THE EFFECT OF ADDING A LIQUID SUSPENSION OF ANHYDROUS AMMONIA, MINERALS AND MOLASSES TO CORN SILAGE AT ENSILING, ON FERMENTATION PARAMETERS AND BEEF CATTLE PERFORMANCE

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ABSTRACT

THE EFFECT OF ADDING A LIQUID SUSPENSION OF ANHYDROUS AMMONIA, MINERALS AND MOLASSES TO CORN SILAGE AT ENSILING, ON FERMENTATION PARAMETERS AND BEEF CATTLE PERFORMANCE

By

David Beattie

A feeding trial and two metabolic studies were conducted to investigate the effect of corn silage treated with a liquid suspension of anhydrous ammonia, minerals and molasses (Pro-Sil) on yearling steer performance and metabolic parameters.

In the feeding trial, 108 head of yearling steers were fed either all silage or 60% silage + 40% shelled corn rations. Silages treated with three levels of Pro-Sil were compared to urea-treated silage and both negative (no protein supplement) and positive (protein supplement fed) control silages. The Pro-Sil and urea additions at ensiling increased crude protein equivalent of the treated silages ($P < .01$), generally in proportion to the level of non-protein nitrogen (NPN) added.

Nitrogen losses for all treated silages were less than 5% of the amounts added. All treated silages showed increased water insoluble nitrogen (probably true protein) fractions. The NPN from Pro-Sil was mainly recovered as ammonium salts of organic acids, urea was recovered as intact urea (58%) and ammonium salts.

All treated silages showed significantly ($P < .01$) higher lactic acid content and the higher levels of Pro-Sil additions (25 and 35 Kg. per 1000 Kg.) significantly ($P < .05$) decreased acetic acid levels.

Steer performance was similar for Pro-Sil 12 (25 Kg. Pro-Sil per 1000 Kg.), urea and positive control silages and significantly ($P < .01$

and $P < .05$) higher for these treatments over all other treatments at both concentrate levels. No significant differences were found in carcass characteristics within or between concentrate levels.

Feed costs favored the Pro-Sil 12 and urea-treated silages at both concentrate levels.

Metabolic studies at both concentrate levels indicated no significant differences in apparent dry matter digestibility, nitrogen digestibility or nitrogen retention between treatment groups. Apparent dry matter digestibility was higher on the 40% concentrate ration but differences were not significant.

Rumen ammonia and blood urea levels were higher in steers fed treated silages on the all silage program (not significant). The same trend was not apparent on the 40% concentrate ration but blood urea levels were higher for Pro-Sil 14 silage (35 Kg. Pro-Sil per 1000 Kg.) than the other treatments (not significant).

Rumen volatile fatty acid (VFA) concentrations were similar at both concentrate levels, propionic and butyric acids were slightly higher for treated silages on the all-silage program and propionic acid was also higher for treated silage rations on the 40% concentrate program, however, differences were not significant. Peak production of VFA's occurred at two hours post-feeding on all silage rations and at four hours post-feeding on the 40% concentrate rations. Differences again were not significant.

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I. INTRODUCTION

Use of whole plant corn silage as a feed for ruminant animals is now a widely accepted practice on progressive beef and dairy farm operations. The corn plant, of all the silage crops, gives the highest yield of total digestible nutrients per acre, and as silage, is readily consumed in large quantities by both beef and dairy animals. The corn plant and hence the ensuing corn silage, requires supplementation with substantial amounts of crude protein and minerals to meet the requirements of beef cattle as listed by the National Research Council (1970). Crude protein and mineral content of corn silage are known to vary with type of soil, soil fertility levels, climate and plant variety, but supplementation is generally required.

Extensive research over the last fifty years has conclusively shown that ruminant animals have a unique ability to utilize sizeable quantities of non-protein nitrogen (NPN), as a replacement for true protein, through the protein-synthesising ability of bacteria and protozoa in the rumen. These rumen microorganisms utilize ammonia (from breakdown of true protein, or from NPN sources) and carbohydrates in the feed in the synthesis of their body protein. They in turn are digested by the host animal which utilizes the high quality bacterial and protozoal protein for its own metabolic functions.

Low cost NPN compounds (mainly urea) are now widely used to replace part of the true protein in ruminant rations. The use of urea as an additive to elevate crude protein levels in corn silage rations, either at feeding or at ensiling time is well documented in the literature. The addition of urea at ensiling time appears to be beneficial in that the urea is diluted through the silage, affording the animals a gradual intake which may help avoid palatability and toxicity problems associated with high concentrations of urea in the feed.

Hatfield and Garrigus (1967), published a guide to urea and mineral levels required for "balancing" corn silage, based on silage dry matter content at ensiling.

The addition of NPN compounds to corn silage at ensiling increases the crude protein content (N x 6.25) of the final silage. Polan *et al.* (1967) showed that the increase is proportional to the amount of NPN added.

True protein degradation occurring during fermentation, results in decreased true protein content, and a corresponding increase in the water soluble NPN fraction composed of ammonia (product of deamination), alpha amino nitrogen (free amino acids) and other undetermined nitrogen compounds (Hawkins, 1969). Degradation of protein is greater at low dry matter levels of the silage (Hawkins, 1969, Geasler, 1970). Addition of NPN at ensiling increases the total NPN content of the silage; with urea additions, the increase is measured as ammonia (from urea breakdown) and unchanged urea (Bentley *et al.* 1955; Goodrich and Meiske, 1966; Polan *et al.* 1967; Johnson *et al.* 1967). Increased true protein content of the silage may occur with NPN additions at ensiling, due to increased bacterial protein as a result of the fermentation (Bentley *et al.* 1955; Modyanov *et al.* 1958; and Pesotskiy, 1963; Abgarowicz *et al.* 1963).

Organic acid content and final pH values are generally higher in treated silages due to prolonged fermentation (Klosterman et al. 1961 & 1962; Johnson et al. 1967; Huber et al. 1968).

Apparent digestibility of dry matter, crude protein and crude fiber are enhanced by urea additions to corn silage at ensiling (Bentley et al. 1955; Wetterau, 1959; Gorb and Lebedinsky, 1960; Johnson et al. 1965).

In vitro studies indicate that rumen microorganisms can utilize various NPN compounds in the synthesis of protein, but to different degrees, as indicated by bacterial growth. Urea is well utilized but ammonium salts of certain organic acids (lactic, succinic, and formic) appear to be preferred (Belasco, 1954).

Palatability of urea-treated silage appears to decrease with increasing level of addition (Wise et al. 1944). Urea added at 0.5% appears to have no affect on palatability in the majority of trials reported. Beef and Dairy cattle performance on urea-treated silages in most trials has equalled or surpassed performance on control silage plus true protein supplements (Bentley et al. 1955; Klosterman et al. 1961, 1962; Modyanov et al. 1963; Newland and Henderson, 1965; Huber et al. 1968; Henderson and Purser, 1968).

The use of urea in corn silage is a widely accepted practice at this time, but the risk of incurring palatability problems and perhaps toxicity still exists and level of addition has to be strictly controlled. Other sources of nitrogen such as biuret (urea derivative), various inorganic ammonium salts, ammonia water and cyanuric acid have been added to corn silage to increase crude protein content in several experiments, but insufficient data are available to critically evaluate them.

The use of anhydrous ammonia as an additive to corn silage at ensiling has recently been tested at Michigan State University, primarily because of the lower cost of this material as compared to urea, and the consideration that much of the urea added at ensiling is broken down to ammonia in the silo anyway. A process was developed for the direct application of anhydrous ammonia to corn silage at ensiling by Henderson, Purser and Huber, 1969 (unpublished data). A liquid suspension of anhydrous ammonia, minerals and molasses (Pro-Sil) was finally developed for safe and convenient application to the silage. The additive was formulated to correct for crude protein and mineral deficiencies in the final silage.

The objective of the following study was to evaluate the effects of various levels of Pro-Sil added to corn silage at ensiling, on the following factors:

a) corn silage fermentation,

b) feedlot performance and feed costs of yearling steers,

c) digestion parameters in steers.

Regular corn silage and urea-treated corn silage were used as bases for comparison.

II. LITERATURE REVIEW

A considerable amount of recent research has been devoted to the use of chemical additives to corn silage at time of ensiling, the objective being to increase total nitrogen content and thereby improve the nutritive value of the silage as a feed for ruminant animals.

The addition of minerals to corn silage has received less attention, however the entire area of additives to corn silage remains of prime interest to many animal researchers.

Fermentation of Corn Silage

One of the earliest reports on fermentation of the corn plant was that by Annett and Russell (1907). Chemical analyses of the corn plant before and after ensiling indicated that the principle changes occurring during fermentation were a decrease in nitrogen-free extract, an increase in non-protein nitrogen content with a corresponding decrease in protein nitrogen, a reduction in sugar content, and the appearance of fermentation acids (volatile fatty acids (VFA) and lactic acid). Owens (1968) quoted work by Dox and Niedig (1912, 1913) and Niedig (1914) who reported the presence of ethanol as well as lactic acid and volatile fatty acids. Lactic acid content was usually greater than that of the VFA's, and total organic acid content maximized 8 to 10 days following ensiling.

