Crude Protein equivalent[b]	9.64	12.37	14.85	12.26
% of Theoretical C.P.E.[c]				
1963-64	100	85.2	--	87.4
1964-65	100	88.9	87.2	--
% Urea C.P.E. loss[d]				
1963-64	0	44.5	--	36.7
1964-65	0	35.5	31.6	--

[a]D.A.P.--diammonium phosphate.

[b]Values are from samples taken during feeding trials.

[c]Theoretical value of treated silage divided into actual or analyzed value = % of Theoretical.

[d]Theoretical value--analyzed value divided by urea crude protein equivalent = % of urea crude protein equivalent lost.

Organic Acid Production

The effect of treatment on acetic and lactic acid production is illustrated in Table 4. Silages containing 0.5 percent calcium carbonate and 0.5 percent urea (silo 7) or 0.75 percent dicalcium phosphate and 0.5 percent urea (silo 8-T) contained more acetic and slightly less lactic acid than other combination additive silages during the same

TABLE 4.--Organic acid production in experimental corn silages

Silo:	3	4	5	5	6	7	8	8-B	8-T
Treatment:	None	0.5% Urea	0.75% Urea	1.0% DAP[a]	0.5% $CaCO_3$	0.5% $CaCO_3$ 0.5% Urea	0.5% $CaCO_3$ 0.75 Urea	0.5% $CaCO_3$ 1.0% DAP[a]	0.75% Dical[b] 0.5% Urea
						% of Dry Matter			
1963-64									
Acetate[cd]						2.00			2.28
Lactate[cd]						10.88[i]	--	--	8.34[j]
Acetate[d]	1.08[f]	1.19[f]	--	1.19[f]	1.26[f]	1.80[e]	--	1.22[f]	--
Lactate[d]	8.42	9.56	--	9.97	9.21	11.28	--	10.90	--
1964-65									
Acetate[d]	1.67	2.00	1.94	--	2.17	2.20	2.06		
Lactate[d]	9.11	10.19	10.48	--	13.06	11.33	11.32		

Multiple Treatment Comparisons	Acetate	Lactate
	% of Dry Matter	
1963-64		
Silo 3 vs. 4, 5, 6, 7, 8-B	1.08 vs. 1.33	8.42[l] vs. 10.18[k]
Silo 3 vs. 4-5 vs. 6 vs. 7-8	1.08[gn] vs. 1.19[gh] vs. 1.26[gh] vs. 1.51[hm]	8.42[gf] vs. 9.76[gh] vs. 9.21[gh] vs. 11.09[he]
Silo 3 vs. 4-5 vs. 6-7-8	1.08 vs. 1.19 vs. 1.43	8.42[gn] vs. 9.76[gh] vs. 10.46[hm]

1964-65		
Silo 3 vs. 4, 5, 6, 7, 8	1.67^{f} vs. 2.08^{e}	9.11^{n} vs. 11.27^{m}
Silo 3 vs. 4-5 vs. 6 vs. 7-8	1.67^{fh} vs. 1.97^{gh} vs. 2.17^{ge} vs. 2.13^{ge}	9.11^{gnp} vs. 10.33^{ghn} vs. 13.06^{rm} vs. 11.32^{hro}
Silo 3 vs. 4-5 vs. 6-7-8	1.67^{fh} vs. 1.97^{gh} vs. 2.15^{ge}	9.11^{gn} vs. 10.33^{gh} vs. 11.90^{hm}

[a]DAP--Diammonium phosphate.

[b]Dical--Dicalcium phosphate.

[c]Acetate and lactate of silages fed in first growth trial, analyzed separately because of difference in time when fed.

[d]Values represent mean of three fermentation samples and composited samples taken during feeding trial.

[ghr]Values with same superscript are a homogeneous group: $e > f$ ($P < 0.05$); $i > j$ ($P < 0.005$); $k > l$ ($P \gtrsim 0.07$); $m > n$ ($P \gtrsim 0.10$); and $o > p$ ($P \gtrsim 0.10$).

year (1963-64). The silage from silo 7 produced higher ($P < 0.05$) amounts of lactic acid than the silage from silo 8-T. There was no statistical difference in lactic acid production among the silages from silos 3, 4, 5, 6, 7, and 8-B even though the combination additive silages produced larger amounts than the single additive silages. The silage containing 0.5 percent calcium carbonate and 0.5 percent urea produced greater ($P < 0.05$) amounts of acetic acid than the remaining silages (silos 3, 4, 5, 6, 7, and 8-B). The silage containing 0.5 percent calcium carbonate had larger, but not significant, amounts of acetic acid than the remaining single additive and control silages (silos 3, 4, 5). A similar trend was also true for the 1964-65 silages. When compared to these same silages, the 0.5 percent calcium carbonate silage contained the greatest amount of lactic acid (1964-65 silages).

Multiple treatment comparisons are also presented in Table 4. When compared to the control silage the use of chemical additives (silo 3 vs. 4 - 8-B or 4 - 8) increased the lactate production ($P \gtrsim 0.07$) 1963-64 silages and ($P \lesssim 0.10$) 1964-65 silages. Similar trends were noted for the acetate production, but this was significant ($P < 0.05$) only in the 1964-65 silages. Combination additive silages (silo 7 - 8) increased ($P < 0.05$, 1963-64 silages), ($P \lesssim 0.10$, 1964-65 silages) lactic acid production when compared to the control silage. The 0.5 percent calcium carbonate silage (silo 6, 1964-65) produced similar results ($P \lesssim 0.10$). Significant increases in acetate production were noted for the combination additive silages (silo 7 - 8) in 1964-65 ($P < 0.05$). In the 1964-65 silages, the 0.5 percent calcium carbonate silage (silo 6) contained greater amounts ($P < 0.05$) of acetate than the control silage (silo 3). This same trend was noted in all calcium carbonate silages (silos 6, 7, 8) and was significant for lactate (1963-64 silages, $P \lesssim 0.10$) and both acetate and lactate in the 1964-65 silages ($P < 0.05$ and $P \lesssim 0.10$).

Chemical Composition of Silages

The proximate analyses of the experimental silages are presented in Table 5. The addition of either calcium carbonate or diammonium phosphate increased the ash content of the silages. In general, the greatest increase in ash was in the combination additive silages. Crude protein content was increased but only in silages containing added nitrogen.

Animal Performance

Heifer Growth Trials

Silages from both experiments were offered to growing dairy heifers to measure relative feeding value of the various treated silages. Data from the first experiment are given in Table 6.

Heifers fed calcium carbonate plus urea silage had an average live body weight gain of 1.22 pounds per day while those receiving the dicalcium phosphate plus urea silage gained 1.31 pounds per day. One heifer in the first group ($CaCO_3$-urea silage) was off feed for a short time during the experiment which may have effected the group average since she completed the experiment with only a 0.91 pound per day gain. Differences between groups in dry matter consumption and feed utilization were small.

TABLE 5.--Chemical composition of experimental silages

Chemical Constituent	Dry Matter	Ash	Crude Fiber	Ether Extract	Protein	Nitrogen Free Extract
				Percent		
1963-64						
Control silage	24.9	4.9	22.1	3.2	9.6	60.2
0.5% urea silage	24.4	4.8	20.5	3.7	13.4	57.7
1.0% DAP[a] silage	26.9	6.0	19.0	3.4	12.7	59.0
0.5% $CaCO_3$ silage	28.3	5.0	17.5	3.4	8.8	65.2
0.5% $CaCO_3$ + 0.5% urea[b] silage	28.0	5.8	20.5	4.1	12.5	57.1
0.5% $CaCO_3$ + 0.5% urea[c] silage	30.8	6.7	19.3	3.4	11.3	59.3
0.5% $CaCO_3$ + 1.0% DAP[a] silage	27.5	6.7	19.9	5.0	11.9	56.5
0.75% Dical[d] + 0.5% urea silage	29.7	5.9	18.4	3.4	10.4	61.8
1964-65						
Control silage	28.2	4.5	19.2	5.1	10.4	60.8
0.5% urea silage	28.4	4.2	18.9	2.8	13.1	61.1
0.75% urea silage	27.8	4.3	19.1	2.9	15.1	58.5
0.5% $CaCO_3$ silage	27.9	5.7	18.9	2.8	9.8	62.8
0.5% $CaCO_3$ + 0.5% urea silage	28.4	5.5	19.0	2.8	13.1	59.6
0.5% $CaCO_3$ + 0.75% urea silage	28.9	5.3	19.2	2.7	14.6	58.3

Concentrates						
1963-64						
Soybean meal	89.2	5.8	4.3	.8	54.4	34.7
Ground shelled corn	88.0	1.6	2.2	4.5	10.3	81.4
16% CP[e] grain mixture	87.9	4.6	2.6	3.6	18.0	71.2
1964-65						
Shelled corn	87.8	1.6	2.4	4.3	11.3	80.4
Soybean meal	88.8	5.9	4.0	.5	57.9	31.7

[a]DAP--diammonium phosphate.

[b]Analyzed when fed to milking cows.

[c]Analyzed when fed to heifers.

[d]Dical--dicalcium phosphate.

[e]CP--crude protein.

TABLE 6.--Growth of dairy heifers fed treated corn silages (1963-64 silages)

Treatment	0.5% $CaCO_3$ 0.5% Urea	0.75% Dicalcium Phosphate 0.5% Urea
Number	7	8
Feed intake (lb. DM/day)	13.65	14.04
Average daily gain (87 days)	1.22	1.31
Feed utilization (lb. DM/lb. gain)	11.38	10.98

All silage treatments in the second experiment were utilized in a 70-day heifer growth trial. The daily live body weight gains, feed intake, and feed utilization data are given in Table 7.

There was an increase in the silage dry matter consumed per day as the urea level in the single additive treated silage was increased. The dry matter intake was depressed ($P < 0.05$ and $P < 0.01$) in the groups receiving the silages containing 0.5 percent calcium carbonate. When urea and calcium carbonate were added in combination, the depressing effect of the calcium carbonate was decreased. Similar trends were noted in the average daily live body weight gains with the 0.75 percent urea group gaining 2.11 pounds per day followed by the 0.5 percent urea group and the control group gaining 2.00 and 1.91 pounds per day respectively. The group receiving silage containing 0.5 percent calcium carbonate gained the least of any group with slightly greater gains being made by the groups receiving the combination additive silages. The two groups gaining 1.49 and 1.55 pounds per day (0.5 percent calcium carbonate and 0.75 percent urea and 0.5 percent calcium carbonate) were lower ($P < 0.05$ and $P < 0.01$) than

TABLE 7.--Growth of dairy heifers fed treated corn silages
(1964-65 silages)

Treatment	None	0.5% Urea	0.75% Urea	0.5% $CaCO_3$	0.5% Urea 0.5% $CaCO_3$	0.75% Urea 0.5% $CaCO_3$
Number	8	8	8	8	8	8
DM intake/day (lb.)	14.7^{ejf}	14.7^{ejf}	15.6^{ea}	13.4^{kgb}	14.1^{jkb}	14.1^{jkb}
Avg. daily gain (lb.) (70 day)	1.91^{ekf}	2.00^{ef}	2.11^{ea}	1.49^{jbg}	1.75^{ekj}	1.55^{kjbg}
Lbs. DM/lb. gain	7.8^{gk}	7.4^{gk}	7.7^{gk}	9.4^{ek}	8.2^{gk}	11.0^{ef}

^{ekj}Mean values with same superscript are a homogeneous group: a > b ($P < 0.01$); f > g ($P < 0.05$).

the remaining groups. The feed utilization (pound of dry matter per pound of gain) of the different silage groups showed similar trends. The group receiving the 0.5 percent calcium carbonate plus 0.75 percent urea silage required more silage dry matter per pound of gain than any other group ($P < 0.05$). Similarly, the group receiving 0.5 percent calcium carbonate silage required more dry matter per pound of gain than the remaining four groups, but this difference was not significant ($P < 0.05$).

Lactation Studies

The remaining silages in Experiment I, which were not utilized in the heifer growth trial, were fed to 36 lactating Holsteins in a 90 day trial. Feed consumption and production response data are presented in Table 8.