A thorough description of the various stages of fermentation and production patterns of VFA's (mainly acetic acid) and non-volatile acids (mainly lactic acid) from soluble carbohydrates is given by Barnett (1954).

A detailed study of the composition of corn plants at various stages of growth, including thorough chemical evaluation of the individual parts of the plant, was conducted by Benne _et al._ (1964).

Johnson _et al._ (1966) compared soluble carbohydrate content of corn plant material before and after ensiling and found a large decrease due to ensiling. Most of the loss of soluble carbohydrate was recovered as lactic and acetic acids. Soluble carbohydrate content of the plant was shown to decrease with maturity.

A highly significant correlation between soluble carbohydrate content and organic acid content of corn silage was reported by Geasler (1970), it was also noted that increasing maturity of the corn plant material significantly reduced lactic acid content in the final silage. In the same study, total nitrogen in the silage as a percent of dry matter, decreased with maturity, as did water soluble nitrogen (expressed as a percent of total nitrogen). Hawkins (1969) working with alfalfa silage also reported a negative correlation between total organic acid production and silage dry matter content. Protein degradation during ensiling was increased with decreasing dry matter content, as measured by the increase in water soluble NPN (expressed as a percent of total silage nitrogen).

Early work by Russell (1908) indicated that the breakdown of protein in maize silage fermentation was due to tryptic enzymes of the cell. This work was repeated by Kirsch in 1930 (as reported by Watson and Nash, 1960) using red clover, and confirmed the findings of Russell. Watson and Nash conclude from this and supportive evidence from Lamb (1917) and Hunter (1921) that plant enzymes are entirely responsible for the breakdown of protein to amino acids, and that further changes (beyond amino acids) are not necessarily due to plant enzymes but may also be caused by bacteria.

Mineral constituents of plant material are affected during ensiling (Watson and Nash, 1960) but the changes take the form of recombinations and do not result in actual losses, except in so far as material is leached from the silo. There is a lack of information in the literature regarding mineral loss from silage.

Effect of Silage Additives on Silage Fermentation

According to Owens et al. (1968), the earliest reported additions of NPN to corn silage were by Brigl and Windheuser (1932) and Windheuser et al. (1935) using urea, ammonium carbonate and ammonium bicarbonate as nitrogen sources. They reported increased lactic acid content of the silages and improved crude protein digestibility, but greater dry matter loss during fermentation with the addition. Cullison (1944) observed prolonged fermentation in regular sorghum silage, which was prevented by increasing the crude protein content by addition of 10 lbs. urea per ton of silage. He also reported improved palatability and general feeding value of the silage with the addition of urea at ensiling. Other work with sorghum silage (Davis et al. 1944) which compared various levels of urea at ensiling, indicated that the major part of the urea added remained as intact urea in the silo. Higher final pH in the treated silage over control silage indicated an extended fermentation due to buffering, especially with high urea levels.

Urea additions (0.5% added) to corn silage by Woodward and Shephard (1944), did not reduce silage losses of dry matter, nitrogen and carotene, but little loss of urea occurred. Wise et al. (1944) added urea in aqueous solution (0.5% urea addition to silage) and reported increased crude protein content and elevated pH of the final silage. Numerous reports in the literature show conclusively that additions of NPN compounds will increase crude protein content of silage and amount of increase is dependent on level of addition of NPN (Davis _et al_. 1944; Bentley _et al_. 1955; Wetterau, 1959; Klosterman, 1961; and Schmutz, 1966). Silo losses of urea were extensively examined by Austin (1967) and negligible losses were reported.

Russian workers (Modyanov _et al_. 1958) used various levels and mixtures of urea and ammonium sulfate as additions to corn silage at ensiling and reported increases in both total nitrogen and protein nitrogen levels. They recommended from their results that a 2:5 ratio of ammonium sulfate to urea should be used. Abgarowicz and co-workers in Germany (1963) used urea, ammonium sulfate and ammonia water additions to silages, and reported a greater increase in crude protein level (over control silage)with urea, followed by ammonium sulfate. Poor results were obtained with ammonia water which they concluded was due to weak bonding of the ammonia and to silo seepage. Increased acetic acid and final pH values but decreased lactic acid content were reported for all treated silages. An increase in true protein due to treatments, (highest increase due to ammonia water) confirmed the results of the previous study, (Modyanov _et al_. 1958). Further evidence of a true protein increase in treated silages was provided in a study by Pesotskiy, (1963) using ammonia water additions to corn silage. Additional increases were reported for NPN, ammonia, acetic acid, and pH, but lactic acid level was decreased as in the previous study by Abgarowicz _et al_. 1963.

Klosterman _et al_. (1961) suggested that the high feeding value of corn silages might be due to their organic acid content and stated "It was also found that the amount of acetic and lactic acids in these silages could be markedly increased by the addition of a neutralizing material at the time of ensiling." Limestone or urea and combinations of these two were used as additions to corn silage in a laboratory experiment by these workers which showed increased organic acid content for all treatments over a control silage. Highest levels of lactic and acetic acids were achieved with 0.5% urea + 0.5% limestone and 0.5% urea + 1% limestone combinations, and levels for these treatments were similar. In 1962 Klosterman et al. again reported increased lactic and acetic acid with urea-limestone additions.

Johnson et al. (1967) confirmed the previous findings using limestone-urea treated silage and reported that the amount of acids (lactic and acetic) produced, decreased as dry matter content of the silage increased. At low dry matter content (20% dry matter) of the silage, lactic acid was decreased and acetic acid increased with urea-limestone additions, which supports the findings of the European workers previously mentioned (Abgarowicz et al. 1963 and Pesotskiy, 1963). In all other treated silages with higher dry matter content both lactic and acetic acids increased. True protein decreased in untreated silage as a result of fermentation, with a corresponding increase in soluble NPN, most of which was ammonia and urea, however part of the total was unidentified. In treated silages, increased proteolysis was reported for low dry matter silages but this effect decreased in silages of later maturity. Only a partial breakdown of urea occurred in the silage (35-63% breakdown), and the trend indicated less breakdown as maturity of silage increased. (Similar results were reported by Huber et al. 1968). Diammonium phosphate (DAP) was also used in this study with similar trends reported but less organic acid produced. The authors postulated that much of the urea in silage may be hydrolysed and appear as ammonium salts.

A study using miniature silos by Owens, Goodrich and Meiske (1966) also reported increased lactic and acetic acid production with urea additions at ensiling, but in contrast to the results of Klosterman et al. (1961) no increase in lactic acid was obtained with limestone additions. However silage dry matter content was high in this study.

In vivo evaluation of silage additives

Bentley, Klosterman and Engle (1955) used wether lambs to compare digestion parameters for urea-treated silage and control silage (unsupplemented and with soybean and corn-urea supplements). Apparent dry matter digestibility was similar for all rations, apparent crude protein digestibility was low for unsupplemented control silage but high for all other treatments indicating good utilization of urea whether added at ensiling or at feeding. Cellulose digestibility was higher for urea-treated silage than for control silage with urea added at feeding. Nitrogen retention data showed that lambs on all treatments were essentially at nitrogen equilibrium. Digestion studies by Wetterau (1959) using lambs, indicated that urea-treatment of silage (0.5% added) improved crude protein digestibility and nitrogen retention compared to no treatment. As in the previous experiment, apparent dry matter digestibility was similar for treated and untreated silages. Gorb and Lebedinsky, 1960, (as reported by Owens, 1968) found slight increases in apparent digestibility of dry matter and crude protein for urea-treated silage as compared to control silage when fed to lambs. Results were similar in a series of digestion trials conducted by Karr et al. (1965) with lambs. Improved total nitrogen and digested nitrogen retained were reported using urea-treated and biuret-treated silages as compared to adding urea or biuret to control silage at feeding.

Johnson et al. (1965) reported improved apparent dry matter digestibility of urea-limestone treated and DAP treated corn silages, using sheep. The DAP-limestone treatment depressed dry matter digestibility. Results of two digestion trials with sheep, reported by Schmutz (1966), revealed that urea-treated silages (0.5% and 1% urea added) and urea-limestone treated silage (0.5% urea + 0.5% $CaCO_3$ added) slightly decreased dry matter, ash and crude protein digestibility coefficients and significantly decreased crude fiber digestibility.

In vitro evaluation of silage additives

A detailed in vitro study of nitrogen feed compounds for ruminants was conducted by Belasco (1954) using an artificial rumen described by Burroughs et al. (1950). The amount of bacterial growth on urea was used as a standard for comparing the value of other compounds. Urea derivatives (methylenediurea and biuret) gave poor bacterial growth, propionamide gave good results (92% of urea response). Some amidines gave good bacterial growth but not higher than urea. Greatest response was obtained with organic ammonium salts which demonstrated high availability of their nitrogen to the microflora. A high level of NH_4+ ion was noted when they were introduced into the system. Belasco concluded that excess ammonium salts may not be as hazardous as excess urea because of the acid radical, which might enter into some biosynthetic process stimulatory to nitrogen fixation by the rumen microflora. Several organic ammonium salts, namely ammonium succinate, -lactate and -formate were utilized to a greater degree than urea. Free ammonia levels from inorganic ammonium salts were similar to those for urea. Ammonium nitrate was found to be toxic to the microflora.