The silages in this experiment were equally acceptable to the cows as indicated by the silage dry matter intake per day, or per 100 pounds of body weight with the exception of the silage containing 1.0 percent diammonium phosphate which was significantly lower ($P < 0.05$) than all other groups in silage dry matter intake per day and silage dry matter per 100 pounds of body weight ($P < 0.05$ and $P < 0.01$). Because of lower nutrient consumption, this group produced less 4.0 percent fat-corrected milk, solids-not-fat, and milk fat per day than the remaining treatment groups. None of these differences were significant, except for the pounds of solids-not-fat produced per day ($P < 0.05$). In the latter measurement, comparisons of all possible pairs by Duncan's Multiple Range test failed to reveal any

TABLE 8.--Lactation trial (1963-64 silages)

Silo:	3	4	5	6	7	8-B
Treatment	None	0.5% Urea	1.0% DAP[k]	0.5% $CaCO_3$	0.5% $CaCO_3$ 0.5% Urea	0.5% $CaCO_3$ 1.0% DAP
Silage DM intake[l] (lb/day)	21.0^{f}	20.8^{f}	15.5^{g}	21.1^{f}	21.7^{f}	21.1^{f}
Silage DM/100 lb. BW[m]	1.7^{ea}	1.7^{ef}	1.3^{bg}	1.8^{ea}	1.8^{ea}	1.9^{ea}
Grain DM intake (lb/day)	6.3	6.3	6.2	6.3	6.3	6.3
Total DM intake (lb. DM/day)	27.3^{f}	27.1^{f}	21.7^{g}	27.3^{f}	28.0^{f}	27.4^{f}
TDN/day (lb.)[n]	21.1^{f}	20.1^{f}	16.4^{g}	20.2^{f}	20.7^{f}	20.3^{f}
4% FCM (lb.)[o]	33.9	31.3	28.5	32.5	33.1	31.1
% SNF[p]	8.5	8.5	8.3	8.6	8.3	8.2
Lbs. SNF/day	3.2^{eh}	2.9^{eh}	2.8^{hg}	3.3^{ef}	3.2^{eh}	2.3^{eh}
% milk fat	3.5	3.5	3.0	3.1	3.0	3.1
Lbs. milk fat/day	1.3	1.2	1.0	1.2	1.2	1.1
Lb. TDN/lb. 4% FCM	$.35^{hjbg}$	$.40^{eh}$	$.39^{ehj}$	$.35^{hjbg}$	$.43^{ef}$	$.45^{ea}$

[ehj]Values with the same superscript are a homogeneous group.
[k]DAP--diammonium phosphate.
[l]DM--dry matter.
[m]BW--body weight.
[n]TDN--total digestible nutrients.
[o]FCM--fat corrected milk.
[p]SNF--solids-not-fat.
$a > b$ ($P < 0.01$)
$f > g$ ($P < 0.05$)

significant differences at the 0.05 probability level, except that the difference between silos 5 and 6 approached this level. It was also noted that cows receiving either 0.5 percent calcium carbonate plus 0.5 percent urea or 0.5 percent calcium carbonate plus 1.0 percent diammonium phosphate required more ($P < 0.05$ and $P < 0.01$) total digestible nutrients per pound of 4.0 percent fat-corrected milk than cows receiving either the control or 0.5 percent calcium carbonate silages. No other differences were observed among treatment groups.

Results of the lactation study using silages from the second experiment are presented in Table 9. Cows fed either the 0.75 percent urea silage or the 0.5 percent calcium carbonate plus 0.75 percent urea silage consumed less ($P < 0.05$, $P < 0.01$) silage dry matter per day than the remaining treatment groups with the exception of the group receiving the 0.5 percent calcium carbonate plus 0.5 percent urea silage. The latter group consumed less ($P < 0.05$) than the 0.5 percent calcium carbonate group. Similar trends were noted in silage dry matter per hundred pounds of body weight, total dry matter intake per day and total digestible nutrient intake per day. In all values, the two 0.75 percent urea silages were inferior to the other silages.

The production response indicated that the groups receiving either of the two silages containing 0.5 percent urea produced the most 4.0 percent fat-corrected milk per day (44.3 and 42.7 pounds), while the group receiving the 0.5 percent calcium carbonate silage produced the least amount (35.7 pounds) of 4.0 percent fat-corrected milk. All remaining groups were intermediate to these levels and differences were not statistically significant. Differences among

TABLE 9.--Lactation trial (1964-65 silages)

Treatment	None	0.5% Urea	0.75% Urea	0.5% $CaCO_3$	0.5% $CaCO_3$ 0.5% Urea	0.5% $CaCO_3$ 0.75% Urea
Silage DM intake[j] (lb/day)	21.1^{ech}	21.0^{ecj}	16.6^{dbio}	23.9^{eaf}	19.1^{edg}	16.2^{dbio}
Silage DM/100 lb. BW[k] (lb.)	1.9^{eaf}	1.8^{edh}	1.5^{dg}	1.8^{eaf}	1.6^{ed}	1.4^{dbi}
Grain DM intake (lb/day)	9.4	10.1	9.9	7.6	10.9	10.4
Total DM intake (lb/day)	30.5^{eh}	31.1^{ef}	26.5^{dbgio}	31.4^{ea}	30.0^{ej}	26.5^{dbgio}
TDN intake[l] (lb/day)	22.2^{edr}	22.9^{ef}	19.9^{tgios}	22.2^{edj}	22.3^{edh}	20.1^{dtg}
4% FCM (lb/day)[m]	39.2	44.3	38.8	35.7	42.7	38.4
% SNF[n]	9.0	8.8	8.6	8.9	8.7	8.7
Lb. SNF/day	3.8	3.9	3.7	3.3	4.1	3.9
% milk fat	3.6	4.0	3.4	3.8	3.4	3.1
Lb. milk fat/day	1.5	1.8	1.5	1.4	1.6	1.4
Lb. TDN/lb. 4% FCM	.31	.30	.30	.34	.30	.32

[j]DM--dry matter.

[k]BW--body weight.

[l]TDN--total digestible nutrients.

[m]FCM--fat-corrected milk.

[n]SNF--solids-not-fat.

[edt]Values with same superscript are a homogeneous group: a > b (P < 0.01); f > g, h > i, j > o, r > s (P > 0.05).

treatment groups in percent SNF, pounds of SNF per day, percent milk fat, and pounds of milk fat per day were not statistically significant. While little difference was observed in efficiency values (pound TDN per pound gain), the group receiving 0.5 percent calcium carbonate silage produced less milk and therefore was less efficient than all other groups.

Digestibility and Nitrogen Balance Studies

Wether lambs were used in digestibility and nitrogen balance studies to further evaluate silages fed in the second experiment (1964-65). The results of this study are presented in Table 10. The total feed (silage plus grain) intake per day was as follows: Control, 7.267 pounds; 0.5 percent urea, 7.250 pounds; 0.75 percent urea, 7.210 pounds; 0.5 percent calcium carbonate plus 0.5 percent urea, 7.629 pounds; 0.5 percent calcium carbonate, 8.452 pounds and 0.5 percent calcium carbonate plus 0.75 percent urea, 8.248 pounds, respectively. When analyzed across trials, differences in feed intake among groups were not statistically significant. Within trials the range between the low and high feed intake was 0.419 pounds in Trial I and 0.204 pounds in Trial II. In Trial I, there was a definite depression in digestibility of dry matter, ash, and protein in the treated corn silages with a significant ($P < 0.05$, $P < 0.01$) depression of crude fiber digestibility in the 0.5 percent urea silage. In Trial II, similar trends were noted in ash, ether extract, and protein digestibility when urea was present. In this trial, ash digestibility was depressed ($P < 0.05$) when urea was added in combination with

TABLE 10.--Coefficients of digestibility and nitrogen balance of experimental corn silages fed to lambs (1964-65 silages)

Constituent	Dry Matter	Ash	Crude Fiber	Ether Extract	Protein	NFE[c]	Nitrogen Balance
				Percent			
Treatments							
Trial I[a]							
Control silage	75.2	33.5	56.9[ea]	83.5	69.4	82.4	+6.9
0.5% urea silage	72.3	22.2	38.5[bg]	81.2	63.9	81.4	+5.5
0.75% urea silage	73.9	24.2	59.5[ea]	83.0	65.3	80.9	+3.0
0.5% $CaCO_3$ + 0.5% urea silage	73.6	23.5	52.4[ef]	83.6	66.0	81.9	+4.7
Trial II[a]							
0.5% $CaCO_3$ silage	70.5	35.2[f]	46.6	82.5	64.6	78.9	+3.8
0.5% $CaCO_3$ + 0.75% urea silage	70.9	29.1[g]	46.0	80.4	62.9	79.3	+3.8

[a]Each value is the average of three lambs in Trial I, four lambs in Trial II.

[c]NFE--Nitrogen-free extract.
$a > b$ ($P < 0.01$); $f > g$ ($P < 0.05$).

calcium carbonate. The effect of urea level on apparent digestibility is presented in Table 11.

TABLE 11.--Effect of urea on apparent digestibility of treated corn silages

Chemical Constituent	Dry Matter	Ash	Crude Fiber	Ether Extract	Protein	Nitrogen-Free Extract
Urea level						
0% urea	72.5	34.5	51.0	82.9	66.6	80.4
0.5% urea	73.0	22.8	45.4	82.4	64.9	81.7
0.75% urea	72.2	27.0	51.8	81.5	64.0	80.0

When urea was used as an additive in silage, there was a slight depression in the digestibility of ash and protein. The depression in ash digestibility was highly significant but confounded with time and thus difficult to evaluate. When these data were analyzed across trials, ash digestibility was significantly lower in the 0.5 percent urea, 0.75 percent urea and 0.5 percent urea plus 0.5 percent calcium carbonate silages than in the control silage. The crude fiber digestibility of the 0.5 percent urea silage was also lower ($P < 0.01$) than the control, 0.75 percent urea, and 0.5 percent calcium carbonate plus 0.5 percent urea silages. The differences in dry matter digestibility approached significance ($P < 0.05$). There were no significant differences in nitrogen balance within or across trials by levels of urea. The nitrogen balance for the 0, 0.5, and 0.75 percent urea silages was +5.12, +5.05, and +3.46 gm. per day, respectively. Likewise, there was no difference in the urinary or fecal nitrogen excretion per day as the level of urea increased. These values for the 0, 0.5 and 0.75 percent urea silages were 10.34, 7.80; 8.78, 7.49; and 9.44, 7.26 gm. per day, respectively.

The urea containing silages appeared to have a diuretic effect upon the lambs as there was a slight increase in total urine volume as the level of urea increased. The total urine volume for the lambs fed the 0, 0.5 and 0.75 percent urea silages was 4,170, 5,140, and 4,739 ml., respectively. These differences were not significant.

The biological values of the silage proteins were determined with the data presented in Table 12. Only two lambs are represented for the value of the 0.5 percent urea silage. The third lamb had a higher calculated metabolic fecal nitrogen excretion than the total fecal nitrogen excretion and could not be used. The value for the 0.5 percent calcium carbonate silage was higher, 68, but a low biological value, 16.19, from one lamb reduced the group value. However, no real trends could be concluded from the data because of wide variation within treatment groups.

TABLE 12.--Biological values of experimental corn silage protein[a]

Treatment	None	0.5% Urea	0.75% Urea	0.5% $CaCO_3$	0.5% $CaCO_3$ 0.5% Urea	0.5% $CaCO_3$ 0.75% Urea
			Percent			
Biological value	67	70	54	55	60	62

[a]Silages supplemented with cornstarch and soybean oil meal.

Silage Input-Output Data

The loss in dry matter from the silages is presented in Table 13. Less silage was put into silos 3 - 6 (1963-64) than in silos 7 and 8. The remainder of the silos were filled with high moisture corn silage, used in another experiment, and was separated from the whole plant corn silage by a sheet of black plastic. The average percent loss of dry matter for the 1963-64 and 1964-65 silages was 8.6 and 11.0 percent, respectively.

TABLE 13.--Silage input-output data

Silo:	3	4	5	6	7	8
Treatment:	None	0.5% Urea	1.0% DAP[a]	0.5% $CaCO_3$	0.5% Urea 0.59 $CaCO_3$	0.5% $CaCO_3$ 1.0% DAP[a] or 0.75% Dical[b] 0.5% Urea
					Lbs.	
1963-64						
DM[c] input (1000 lbs.)	18.3	18.0	19.8	18.8	35.8	35.9
Edible DM[c] (1000 lbs.)	16.4	16.4	16.5	18.0	32.7	34.9
Spoilage (DM[c])	--	--	--	--	550.1	448.4
% loss	10.5	8.8	16.8	4.2	8.7	2.8
Silo:	3	4	5	6	7	8
Treatment:	None	0.5% Urea	0.75% Urea	0.5% $CaCO_3$	0.5% Urea 0.5% $CaCO_3$	0.75% Urea 0.5% $CaCO_3$
					Lbs.	
1964-65						
DM[c] input (1000 lbs.)	35.2	35.0	37.0	35.5	34.0	34.4
Edible DM[c] (1000 lbs.)	30.3	32.1	32.4	32.1	30.0	30.9
Spoilage (DM[c])	--	281.1	--	176.4	--	358.7
% loss	13.8	8.4	12.6	9.5	11.6	10.1

[a]DAP--Diammonium phosphate.

[b]Dical--Dicalcium phosphate.

[c]DM--Dry matter.