Pearson and Smith (1943) found that rumen liquor could split urea and predicted very rapid conversion of urea to ammonia. They further concluded in a following experiment that protein was synthesized at the expense of ammonia. In vivo and in vitro studies by Johnson and McClure (1964) using urea, biuret and DAP led them to conclude that urea was used more efficiently by sheep than biuret or DAP. The in vitro study demonstrated clearly that microorganisms from sheep "adapted" to biuret failed to release ammonia from biuret when incubated in vitro.

Effect of Silage Additives on Beef and Dairy Cattle Performance

Early reports on urea additions to corn silage mentioned impaired palatability of the silage but no effect on animal performance (Woodward & Shephard, 1944; Wise et al. 1944). Bentley et al. (1955) reported that treated silage compared favorably with control silage + soybean meal in a steer feeding trial. Later work at Ohio showed improved weight gains and feed efficiency with heifers fed urea-limestone treated silage (Klosterman et al. 1961; Klosterman et al. 1962). Performance was superior with treated silage at three levels of soybean meal supplementation and at various concentrate levels as compared to control silage.

The Russian workers, Modyanov et al. (1963) reported improved performance in cattle and sheep as measured by higher gains, greater milk production and greater feed intake when corn silage was treated with urea and ammonium sulfate compared to no treatment. Complete ensiled rations containing urea, promoted higher liveweight gains and greater efficiency in two beef feeding trials conducted by Goodrich and Meiske (1966), digestion trials with lambs suggested that crude fiber in the complete ration was more available. In a study with lactating dairy cows, Huber,

Thomas and Emery (1968), found no difference in average production levels of cows fed urea treated silage as compared to untreated corn silage, but they did report a significant interaction between urea treatment and silage maturity, persistency of lactation was lower for cows on urea treated high dry matter corn silage. The authors suggested that the high heat of fermentation could have rendered nitrogen unavailable. Newland and Henderson (1965) used beef heifers to examine effects of urea-limestone treatment of corn silage, and reported slightly higher gains, greater feed efficiency and cheaper gains as compared to lots receiving control silage.

Henderson and Purser (1968) reported soybean oil meal supplementation of corn silage at feeding to be superior to urea supplementation at ensiling or at feeding on all silage rations, as measured by rate of gain of beef heifer calves. However, feed costs favored urea fed calves. They further reported that addition of urea at ensiling was superior to supplying the same amount of urea at feeding. Daily dry matter consumption was similar for urea-treated silage and control ration, but reduced for groups receiving urea additions to silage at feeding time. In the same study, groups receiving a 1% concentrate addition to silage at feeding showed no differences between daily intake of urea-treated silage and control silage. Feed costs decreased as the level of urea in the ration increased.

Recent studies at Michigan State by Henderson, Purser and Geasler (1969) comparing the addition of a liquid suspension of anhydrous ammonia, minerals and molasses (Pro-Sil) to corn silage at ensiling, with urea and urea + mineral additions, indicate that Pro-Sil and urea-mineral additions improved performance of steers as compared to urea addition alone.

Improved feed consumption was reported for steers fed Pro-Sil treated silage. Data from a later experiment (Henderson and Geasler, 1969) using rye silage treated with Pro-Sil and fed to yearling steers, shows improved gains and lower feed costs for steers fed the Pro-Sil treated silage over those fed control silage with a urea supplement at feeding.

III. MATERIALS AND METHODS

Experiment I - Yearling Steer Feeding Trial

Design:

A 6 x 2 factorial (Appendix II, Table I) design was utilized to study the following treatments on yearling steers.

A. Silage Treatments:

1) Negative Control Corn Silage - Silage not treated, mineral supplement fed but no protein supplement fed.
2) Positive Control Corn Silage - Silage not treated, mineral and protein supplement (soybean oil meal) fed.
3) Pro-Sil treated corn silage (10.5% Crude Proptein Equivalent) - Silage treated with Pro-Sil (protein and minerals) - no other protein or mineral supplement fed. (Pro-Sil 10)
4) Pro-Sil treated corn silage (12% Crude Protein Equivalent) - Same as #3 above but a higher level of Pro-Sil was added. (Pro-Sil 12)
5) Pro-Sil treated corn silage (14% Crude protein equivalent) - Same as #4 above with a further increase in level of Pro-Sil added. (Pro-Sil 14)
6) Urea-treated corn silage - silage treated with urea, mineral supplement fed but no protein supplement fed.

B. All six silage treatments were compared at two levels of concentrate feeding:

1) Full feed of corn silage with no added shelled corn

2) Full feed of a mixture of 60% corn silage and 40% rolled shelled corn on a dry matter basis (equivalent to 1% of bodyweight daily in shelled corn).

Harvesting of Silages

Control silage (received no additive) was harvested during the entire 15 day period from September 15 to September 30, 1969 and stored in a 9m. x 18m. concrete stave silo. Dry matter (DM) content of individual loads varied from 28.5% to 32.8% with an overall average of 30.5%.

Silage treated with Pro-Sil was harvested during a seven day period from September 12 to September 19, and stored in three 4.8m. x 15m. concrete stave silos. Different amounts of Pro-Sil were added in each silo; for Pro-Sil 10 silage the equivalent of 13.7 Kg. Pro-Sil per 1000 Kg. of 35% DM silage was added, for Pro-Sil 12 the addition was equivalent to 25 Kg. per 1000 Kg. of 35% DM silage and for Pro-Sil 14 the addition was equivalent to 35 Kg. per 1000 Kg. of 35% DM. The formulation of the Pro-Sil used in this experiment is shown in Table 1.

Individual loads of silage treated with Pro-Sil varied from a low of 26.5% DM to a high of 31.5% DM. Pro-Sil 10 silage averaged 27.9% DM, Pro-Sil 12 silage averaged 29.9% DM and Pro-Sil 14 averaged 29.5% DM. The Pro-Sil was applied by pumping the required amount of the liquid material directly into the blower housing as each load of silage was being unloaded and blown into the silo (Figure I).

Silage treated with urea was harvested over a three day period just prior to the other silages and was also stored in a 4.8m. x 15m. concrete stave silo. Individual loads varied from a low of 25.5% DM to a high of 32.5% DM and averaged 28.6% DM. Each load was weighed and treated with an equivalent of 6.2 Kg. urea per 1000 Kg. of 35% DM silage, by evenly spreading the required amount of urea over the top of each load just prior to ensiling.

The formulation of the mineral supplement fed with urea-treated and control silages is shown in Table 2. This supplement was added at the rate of 5% of daily silage dry matter intake.

The positive control group received soybean oil meal (50% crude protein) at a level equivalent to 2.1 Kg. per 20 Kg. of silage dry matter.

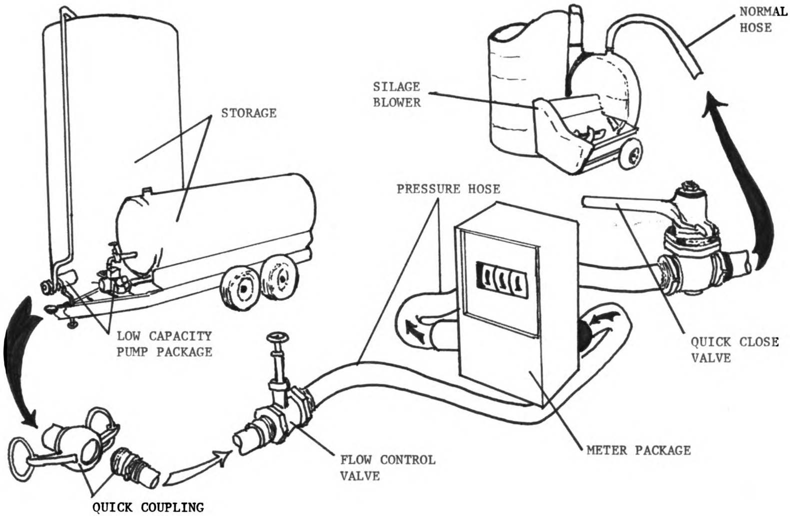

FIGURE 1. Schematic illustration of equipment used in applying Pro-Sil to corn silage in a tower silo.

TABLE 1

Pro-Sil Formulation 1/

Element	Percent
Molasses	55.12
Water and inert ingredients	23.04
Nitrogen	13.13
Calcium	.7936
Phosphorus	.4850
Sodium	2.0450
Chlorine	3.8420
Sulfur	.9371
Magnesium	.4886
Zinc	.0597
Copper	.0088
Cobalt	.0002
Iodine	.0530
TOTAL	100.0%

1/ Applied at the rate of 25 Kg. per 1000 Kg. of 35% DM silage.

TABLE 2

Formulation of Mineral Supplement 1/

Ingredient	Percent
Dicalcium phosphate (26.5%C-20.5%P)	16.8
Trace mineral salt (High Zn)	11.2
Sodium Sulfate (22.5%S)	10.2
Ground Shelled Corn	61.8
TOTAL	100.0%

1/ Added to control silage and urea treated silage at the rate of 5% of silage dry matter.

Feeding Trial

Yearling steers (108 head) utilized in this experiment were purchased in a Virginia sale on October 8, 1969 and acclimated on a full feed of control silage supplemented with protein, minerals and vitamins prior to being placed on experiment. The experiment was initiated on December 9, 1969. Each steer was implanted with 36 mg. of stilbestrol and injected with five million units of vitamin A. They were individually weighed on two successive days at the beginning and end of the feeding trial and the average of the two-day weights in each case were used as initial and final weights. Steers were randomly assigned by initial weight blocks to the twelve treatment groups. All lots of cattle were group-weighed every 28 days during the course of the experiment. The experiment was terminated for all cattle when their weights averaged more than 500 Kg. For the 40% concentrate cattle this was 110 days from the beginning of the experiment and for the all silage cattle, 128 days.

Immediately following the final weighing, all cattle were trucked 100 miles to a commercial slaughtering plant, were allowed to stand overnight, and were slaughtered the following morning. Carcasses were allowed to hang 48 hours in the cooler, and were then ribbed, graded and carcass measurements taken. All estimates of kidney, heart and pelvic fat, as well as carcass quality were made by a Federal grader. Loin-eye and fat tracings were made at the 13th rib for accuracy in determining cutability grade, fat thickness and ribeye area.

All silages were sampled regularly three times a week throughout the experiment and oven dried to compute daily dry matter consumption. A composite sample of each silage was analyzed on a wet basis every two weeks during the period of the experiment for nitrogen and organic acid fractions.

Feeding Regime: In cases where silages were supplemented, all rations were thoroughly mixed prior to feeding, in a horizontal mixer. All lots of steers were fed *ad libitum* twice daily and water was supplied *ad libitum* in all pens.

Silage Analysis:

Dry matter was determined for intake estimates by oven-drying the silage samples at 105°C for 24 hours. Composite samples of moist silage were analyzed for nitrogen and organic acid fractions and then expressed on a dry matter basis from analysis of a paired sample dried at 55°C for 48 hours. Total nitrogen was determined by macro-Kjeldahl procedures. Soluble extracts of silage were prepared by homogenizing 25 gm. of fresh silage with 100 ml. of deionized, distilled water for one minute. The pH of the solution was determined using a Corning Model 12 pH meter. The solution was strained through two layers of cheesecloth and total water soluble nitrogen was determined by micro-Kjeldahl.

A second sample of extract was deproteinized with 1 ml. of 50% sulfosalicylic acid (SSA) per 9 ml. of extract, and a micro-Kjeldahl analysis of this fraction gave total water-soluble non-protein nitrogen.

The microdiffusion method of Conway (1960) was used to determine the ammonia and urea fractions in the water-soluble non-protein nitrogen fraction.

The remaining extract was deproteinized with 1 ml. of 50% SSA per 9 ml. extract as before, and then centrifuged for 10 minutes at 18,000 r.p.m. Volatile fatty acid content of the silage was determined by injecting samples of this deproteinized extract into a Packard gas chromatograph. Lactic acid content of the silage was determined on the deproteinized extract by the colorimetric method of Barker and Summerson (1941).

Experiment 2 - Metabolism Trial with All Silage Rations

Design: A 4 x 4 Latin Square design was utilized in this experiment, in which four silages were fed to four yearling Hereford steers fitted with permanent rumen cannulas over four periods. Treatments were randomized by time and animal as shown in Appendix II, Table 2. The length of each period was 28 days, of which 21 days were allowed for steers to adjust to the new ration, before being placed in collection stalls. After an adjustment period of 14 hours (overnight) in the stalls, feed intake, fecal output, and urine production were measured and sampled for chemical analysis over a period of six days. During the day following collection, jugular vein blood samples and rumen samples were taken immediately before feeding and at two hour intervals thereafter up to 10 hours post-feeding. The experiment was initiated on March 17, 1970 and completed on July 6, 1970.

Silage Treatments:

1) Positive control corn silage - silage not treated, mineral and protein supplement (soybean oil meal) fed.
2) Pro-Sil - treated corn silage (Pro-Sil 12) - no supplement fed.
3) Pro-Sil - treated corn silage (Pro-Sil 14) - no supplement fed.
4) Urea + mineral treated corn silage (Urea M) - no supplement fed.

Harvesting of Silages:

Control silage for this experiment was harvested during a three day period from September 3 to September 5, 1969 and stored in a 4.8m. x 15m. concrete stave silo. Dry matter content of individual loads varied from 25.5 to 32.0%, average dry matter content of all loads was 28.5%.

Urea-mineral treated corn silage was harvested on September 30 and October 1, 1969 and stored in a 4m. x 12m. silo. Dry matter content of individual loads varied from 27.5 to 31.0% average dry matter content of all loads was 29.5%. The urea-mineral supplement (formulation shown in Table 3) was applied by evenly spreading the measured amount over each load prior to blowing into the silo.

The Pro-Sil treated silages described previously were also used in this experiment.

Silage Analysis: Procedures of analysis were identical to those described for Experiment I.

TABLE 3

Formulation of Urea-Mineral Supplement (for ensiling) 1/

Ingredient	Percent
Feed Grade Urea (45% nitrogen)	30.0
Sodium Sulfate (22.5% Sulfur)	6.0
Dicalcium phosphate (26.5% Ca. - 20.5% P.)	10.0
Trace Mineral Salt (High Zinc)	6.6
Fine Ground Shelled Corn	47.4
TOTAL	100.0%

1/ Added to corn silage at ensiling at the equivalent of 25 Kg. per 1000 Kg. 30% DM silage.

Feeding Regime: While in collection stalls the steers were fed twice daily at 8 a.m. and 5 p.m. in amounts calculated to supply 90% of maximum intake (as measured by *ad libitum* feeding in the adjustment period). The respective silages were removed from the silos just prior to each feeding. The ingredients of the positive control ration (untreated corn silage,

mineral and protein supplement) were thoroughly mixed in a small cement mixer. The mineral supplement used in treatment 1 was the same as that used for a similar treatment in Experiment I and was added to the ration at 5% of the silage dry matter content. This level approximates the level of mineral in the Pro-Sil 12 silage. The protein supplement (50% C. P. soybean oil meal) was added at a level of 2.1 Kg. per 20 Kg. of silage dry matter. The three treated silages fed received no supplementation at feeding time.

Representative samples of all rations were taken just prior to feeding for laboratory analysis and dry matter determination. Any feed which was not consumed was weighed, sampled and discarded prior to the 8 a.m. feeding.

Sample Collection:

Total feces were allowed to pass through a wide-space steel grid in the floor immediately behind each steer and were collected in large plastic-lined containers, in a pit below the collection stalls. Feces were removed once daily and total output was weighed. A 5% aliquot was retained each day and frozen for nitrogen determination. A 100g. sample was analyzed daily for dry matter content. Remaining feces were discarded. At the end of the six day collection period, all frozen samples were thawed and thoroughly mixed. A composite 200g. sample was taken for immediate total nitrogen determination. Total urine was collected in a plastic carboy (in the pit below the collection stalls) which contained 200 ml. of 6N sulphuric acid. The Carboy was emptied daily prior to morning feeding and urine volume was measured then diluted to 8 litres with water, and one-eighth of this diluted urine was retained each day and stored in a cooler. The remainder was discarded.

After the six day collection period all samples were thoroughly mixed and a one liter composite sample was taken for immediate nitrogen determination.

Samples of whole rumen contents were taken through a permanent rumen cannulas fitted to the steers. Rumen samples were strained through two layers of cheesecloth and 19 ml. of the strained rumen fluid was added to 1 ml. mercuric chloride in a test tube and retained for total volatile fatty acid and rumen ammonia analyses.

Jugular vein blood sample (10 ml.) were taken by 18 gauge needle into a heparinized test-tube and retained for plasma urea and ammonia analysis.

Laboratory Analysis:

Dry matter of feed and feces samples was determined daily by oven-drying at 105°C for 24 hours.

Total nitrogen determinations of feed, feces and urine were conducted by macro-Kjeldahl procedures on wet samples.

Rumen volatile fatty acid concentrations were determined by injecting samples into a Packard Gas Chromatograph. The column used was Chromosorb 101, flow rate was 70 ml/min. N_2 and column temperature was 195°C. Samples were prepared by taking 5 ml. of strained rumen fluid and mixing with one ml. of 25% metaphosphoric acid, centrifuging at 10,000 rpm for 10 minutes. The peak areas were converted to micro moles per ml. and molar percentages by comparing to standard solutions of volatile fatty acids analyzed at the same time.

Blood samples were centrifuged at 10,000 rpm for 10 minutes and the plasma removed by pipette. Urea and ammonia content of the plasma was determined by the method of Conway (1960).

Experiment 3 - Metabolism Trial with 40% Concentrate Rations

Design: A 4 x 4 Latin Square design was again utilized in this experiment (Appendix II, Table 3) which ran simultaneously with Experiment II. All procedures and analysis for this experiment were identical to those used in Experiment II. Four yearling Hereford steers fitted with permanent rumen cannulas were used. Silages were the same as those described in Experiment II, but in this experiment shelled corn was fed to all steers in amounts to give a 60% silage and 40% rolled shelled corn mixture (equivalent to 1% of body weight daily in shelled corn). All rations were thoroughly mixed prior to each feeding in a small cement mixer.