DISCUSSION

During the past two decades, many chemical adjuncts have been added to corn silage in an attempt (1) to improve nutritional qualities or (2) to alter fermentation processes.

In some cases, such chemicals exert buffering actions in the silage mass. Because of the complexity of the system, the exact manner by which they do so is not as yet clearly understood. Chemical additives probably combine with silage organic acids to form the corresponding salts and water which is a weakly ionized compound. This reaction neutralizes the acid and thus prevents the rapid decrease in pH normally associated with silage fermentation. Thus, organic acid production continues until all buffering components are saturated and pH decreases to the point of inhibiting fermentation processes. In a biological system, such as a silage fermentation, other reactions producing the same end result (stimulation of organic acids) are conceivable. The organic acids, depending upon their equilibrium constant (pk_a), probably exist in a state of equilibrium between the acid salt and the free acid form. Upon ionization, an increase in hydrogen ions would be expected. In a silage containing no added buffers, but containing the necessary media for an active bacterial fermentation, the only resistance to a rapid decline in pH occurs from naturally occurring buffer compounds. This process would occur until the hydrogen ion concentration is great enough to inhibit further fermentation processes. If compounds are added to the silage containing buffering components, such as NH_4^+, Ca^{++}, or CO_3^{--} ions, an increase in the buffering action would occur. Calcium carbonate in solution may be hydrolyzed to form calcium hydroxide and carbonic acid. The calcium hydroxide, which is strongly ionized, would form Ca^{++} and OH^- ions with the result that the OH^- ions could remove free hydrogen ions from solution. Urea, under the action of bacterial or plant enzymes, would be broken down to ammonia and carbon dioxide. The carbon dioxide could react with water to form carbonic acid, a weak acid, and ammonia with water to form ammonium hydroxide or hydrogen to form NH_4^+. In all cases, free hydrogen ions would be removed from the media and, until the different buffer components become saturated, the hydrogen ion concentration would not increase at as rapid a rate as in untreated silage. All these reactions and undoubtedly many others occur in a buffered silage. However, which reactions actually occur and which function as the predominant buffering reactions is still a matter of theoretical conjecture.

In the present study, there was a slight increase in pH when either urea, diammonium phosphate, calcium carbonate, or dicalcium phosphate was included in the silage. While urea produced only slight increases in pH in this study during the fermentation period, the values for those samples taken during the feeding experiments were comparable to the untreated silages. Bentley _et al_. (1955) and Klosterman _et al_. (1963) reported pH values ranging from 4.1 to 7.6. However, most of their silage mixtures contained 10 to 25 pounds of urea. Bentley et al. (1955) also ensiled corn silage with 20 pounds of urea and 2.0 pounds of dicalcium phosphate per ton. The resulting pH of the silage was 3.95, while in the present study with 15 pounds of dicalcium phosphate and 10 pounds of urea, the pH was 4.4. The difference in level of chemical additives may account for the difference in pH observed in the two studies.

Limestone or calcium carbonate produced similar trends in pH. The mean pH values of these as fed samples for the two calcium carbonate treated silages in the present study were 3.7 and 3.7, respectively. Simkins et al. (1964), Byers et al. (1964) and Klosterman et al. (1963) reported pH values of 3.9 to 4.2 for silages treated with 10 to 20 pounds of limestone.

As mentioned previously, no reports were available on the effect of adding diammonium phosphate to silage. From the data of this study, diammonium phosphate may react similar to urea in its chemical action by the formation of acid salts. The phosphate portion of this compound could conceivably react with available hydrogen ions, forming a phosphoric acid radical, thereby creating an opposing force to the elevation of pH. However, since this would occur only at a neutral or basic pH, the quantitative effect of this reaction is questionable.

Additive combinations increased the silage pH more than a single additive ($P < 0.01$). This was true for all additive combinations, and especially at their higher concentrations (0.5 percent calcium carbonate plus 0.75 percent urea). All chemical additions resulted in increased organic acid production compared to the control silage. When used as the only additive, calcium carbonate stimulated greater amounts of organic acids than urea or diammonium phosphate in the 1964-65 silages, but this did not occur in the 1963-64 silages. A slight difference in acid production due to either the height in the silo at which the silage was taken or the time of year at which it was fed was noted in the 1963-64 silage containing 0.5 percent calcium carbonate plus 0.5 percent urea. The samples taken for the growth trial were from the top of the silo during the time of the year between January and April. The lactation study was performed during early summer with silage from the bottom one-half of the silo. The acetate was higher and lactate lower in the top half of the silo whereas the reverse occurred in the bottom half of the silo. Whether this was due to a difference in fermentation at varying levels in the silo, to elevated environmental temperatures or elevated silage temperatures from surface fermentation, or sampling error is not known.

The range for all silages of acetate and lactate expressed on a dry matter basis was 1.08 to 2.28 and 8.42 to 13.06 percent, respectively. These values are in close agreement with those reported by Klosterman _et al_. (1963) for chemically treated corn silages. The use of adjuncts increased the lactate production over that found in the control silage ($P \lesssim 0.07$, 1963-64 silages and $P \lesssim 0.10$, 1964-65 silages). Chemical additives also increased acetate production, but differences among treatment means were significant only in the 1964-65 silages ($P < 0.05$). When additives were combined, lactic acid was increased over that found in the control silage ($P < 0.05$, 1963-64 silages and $P \gtrsim 0.10$, 1964-65 silages). The same trend was also true for acetate production ($P < 0.05$, 1964-65 silages). This would indicate an even greater chemical action allowing greater acid production when the concentration of chemical components increased. In 1964-65, the silages containing 0.5 percent calcium carbonate contained greater amounts of lactic and acetic acids than the control silage ($P \lesssim 0.10$ for lactate) and ($P < 0.05$ for acetate). Silages with added calcium (silos 6, 7, 8) contained greater amounts of both acetic and lactic acid ($P \gtrsim 0.10$ for lactate, 1963-64 and $P < 0.05$ and $P \gtrsim 0.10$ for acetate and lactate, 1964-65). These acid data in the present study indicate that calcium carbonate is a stronger chemical adjunct than urea and are in agreement with the results of Klosterman _et al._ (1963).

Urea and diammonium phosphate additions increased the crude protein equivalent of the treated silages ($P < 0.01$ and $P < 0.05$ for both additives). In general, the crude protein equivalent of the silages increased in proportion to the level of urea added to the silage. These data are in agreement with reports by Bentley _et al._ (1955), Wise _et al._ (1944), Gorb and Lebedinskij (1961), Goode (1955), Palamaru et al. (1961) and Klosterman _et al._ (1961). Whether this increase in crude protein is in the form of bacterial protein or other nitrogenous compounds is not known and deserves further study.