Statistical Analysis

All data from the three experiments were analyzed on an IBM 3600 computer at the Michigan State University Computer Laboratory. Analysis of variance procedures were used in all experiments, and Duncan's New Multiple Range Test was used to test for significant differences between means, (examples in Appendix 1). In experiments 2 and 3 a Least Squares procedure was used (Harvey 1960) because of missing data.

IV. RESULTS AND DISCUSSION

Experiment 1 - Feeding Trial

Chemical Analysis of Silage

Results of eight different analyses on each of the five silages used in the experiment are averaged in Table 4. Dry matter values listed are an average of all values obtained by oven drying samples three times per week during the course of the experiment.

Percent dry matter was not significantly different between silages and values were very similar to those obtained when filling the silos. Crude protein content was lowest for the control silage, and addition of Pro-Sil increased crude protein content in relation to amount added (33% at low level, 58% at medium level and 80% at high level). Urea addition increased crude protein content of the silage by 59% which corresponded closely to the medium level of Pro-Sil addition (Pro-Sil 12). Approximately 95% of the nitrogen applied to silages was accounted for as increased crude protein content.

Nitrogen Fractions:

Crude protein levels were calculated from total nitrogen for each silage. All silages except Pro-Sil 12 and Urea differed significantly ($P<.01$) in total nitrogen content (Figure 2). Water insoluble nitrogen content was higher for all Pro-Sil treated silages and urea treated silage as compared to the control. Pro-Sil 14 was significantly higher in water insoluble nitrogen ($P<.01$) than the control silage and Pro-Sil 10, and was significantly higher than Pro-Sil 12 and the urea silage at

TABLE 4

Average Chemical Analyses of Silages (Expt. 1).

Dry Matter Analysis	Silage Treatments					
	Control	Pro-Sil 10	Pro-Sil 12	Pro-Sil 14	Urea	S. E 1/
Dry Matter %	29.64	28.80	29.93	29.86	28.23	2.7
Crude Protein (% of DM)	7.88	10.44	12.44	14.19	12.56	
Nitrogen Fractions (% of DM)						
Total Nitrogen	1.26^{D}	1.67^{C}	1.99^{B}	2.27^{A}	2.01^{B}	.37
Water Insoluble Nitrogen 2/	$.87^{B}$	$.92^{B}$	1.02^{b}	1.19^{Aa}	1.01^{b}	.18
Water Soluble Protein Nitrogen	.00	.00	.00	.00	.00	
Water Soluble NPN	$.39^{C}$	$.75^{B}$	$.97^{A}$	1.08^{A}	1.00^{A}	.29
Ammonia Nitrogen	$.07^{C}$	$.42^{B}$	$.49^{ABb}$	$.69^{Aa}$	$.22^{C}$	.25
Urea Nitrogen	$.01^{B}$	$.01^{B}$	$.01^{B}$	$.01^{B}$	$.44^{A}$	.26
Undetermined Nitrogen 3/	.31	.32	.47	.38	.34	.18
Organic Acid Fractions (% of DM)						
Total Organic Acid 4/	8.68^{B}	11.55^{A}	11.62^{A}	12.67^{A}	10.79^{A}	2.00
Acetic Acid	3.64^{a}	3.53^{a}	2.48^{b}	2.55^{b}	3.84^{a}	1.07
Lactic Acid	5.04^{E}	8.03^{C}	9.14^{B}	10.03^{A}	6.85^{D}	2.29
pH	4.0	4.1	4.2	4.2	4.0	.25

1/ S. E. = Standard Error
2/ Water insoluble nitrogen = Total Nitrogen - water soluble Nitrogen
3/ Undetermined Nitrogen = water soluble NPN - (Urea Nitrogen + Ammonia Nitrogen)
4/ Total Organic Acid = Lactic Acid + Acetic Acid
Significance: A, B, C, D, E - Values having different superscripts differ significantly ($P < .01$)
a, b - Values having different superscripts differ significantly ($P < .05$)

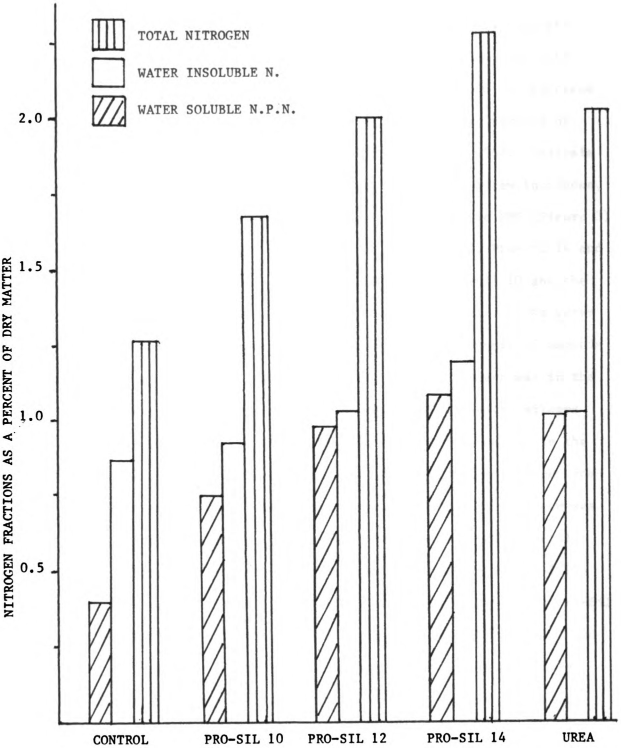

FIGURE 2. Mean total nitrogen, water insoluble nitrogen and water soluble NPN concentrations, as % of DM (Expt. 1)

(P <.05) probability. Other differences in water insoluble nitrogen were not significant.

These increases appear to indicate an increase in true protein content of silages which were treated with ammonia and urea, and this protein increase must be due to increased bacterial protein, or decreased proteolysis during fermentation. These results agree with results of Modyanov et al. 1958; Abgarowicz et al. 1963; Pesotskiy, 1963. Analysis for water soluble protein revealed only trace amounts in a few instances, however, no measurable amounts were present. Water soluble NPN (Figure 3) varied with level of NPN added to the silages, Pro-Sil 12, Pro-Sil 14 and urea silages were significantly higher (P< .01) than Pro-Sil 10 and the control silages. The chemical analysis of the constituents of the water soluble fraction of the silages revealed only very low amounts of ammonia and urea nitrogen present in the control, 79% of the nitrogen was in the form of unidentified compounds. In all of the Pro-Sil treated silages the increase in water soluble NPN over control silage was mainly in the form of ammonia nitrogen with some increase in unidentified nitrogen compounds. In the urea-treated silage the increase in ammonia nitrogen was less and a considerable amount of urea was found intact (58% of total urea added). Differences in ammonia nitrogen were significant (P<.05) for Pro-Sil 14 over Pro-Sil 12 and highly significant (P<.01) for Pro-Sil 14 over all other silages. The slight difference between Pro-Sil 12 and Pro-Sil 10 was not significant but values for both were significantly (P<.01) higher than those for urea-treated and control silages. The urea silage contained significantly (P<.01) higher amounts of urea nitrogen than all other silages. Differences in unidentified nitrogen levels were not significant due to the accumulated error involved in the

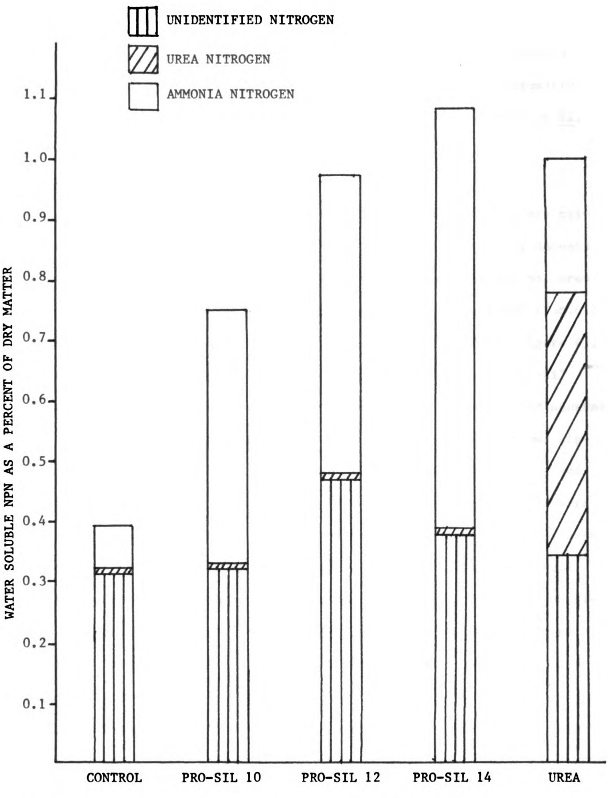

FIGURE 3. Mean total water soluble NPN (as % of DM) of silages, showing actual urea and ammonia fractions (Expt. 1).

calculations.

These finds, in regard to urea breakdown, agree with other work (Johnson et al. 1967; Huber et al. 1968), and the increase in ammonia with increased Pro-Sil addition is as expected, the ammonia presumably being in the form of ammonium salts of organic acids (Klosterman et al. 1961).