The percent of theoretical crude protein equivalent of the treated silage and the percent loss of protein equivalent from added non-protein nitrogen (NPN) were computed with the following considerations. The crude protein of the control dry matter times the dry matter of the treated silage would give the crude protein of the

treated silage before NPN was added. The pounds of added NPN times the percent crude protein equivalent of the NPN (262 percent for urea and 132 percent for diammonium phosphate) would give the pounds of crude protein equivalent added to the treated silage. The sum of both crude protein equivalent values (natural plus added NPN) would give the theoretical crude protein in treated silages. When the theoretical values of the treated silage were divided into the actual or analyzed crude protein equivalent value, the percent of theoretical was obtained. The theoretical value minus the analyzed value divided by the NPN crude protein equivalent which was added to the silage would give the percent of NPN crude protein equivalent lost. The percent of the theoretical crude protein ranged from 85 to 89 percent, while the percent NPN crude protein equivalent lost ranged from 32 to 45 percent. Bentley et al. (1955) reported apparent urea recovery values ranging from 94 to 112 percent, respectively, over a three year period for silages containing 17 to 25 pounds of urea. In the present study, the lowest loss (31.6) occurred in the silages containing 15 pounds of urea. These values are subject to error in sampling accuracy, loss of NPN at the time of ensiling or any factors which would prevent the attainment of the theoretical crude protein equivalent.

Further evaluation of the data indicated that within the first twenty days after ensiling, 25 to 30 percent of the NPN crude protein equivalent was lost. This loss may occur due to fermentation processes. However, the possibility still exists that all of the calculated amount of NPN did not become ensiled which would enter a larger error into any loss calculations. This loss was computed in the same manner as the total NPN crude protein equivalent loss using the 0 to 20 day samples. Approximately 86 percent of the NPN crude protein equivalent present after 20 days fermentation was recovered in the samples fed during the feeding trials.

The addition of compounds containing either calcium or phosphorus increased the ash content of the silages. The greatest increase in ash content appeared in the combination additive silages. Whether the increase in ash content could be attributed directly to a rise in either calcium or phosphorus is not known. The crude protein content of the silages was increased, but as noted previously, this was true only in those silages with added non-protein nitrogen compounds. No other changes in composition were noted, except for the 1964-65 control silage which contained a higher percentage of ether extract than the remaining silages. The reason for this is not known.

In growth trials, heifers made adequate live body weight gains when fed the treated silages. These gains were not different statistically for the two silages compared the first year (1963-64). In the second year (1964-65), the individual silages were fed without equalizing protein intake to compare the silage mixtures as the sole feed for growing heifers. The heifers receiving the silages containing 0.5 percent calcium carbonate either alone or in combination with 0.5 or 0.75 percent urea gained less than similar heifers fed the control or urea treated silages (probability range of 0.01 to 0.05). Cattle fed the 0.5 percent calcium carbonate silage consumed less silage dry matter per day (probability range of 0.01 to 0.05). The group receiving the 0.5 percent calcium carbonate plus 0.75 percent urea silage required more dry matter to produce a pound of gain ($P < 0.05$). These results are in agreement with McCullough (1964), Nicholson and Cunningham (1964) and Megli et al. (1965) who have reported reduced gains or intake with limestone treated silages. However, Mohler et al. (1962) and Klosterman et al. have not reported these adverse effects.

The heifers receiving silages with urea serving as the only chemical additive made slightly better gains as the level of urea increased. These gains were significantly better than the gains made by heifers receiving 0.5 percent calcium carbonate or 0.5 percent calcium carbonate plus 0.75 percent urea silages (probability range of 0.01 to 0.05). This improvement in gains was probably due to increased crude protein equivalent in the silages. When combined with 0.5 percent calcium carbonate, increased gains were not associated with increasing levels of urea. Bentley et al. (1955), Bentley et al. (1956a), Harvey et al. (1962), Harvey et al. (1963), Klosterman et al. (1964), and Karr et al. (1965a) have reported good live body weight gains with urea silages and in addition Newland and Henderson (1965), Klosterman et al. (1960) and Klosterman et al. (1962) reported good results with limestone-urea silages. In most of these studies, additional energy and protein were fed while in the present study corn silage was the sole source of energy and protein. Even under this regime, the group receiving untreated control silage gained an average of 1.91 pounds per day. The control silage provided approximately 10 percent crude protein (D.M. basis) and raises the question concerning additional protein supplementation from concentrate feeds for raising heifers in this weight range (380-900 pounds) on a corn silage diet. In the

present study ad libitum silage feeding was followed. If controlled fed, protein intake would probably have limited growth of heifers fed control silage but not those fed the urea supplemented silages. Heifers fed ad libitum corn silage for long periods may become excessively fat. However, if the silage contains 0.5 percent urea, controlled feeding practices may be employed and still meet both energy and protein requirements for normal growth.

In the lactation studies, corn silage was the major source of nutrients for all cows on experiment. In the first year's work (1963-64), the animals receiving the 1.0 percent diammonium phosphate silage consumed less silage dry matter per day, dry matter per hundred pounds of body weight, total dry matter and T.D.N. per day (probability range of 0.01 and $P < 0.05$). As a consequence, less 4.0 percent FCM was produced by the animals of this group. Oltjen _et al_. (1963) reported that ammonia was released when diammonium phosphate was added to saliva or distilled water. The amount of this compound remaining in the silage after fermentation is not known. If this compound is broken down in a similar manner as urea, (Schmutz _et al_. 1964) a small amount of diammonium phosphate may be present in the silage after cessation of active fermentation processes. A small amount in the presence of saliva may release sufficient amounts of ammonia to reduce silage consumption. When 0.5 percent calcium carbonate was added in combination with diammonium phosphate, the depression in intake was not observed. Similarly, in contrast to observations in the heifer trial (1964-65), no depression in silage intake by milking cows was observed when 0.5 percent calcium carbonate was used as the sole chemical additive as reported by Simkins _et_ _al_. (1964), Simkins _et_ _al_. (1965) and Kesler _et_ _al_. (1964). Byers _et_ _al_. (1963) and Byers _et_ _al_. (1964) also reported no difference in production or dry matter intake when silage preserved with limestone was fed.

In the second lactation study (1964-65), the animals receiving the 0.75 percent urea silages consumed less silage dry matter per day, silage dry matter per hundred pounds of body weight and total dry matter per day (probability range of 0.01 to 0.05). Total digestible nutrient intake was also lower for these two groups ($P < 0.05$). In this study, 0.5 percent calcium carbonate did not improve performance when included with 0.75 percent urea. Because of this depressed intake, milk production was lower (38.6 vs. 42.1 pound/day) for these two groups than the remaining groups with the exception of the group fed silage containing 0.5 percent calcium carbonate. The highest yield was from the 0.5 percent urea groups (44.3 and 42.7 pounds/day). In the 1964-65 lactation study, the intake of grain was not equalized for each of the silage groups. When the cows were randomly assigned to the silage treatments, by chance, several of the lower producing cows within each outcome group were assigned to the 0.5 percent calcium carbonate silage. Since at the start of this experiment each cow was fed to meet her requirements for maintenance and milk production, these cows were fed lower amounts of grain. This was continued throughout the experiment since each outcome group was fed according to the mean persistency decrease in milk production for that group. Because of lower grain feeding, this group (0.5 percent calcium carbonate) consumed more silage dry matter per day than most of the remaining groups (probability range of 0.01 to 0.05). This group also consumed as much or more total dry matter per day and T.D.N. per day as the remaining groups. However, this group produced less 4.0 percent F.C.M. than the remaining groups. Whether this difference in production is due to a lower feed utilization (pounds T.D.N./pound 4% F.C.M.) or to a slight difference in energy concentration in the total ration is not known. In this trial the animals were randomly placed into outcome groups according to their expected milk production during the experimental period. The average actual milk production expressed as a percentage of the expected production for the control, 0.5 percent urea, 0.75 percent urea, 0.5 percent calcium carbonate, 0.5 percent urea, plus 0.5 percent calcium carbonate, and 0.75 percent urea, plus 0.5 percent calcium carbonate silages was 93.4, 91.4, 89.4, 86.2, 92.4, and 92.6 percent respectively. With the exception of the control and the 0.75 percent urea plus 0.5 percent calcium carbonate silages, similar trends were noted as that found with daily F.C.M. production.

The question may be raised whether stimulation of organic acid production in silage is warranted when the silage is fed to animals for different production purposes. Lactic acid appears to increase more than any of the other organic acids in treated silages. In many cases, treated silages have not significantly affected weight gains or milk production. When organic acids are included in ruminant rations, the rumen fermentation plays a predominant role in assessing the nutritional value of these acids. In this media, one of the recognized breakdown products of lactic acid is propionic acid. When these acids (acetate, propionate or lactate) were fed to lambs or steers, slight to no differences in gains were noted (Bentley _et al._

1956b; Klosterman *et al.* 1960). A depression in intake in proportion to the lactic acid concentration as well as a depression in gains was reported by Emery *et al.* (1961). However, there was an increased feed efficiency in proportion to the intake of lactic acid and with lactate salts the depression in appetite was not as great as with the free acid. In a second report (Emery *et al.* in press), lactic acid feeding did not significantly increase gains or milk production when compared to an equal amount of corn. Similar results for milk production have been reported by Radloff and Schultz (1963). Rook and Balch (1961) infused acetic, propionic and butyric acids intraruminally to study their effect upon lactation. While acetate increased the yield of milk, fat percentage and daily fat yield, propionate and butyrate infusions resulted in a change in milk composition but not in milk yield. Other research by Armstrong and Blaxter (1957) and Armstrong *et al.* (1958) in which acetic, propionic and n-butyric acids were infused either singly or in combination indicated that there was an increased nitrogen retention and the major portion of energy retained in the body was in the form of fat. Ekern and Reid (1963) indicated that diets creating a higher proportion of propionic and butyric acids relative to acetic acid in the rumen favored the energetic efficiency of body gains.

In reports where limestone treated corn silage has been fed to lactating animals, there have been tendencies toward higher rumen propionic acid levels (Byers *et al.* 1964 and Simkins *et al.* 1965). In both reports, milk yield was not significantly affected by the feeding of treated silages. However, milk fat percentage was lower

($P < .10$) in the treated silage group (Simkins et al. 1965), while Byers et al. (1964) reported no difference in milk fat percentage. However, Byers et al. (1964) included hay in the total ration (approximately 8.2 to 9.0 pounds per day) which maintained rumen acetate levels at 63.6 molar percent. When normal rumen acetate levels are maintained no depression in milk fat percentage would be expected. In the study by Simkins et al. (1965) corn silage was the only roughage source. The rumen acetic acid concentration for both control and treated silage groups (approximately 56.0 on a weight percent basis) was lower than the corresponding levels reported by Byers et al. (1964). Infusion or feeding either lactate or propionate did not appear to stimulate milk production. This would be expected since propionate represents one of the major end-products of rumen fermentation of lactic acid. However, since lactic acid has produced variable results for growth or fattening, end-products of lactic acid degradation in the rumen may be beneficial for animal gains. Because of the apparent difference in intermediary metabolism of these compounds, the addition of chemical compounds, other than to improve protein content appears to be a questionable practice for lactating dairy cows. While the infusion or feeding of organic acids has presented the basis for this discussion, the metabolism of these acids naturally occurring in feed or derived from feed via ruminal fermentation may be somewhat different from the results of infusion or feeding experiments.

In digestibility studies, there was a slight, but not significant, depression in apparent digestibility of dry matter, ash and protein in the treated corn silages of the first trial. There was a significant depression in crude fiber digestibility in the 0.5 percent urea silage (probability range of .01 to .05). In the second trial, comparing silages containing 0.5 percent calcium carbonate and 0.5 percent calcium carbonate plus 0.75 percent urea, a depression in apparent digestibility of ash, ether extract and protein was found in the silage containing urea. The difference in ash digestibility was significant ($P < 0.05$). As the level of urea increased, there was a slight but non significant depression in digestibility of protein. These data are in contrast to Karr *et al.* (1965a) who reported an improvement in dry matter digestibility with added urea, and Gorb and Lebedinskij (1960) who found that urea added to maize silage improved both the protein and crude fiber digestibility. In the present study, the rations offered to each lamb were equalized in TDN, and protein. In the study of Karr *et al.* (1965a) a low protein basal ration was compared with non-protein nitrogen supplemented rations. The ration variable may explain the differences in digestibility observed in the two studies.