Organic acids:

Total organic acid fraction (as a percent of dry matter) was calculated by combining total acetic and lactic acid values, as the amounts of other organic acids are **extremely** small and consequently are not presented. All treated silages showed large and highly significant ($P < .01$) increases in total organic acid as compared to control silage (Figure 4). Differences between treated silages were not significant, but Pro-Sil treated silages tended to have higher values, indicating a greater neutralizing affect for the ammonia additions. Acetic acid production was significantly ($P < .05$) depressed for Pro-Sil 12 and Pro-Sil 14 silages and slightly increased for the urea treated silage. Lactic acid levels were increased considerably in all of the treated silages. Greatest increases were evident in the Pro-Sil treated silages, and level of organic acid appeared to be directly related to the amount of Pro-Sil added to the silage. Differences between Pro-Sil treated and urea treated silages were not significant however, but lactic acid levels for all treated silages were significantly greater ($P < .01$) than in the control silage.

It appears that the neutralizing effects of ammonia and urea prolonged the lactic acid fermentation in all silages, and adversely affected acetic acid production in Pro-Sil 12 and Pro-Sil 14 silages. The lowered acetic acid levels were unexpected and cannot be explained at this time.

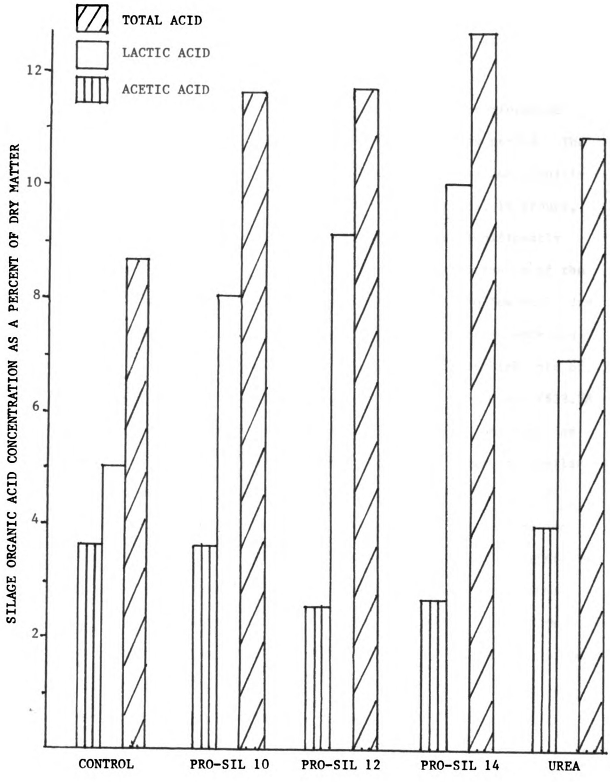

FIGURE 4. Mean organic acid fractions (as % of DM) for the respective silages (Expt. 1).

pH values were slightly higher for Pro-Sil treated silages as compared to control and urea silages, however, the differences were not significant.

Effect of Additives on Feedlot Performance

All Silage Ration: Table 5 shows the means for all performance traits for cattle fed the all silage rations over a 128 day period. The Positive Control, Pro-Sil 10, Pro-Sil 12 and Urea groups gained significantly ($P < .01$) faster than the Negative Control and Pro-Sil 14 groups, and Positive Control, Pro-Sil 12 and Urea groups gained significantly ($P < .05$) faster than the Pro-Sil 10 group. The poor performances of the Negative Control and Pro-Sil 14 groups can be attributed to low daily dry matter consumption as evidenced by intake figures. Feed efficiency was highest for the Pro-Sil 12 group. This, coupled with their high rate of gain (1.04 Kg./day) resulted in lowest cost of gain of all groups ($23.58 per 100 Kg. gain). Urea and Positive Control groups were slightly less efficient in feed conversion and although their rate of gain was similar to that of the Pro-Sil 12 group, cost of gain was higher ($24.53 and $29.35 per 100 Kg. gain). Extra cost of supplementation accounted for the higher expense charged to the Positive Control ration. Feed efficiency for the other rations was considerably poorer. In the case of the Negative Control, low protein content of the ration and resulting low feed intake, would explain this, with Pro-Sil 10, feed intake was not depressed but the protein content of the ration was probably too low for optimum performance. The Pro-Sil 14 group also showed low intake which would account for the poor performance. Treatment of silages with Pro-Sil and urea improved feed intake in all groups as compared to the Negative Control. This is as expected as a protein deficiency is known to cause

TABLE 5

Effect of All Silage Ration on Rate of Gain
and Feed Efficiency (Expt. 1).
(December 9, 1969 to April 16, 1970)

128 Day Test	Negative Control	Positive Control	Pro-Sil 10	Pro-Sil 12	Pro-Sil 14	Urea
No. Yearling Steers	9	9	9	9	9	9
Av. Initial Wt., Kg	370.0	370.9	368.2	371.8	366.4	367.3
Av. Final Wt., Kg	461.4	505.9	488.6	505.5	465.5	500.9
Av. Daily Gain, Kg	0.71^{B}	1.05^{Aa}	0.94^{Ab}	1.04^{Aa}	0.78^{B}	1.04^{Aa}
Daily Feed, Kg 85% DM:						
Corn Silage	6.59	7.58	8.06	7.95	7.09	7.91
Soybean Oil Meal		.71				
Salt Minerals	.29	.34				.35
TOTAL	6.88	8.63	8.06	7.95	7.09	8.26
Percent of Body Weight Daily	1.65	1.97	1.88	1.81	1.70	1.90
Ration DM Analysis:						
Percent Crude Protein	7.85	12.03	10.44	12.44	14.19	12.33
Percent Organic Acid	8.32	7.62	11.55	11.62	12.67	10.33
Feed Efficiency:						
Feed Per Kg Gain Kg	9.63	8.22	8.61	7.60	9.11	7.94
Feed Cost Per 100 Kg, Gain 1/	$27.96	$29.35	$24.82	$23.58	$29.65	$24.53

1/ Feed Cost: 30% DM corn silage $9.35/1000 Kg, Sh. corn $49.50/1000 Kg, soy $110/1000 Kg, Mineral $88/1000 Kg, Urea $88/1000 Kg, Pro-Sil $71.50/1000 Kg.

Significance: A, B Values having different superscripts differ significantly ($P < .01$)
a, b Values having different superscripts differ significantly ($P < .05$)

a severe depression in dry matter consumption. Intake was lowest for Pro-Sil 14 of all treated silages and this may be due to the high level of NPN compounds in this silage. Geasler (1970), however, suggested a negative relationship between intake and undetermined water soluble NPN compounds, which was not evident in this experiment. *?

Carcass data are shown in Table 6 for the Positive Control, Pro-Sil 12 and urea groups. Cattle in the Negative Control, Pro-Sil 10 and Pro-Sil 14 groups had not reached slaughter weight at the termination of the experiment and were not slaughtered at that time.

No significant differences were found for carcass traits between Positive Control, Pro-Sil 12 and urea groups. Mean carcass grade was lowest for the urea group (11.78), intermediate for Pro-Sil 12 (12.13) and highest for the Positive Controls (12.67). Carcass price favoured the Positive Control group, followed by Pro-Sil 12 and urea ($108.77, $107.25, and $106.94 per 100 Kg. respectively).

<u>60% Silage 40% Concentrate Ration</u>

Table 7 shows the means for all performance traits for cattle fed the 40% concentrate rations over a 110 day period. The urea group gained faster (1.29 Kg./day) than all other groups, closely followed by the Pro-Sil 12 and Positive Control groups (1.25 and 1.22 Kg./day). Differences between these three groups were not significant, but all three gained significantly ($P<.01$) faster than the Negative Control (1.03 Kg./day). The urea group gained significantly faster ($P<.01$) than the Pro-Sil 10 and Pro-Sil 14 groups (1.13 and 1.10 Kg./day), as did the Pro-Sil 12 group (significant $P<.05$). The Positive Control group gained significantly faster ($P<.05$) than the Pro-Sil 14 group.

The slower gains of the Negative Control, Pro-Sil 10 and Pro-Sil

TABLE 6

Effect of All Silage Ration on Carcass Quality (Expt. 1)

* No carcass data was obtained for the Negative Control, Pro-Sil 10 and Pro-Sil 14 treatment groups as they had not reached slaughter weight when the trial was terminated.

128 Day Test	Positive Control	Pro-Sil 12	Urea
Carcass Evaluation:			
Carcass Grade 1/	12.67	12.13	11.78
Marbling Score 2/	12.65	15.00	14.67
Fat Thickness, CM.	1.45	1.47	1.27
Rib Eye Area, SQ. CM.	83.04	82.91	78.52
% K.H.P. Fat 3/	2.44	2.19	2.22
% B.T.R. Cuts 4/	2.85	2.69	2.78
Dressing Percent 5/	59.10	58.74	58.16
Carcass Price/100 Kg	$108.77	$107.25	$106.94

1/ Carcass Grade Code - Good=9,10,11; Choice=12,13,14.

2/ Marbling Code - Small=10,11,12; Modest=13,14,15; Moderate=16,17,18.

3/ Percent of Carcass Weight in Kidney, Heart & Pelvic Fat.

4/ Percent of Carcass Weight in Boneless, Trimmed, Retail Cuts.