Urine excretion level increased as the amount of urea in the silage increased. Hart *et al.* (1939) and Drill (1954) both state urea can be diuretic. Krug and McGuigan (1955) in discussing the pharmacological effects of urea stated that, "It inhibits water absorption in the tubule of the kidney and thus produces diuresis."

Since total collections of urine and feces were made for all lambs, biological values were computed using a value of 0.0333 gm. endogenous nitrogen excretion/kilogram body weight and 0.55 gm. metabolic fecal nitrogen/100 gm. of dry matter consumed as stated by Harris and Mitchell (1941a). These values were used because of the similarity of the lamb body weights in the two studies. In a second study (Harris and Mitchell, 1941b), similar values were reported when corn silage and urea were fed to lambs in a growth experiment. The biological value of protein in the control corn silage was 67 percent. Biological values for the treated silages were lower (ranging from 54-62) with the exception of the 0.5 percent urea silage which had a value of 70 percent. This value represented the average of only two lambs since the third lamb had a higher calculated metabolic fecal nitrogen excretion than the total observed fecal nitrogen excreted and could not be used. Because of wide variation among animals treated alike, definite conclusions could not be made. The assumed metabolic fecal and endogenous urinary nitrogen excretion values may have contributed to the observed animal variance.

The loss of silage dry matter from the silo ranged from 8.6 to 11.0 percent. These losses resulted from spoilage, silage juice runoff, fermentation losses, and waste upon removal of the material from the silo. In the 1964-65 silages, three silos (3, 5, and 7) were equipped with automatic silo unloaders. In the remaining silos (4, 6, and 8), the silage was removed by hand. These data indicate less spoilage throughout the silage mass when automatic unloaders were employed than when the silage was removed manually. However, the automatic unloaders would mix spoiled silage with good silage and thus minimize detection of spoiled silage unless present in large quantities.

SUMMARY AND CONCLUSIONS

The value of treated whole plant corn silage was studied over a two year period with urea, diammonium phosphate, calcium carbonate and dicalcium phosphate serving as chemical additives. The fermentation pattern was followed with measurements of pH, crude protein equivalent, and organic acid production. The nutritive value of the individual silages was evaluated by conducting two growth, two lactation, and two digestibility trials.

The initial and final pH values for two untreated control silages were 5.1, 3.6; and 5.4, 3.7, respectively. There was a slight increase in pH when either urea, diammonium phosphate, calcium carbonate, or dicalcium phosphate were included in the silage. While urea produced only slight increases in pH in this study during the fermentation period, the values for those samples taken during the feeding experiment were comparable to the untreated silages. Limestone or calcium carbonate produced similar trends in pH.

Chemical combinations increased the pH more than single chemical additions ($P < 0.01$). This was true for all chemical combinations, and especially at their higher concentrations. No significant differences in pH were observed among silages containing either urea or calcium carbonate. However, the interaction between these two compounds significantly increased the pH values ($P < 0.05$).

Urea and diammonium phosphate additions increased the crude protein equivalent of the treated silages ($P < 0.01$ and $P < 0.05$ for both additives). In general, the crude protein equivalent of the treated silages increased in proportion to the level of urea added to the silage. The percent of the theoretical crude protein recovered ranged from 85 to 89 percent, while the percent N.P.N. crude protein equivalent lost ranged from 32 to 45 percent. However, 25 to 30 percent of the N.P.N. crude protein equivalent loss occurred between the zero and twentieth day of fermentation.

All chemical additions resulted in increased organic acid production compared to the control silage. Calcium carbonate stimulated greater amounts of organic acids than urea or diammonium phosphate in the 1964-65 silages, but this did not occur in the 1963-64 silages. The range of acetate and lactate production expressed on a dry matter basis was 1.08 to 2.28 and 8.42 to 13.06 percent, respectively. Chemical combinations increased lactate production in both years (probability range of 0.05 or 0.10) and acetate production in the 1964-65 silages ($P < 0.05$). Silages with added calcium contained greater amounts of acetate and lactate in the 1964-65 silages (probability range of 0.05 and 0.10) and lactate in the 1963-64 silages ($P \lesssim 0.10$).

The ash content of the treated silages was increased by additions of either calcium carbonate or diammonium phosphate. Silages with added N.P.N. compounds also contained increased crude protein equivalent values.

In growth trials, heifers made adequate gains when fed treated corn silages. In the first trial, differences between two 0.5 percent urea silages with different calcium sources were not significant. In a second trial, heifers receiving the silages containing 0.5 percent calcium carbonate either alone or in combination with 0.5 or 0.75 percent urea made lower gains per day than either the untreated control silage or the 0.5 or 0.75 percent urea silages. This difference was significant (probability range of 0.05 to 0.01) for the 0.5 percent calcium carbonate and the 0.5 percent calcium carbonate plus 0.75 percent urea silages and could be explained by either a significant depression in intake or feed utilization. Those heifers receiving the silages with urea serving as the only added chemical made slightly better gains (probability range of 0.05 to 0.01) as the level of urea increased.

In lactation studies, animals receiving the silage containing 1.0 percent diammonium phosphate consumed less (probability range of 0.01 to 0.05) silage dry matter per day, dry matter per hundred pounds of body weight, total dry matter and T.D.N. per day and produced less 4.0 percent F.C.M. per day. When 0.5 percent calcium carbonate was added in combination with diammonium phosphate, or when 0.5 percent calcium carbonate was added as the only additive, this depression in intake did not occur. In a second lactation study, silages containing 0.75 percent urea followed a similar pattern as the 1.0 percent diammonium phosphate silage in the previous study. One-half percent calcium carbonate did not improve the performance when included with 0.75 percent urea. Because of this depressed intake (probability range of 0.01 to 0.05), milk production was lower for these two groups than the remaining groups with the exception of the 0.5 percent calcium carbonate silage which was lower. The highest yields were from the two 0.5 percent urea groups.

In digestibility studies, there was a slight but non-significant depression in apparent digestibility of dry matter, ash, and protein in the treated corn silages of the first trial. Crude fiber digestibility was significantly depressed (probability range of 0.01 to 0.05). In a second trial, in which silages with and without 0.75 percent urea were compared, a slight depression in apparent digestibility of ash, ether extract, and protein was found in the silage containing urea. The difference for ash digestibility was significant ($P < 0.05$). As the level of urea increased, there was a slight depression in digestibility of protein.

The biological values of the silage proteins were variable and definite conclusions could not be made. This may have resulted from assumed endogenous urinary and metabolic fecal nitrogen values.

The losses of silage dry matter averaged from 8.6 to 11.0 percent for both years of the experiment.

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