5/ Dressing percent=cold carcass weight over final weight off experiment.

TABLE 7

Effect of 40% Concentrate Ration on Rate of Gain
and Feed Efficiency (Expt. 1).
(December 9, 1969 to March 29, 1970)

110 Day Test	Negative Control	Positive Control	Pro-Sil 10	Pro-Sil 12	Pro-Sil 14	Urea
No. Yearling Steers	9	9	9	9	9	9
Av. Initial Wt., Kg	367.3	370.4	376.4	370.0	373.2	368.2
Av. Final Wt., Kg	480.9	504.5	500.5	507.3	494.5	510.9
Av. Daily Gain, Kg	1.03[C]	1.22[ABac]	1.13[BCbc]	1.25[ABa]	1.10[BCb]	1.30[A]
Daily Feed, Kg 85% DM:						
Corn Silage	4.82	5.16	5.56	5.86	5.50	5.72
Gr. Shelled Corn	3.40	3.63	3.49	3.85	3.57	3.98
Soybean Oil Meal		0.67				
Salt Minerals	.22	.23				.26
TOTAL	8.44	9.69	9.05	9.71	9.07	9.96
Percent of Body Weight Daily	1.99	2.22	2.06	2.22	2.09	2.27
Ration DM Analysis:						
Percent Crude Protein	9.18	12.60	9.87	11.93	12.15	11.86
Percent Organic Acid	4.96	4.62	7.09	7.01	7.68	6.19
Feed Efficiency:						
Feed Per Kg Gain, Kg	8.18	7.96	8.03	7.77	8.22	7.69
Feed Cost Per 100 Kg, Gain 1/	$30.51	$33.64	$29.55	$29.79	$32.29	$29.52

1/ Feed Cost: 30% DM corn silage $9.35/1000 Kg, Sh. corn $49.50/1000 Kg, soy $110/1000 Kg, Mineral $88/1000 Kg, Urea $88/1000 Kg, Pro-Sil $71.50/1000 Kg

Significance: A, B, C Values having different superscripts differ significantly ($P < .01$)
a, b, c Values having different superscripts differ significantly ($P < .05$)

14 reflected the lower feed intakes of these groups compared to the other three treatment groups. Lowest daily intake was recorded for the Negative Control group as was the case in the all silage treatment groups discussed previously, and treatment of silages with Pro-Sil or Urea improved feed intake over the Negative Control group.

Intake differences were not as great between groups on the 40% concentrate ration as compared to all silage groups and may be due to higher dry matter content of the rations, and lower intake of fermentation products (NPN) due to the lower silage intake and high concentrate level.

The urea group showed the best conversion rate (7.69 Kg. of feed per Kg. gain), only slightly superior to Pro-Sil 12 (7.77 Kg.). Efficiency was poorest for Pro-Sil 14, Negative Control and Pro-Sil 10 (8.22, 8.18 and 8.03 Kg. feed per Kg. gain respectively). Feed costs per 100 Kg. gain were lowest for the urea group ($29.52) followed by the Pro-Sil 12 group ($29.79) - the slight difference is a reflection of the slightly higher daily gain of the urea group. Pro-Sil 10 ($29.55) compared well with the urea group and Pro-Sil 12 group with regard to feed costs but rate of gain was much lower. The Positive Control group ($33.64) showed the highest feed cost, due mainly to the cost of supplementation with true protein (soybean oil meal).

Carcass data was obtained for only the Positive Control, Pro-Sil 12 and the Urea groups as before and are shown in Table 8. No significant differences were apparent in any of the carcass traits measured. The Urea group graded slightly higher than the other two groups but all groups averaged choice. Carcass price favoured the urea group ($108.77 per 100 Kg.) as compared to Pro-Sil 12 ($108.17) and Positive Control

TABLE 8

Effect of 40% Concentrate Ration on Carcass Quality (Expt. 1)

* No carcass data was obtained for the negative control, Pro-Sil 10 and Pro-Sil 14 treatment groups as they had not attained slaughter weight when the trial was terminated.

110 Day Test	Positive Control	Pro-Sil 12	Urea
Carcass Evaluation:			
Carcass Grade 1/	12.22	12.22	12.89
Marbling Score 2/	15.78	15.11	16.67
Fat Thickness, cm.	1.42	1.78	1.68
Rib Eye Area, sq. cm.	90.72	82.71	83.75
% K.H.P. Fat 3/	2.39	2.72	2.50
% B.T.R. Cuts 4/	2.45	3.33	3.08
Dressing Percent 5/	59.82	60.53	59.27
Carcass Price/100 Kg.	$108.17	$108.17	$108.77

1/ Carcass Grade Code - Good=9, 10, 11; Choice=12, 13, 14.

2/ Marbling Code - Small=10, 11, 12; Modest=13, 14, 15; Moderate=16, 17, 18.

3/ Percent of carcass weight in kidney, heart and pelvic fat.

4/ Percent of carcass weight in boneless, trimmed, retail cuts.

5/ Dressing percent=cold carcass weight over final weight off experiment.

($108.17).

All Silage Ration vs. 40% Concentrate Ration

Tables 9 and 10 show mean values for performance and carcass traits for both feeding regimes, and are composed of means of the Positive Control, Pro-Sil 12 and Urea groups only for both regimes.

Average daily gain was significantly ($P < .01$) higher for those cattle fed concentrate (1.25 vs. 1.05 Kg. gain per day). This was expected as a result of the higher energy content of the ration with shelled corn added, and the higher dry matter intake (9.78 vs. 8.28 Kg. per day). This confirms data from eleven previous experiments conducted at this station. A comparison of the time required for the cattle to reach slaughter weight (110 vs. 128 davs) reveals a 15% longer feeding period was necessary when all silage rations were fed. However, feed cost was considerably lower for the all silage ration ($25.83 vs. $30.98 per 100 Kg. gain) and kilograms of beef produced per hectare of corn fed was 67% higher with the all silage ration (2228 Kg. vs. 1331 Kg). No significant differences were found in carcass traits, although the 40% concentrate cattle tended to have slightly more fat.

The large difference in daily gain can be directly related to dry matter consumed, as efficiency of feed conversion is very similar on both feeding regimes and illustrates the necessity for further research into factors affecting intake of low dry matter silages.

Experiment 2: Metabolism Study with all Silage Rations

Chemical Analysis of Silage: Results of analysis are shown in Table 11. Dry matter differences were slight and not significant between silage treatments. Crude protein levels were slightly below those for silages in the feeding trial but generally the differences appeared to be

TABLE 9

Effect of All Silage vs. 40% Concentrate Ration on Rate of Gain, and Feed Efficiency (Expt. 1). 1/

	40% Concentrate 110 Days on Test	All Silage 128 Days on Test
No. Yearling Steers	27	27
Av. Initial Wt., Kg	369.5	370.0
Av. Final Wt., Kg	507.7	504.1
Av. Daily Gain, Kg	1.25^{A}	1.05^{B}
Daily Feed, Kg 85% DM:		
Corn Silage	5.58	7.81
Gr. Shelled Corn	3.82	
Soybean Oil Meal	.22	.24
Salt Minerals	.16	.23
TOTAL	9.78	8.28
Percent of Body Weight Daily	2.24	1.89
Ration DM Analysis:		
Percent Crude Protein	12.13	12.27
Percent Organic Acid	5.94	9.86
Feed Efficiency:		
Feed Per Kg Gain, Kg	7.81	7.92
Feed Cost Per 100 Kg, Gain 2/	$30.98	$25.83

1/ Data compared are overall means for Positive Control, Pro-Sil 12 and Urea groups only, at each concentrate level

2/ Feed Cost: 30% DM Corn silage $9.35/1000 Kg, Sh. corn $49.50/1000 Kg, soy $110/1000 Kg, Mineral $88/1000 Kg, Urea $88/1000 Kg, Pro-Sil $71.50/1000 Kg.

Significance: A, B Values having different superscripts differ significantly ($P < .01$)

TABLE 10

Effect of All Silage vs. 40% Concentrate Ration on Carcass Quality (Expt. 1)

	40% Concentrates 110 Days on Test	All Silage 128 Days on Test
Carcass Evaluation:		
Carcass Grade 1/	12.44	12.19
Marbling Score 2/	15.85	15.41
Fat Thickness, cm	1.63[a]	1.40[b]
Rib Eye Area, Sq. cm	85.75	81.49
Percent K.H.P. Fat 3/	2.54[a]	2.28[b]
Percent B.T.R. Cuts 4/	2.95	2.77
Dressing Percent 5/	59.87	58.67
Carcass Price per 100 Kg	$108.37	$107.65
Beef/Hectare Corn Fed, Kg 6/	1331	2228
Steers Fed/Hectare Corn Fed, Head	9.6	16.6

1/ Carcass Grade Code - Good= 9, 10, 11; Choice= 12, 13, 14.
2/ Marbling Code - Small= 10, 11, 12; Modest= 13, 14, 15; Moderate= 16, 17, 18.
3/ Percent of carcass weight in kidney, heart & pelvic fat.
4/ Percent of carcass weight in boneless, trimmed, retail cuts.
5/ Dressing percent=cold carcass weight over final weight off experiment.
6/ Based on yield of 40.5 metric tons of 35% DM Corn Silage per Hectare or 6290 Kg Shelled Corn per Hectare.

Significance: a, b Values having different superscripts differ significantly ($P < .05$).

TABLE 11

Average Chemical Analyses of Silages (Expts. 2 and 3)

	Silage Treatments				
	Control	Pro-Sil 12	Pro-Sil 14	Urea-M	*S.E.
Dry Matter %	30.30	31.12	31.69	31.88	2.08
Crude Protein %	7.19	11.56	13.81	11.44	
Nitrogen Fractions (% of DM)					
Total Nitrogen	1.14^{C}	1.84^{B}	2.21^{A}	1.83^{B}	.41
Water Insoluble Nitrogen 1/	$.73^{C}$	$.94^{B}$	1.14^{A}	$.86^{B}$	.19
Water Soluble Protein	--	--	--	--	--
Water Soluble NPN	$.41^{C}$	$.90^{B}$	1.07^{A}	$.97^{AB}$	.28
Ammonia Nitrogen	$.07^{Cb}$	$.54^{B}$	$.65^{A}$	$.13^{Ca}$	.26
Urea Nitrogen	$.01^{B}$	$.01^{B}$	$.01^{B}$	$.49^{A}$	.22
Undetermined Nitrogen 2/	.34	.35	.41	.35	.12
Organic Acid Fractions (% of DM)					
Total Organic Acid 3/	9.61^{C}	10.56^{B}	11.93^{A}	8.91^{D}	1.79
Acetic Acid	3.84^{Aa}	2.17^{B}	2.80^{b}	2.95^{b}	1.01
Lactic Acid	5.77^{B}	8.39^{A}	9.13^{A}	5.96^{B}	1.93
pH	3.8^{B}	4.0^{A}	4.0^{A}	3.9^{B}	.18

*S.E. = Standard error of the means

1/ Water insoluble nitrogen = Total nitrogen - Water soluble nitrogen

2/ Undetermined nitrogen = Water soluble NPN - (Urea nitrogen + ammonia nitrogen)

3/ Total Organic Acid = Lactic acid + acetic acid.

Significance: A, B, C Values having different superscripts differ significantly ($P < .01$)
a, b Values having different superscripts differ significantly ($P < .05$)

in proportion to the addition of NPN.

<u>Nitrogen Fractions</u>: (Figure 5) Pro-Sil 14 silage was highest in total nitrogen and contained significantly ($P<.01$) more than the other three silages. Pro-Sil 12 and Urea-M silage were very similar in total nitrogen concentration (1.84 and 1.83% of DM respectively) and these levels were significantly higher ($P<.01$) than the control silage (1.14% of DM). The water insoluble nitrogen fraction (mainly true protein) was increased in the treated silages, Pro-Sil 14 showed highly significant ($P<.01$) increases of 57% over control silage, 21% over Pro-Sil 12 silage and 32% over the Urea-M silage. Pro-Sil 12 and Urea-M silage showed significantly ($P<.01$) higher levels than the control silage. Differences between Pro-Sil 12 and Urea-M were not significant. These data support the findings of Experiment 1 and again indicate an increase in bacterial protein during silage fermentation when NPN is added.

Total water soluble nitrogen concentration was highest for the Pro-Sil 14 silage (1.07% of DM), followed by the Urea-M silage (0.97% of DM) and Pro-Sil 12 silage (0.90% of DM), and all three were significantly ($P<.01$) higher than the control silage (0.41% of DM). The difference between Pro-Sil 14 and Pro-Sil 12 was also significant ($P<.01$), other differences were not significant.

Figure 6 shows water soluble NPN fractions with relative amounts of urea, ammonia and unidentified nitrogen in each, for the four silage treatments. Pro-Sil 14 and Pro-Sil 12 silages showed high levels of ammonia nitrogen as compared to control silage and Urea-M silage. These differences were highly significant ($P<.01$). Urea-M silage had a significantly ($P<.05$) higher level of ammonia nitrogen than control silage and considerably greater urea nitrogen than all other silages

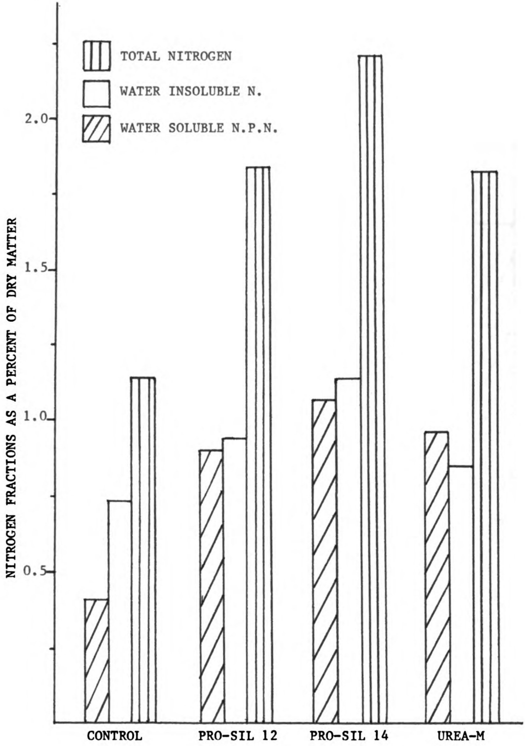

FIGURE 5. Mean total nitrogen, water insoluble nitrogen and water soluble NPN concentrations, as % of DM (Expts. 2 and 3).

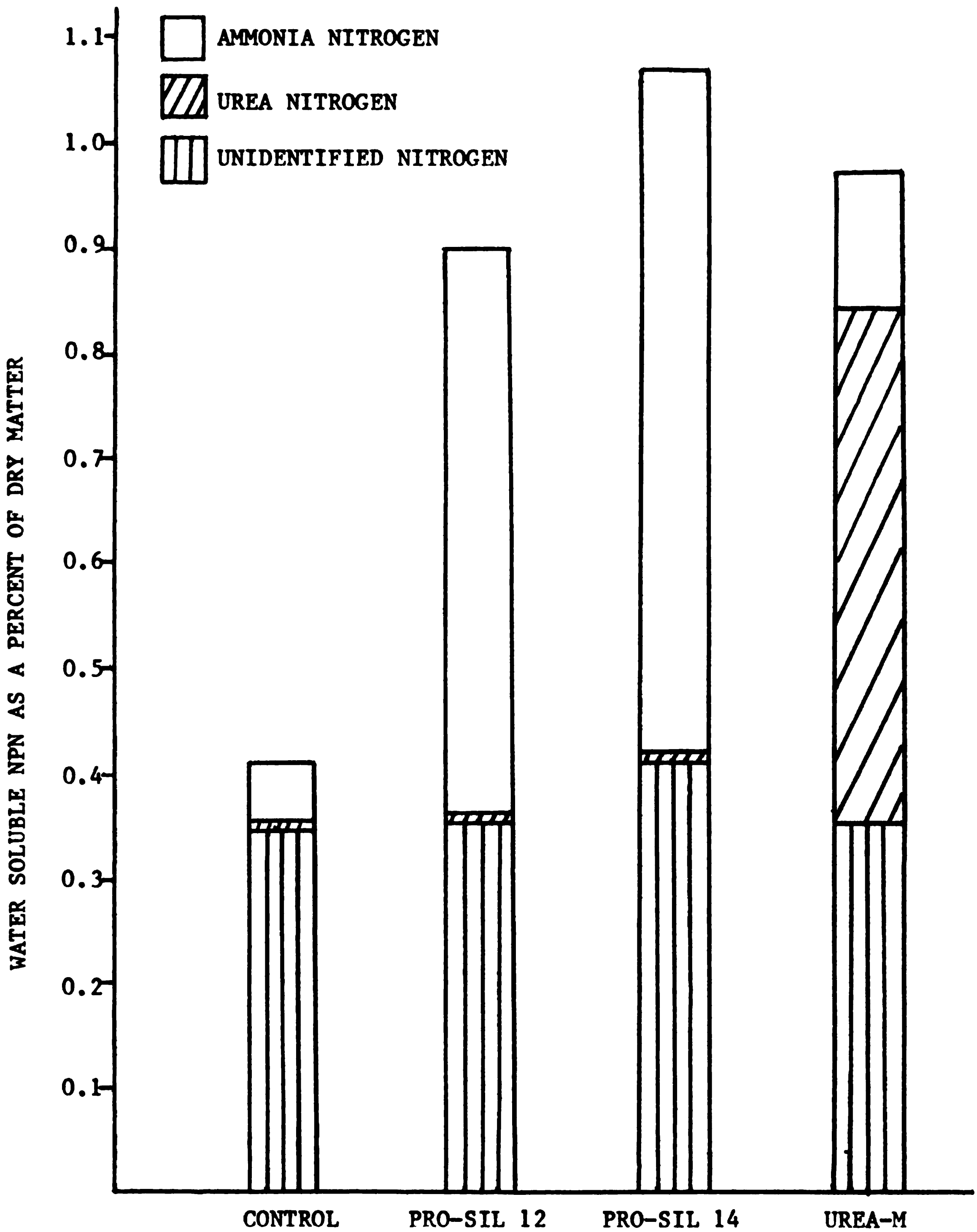

FIGURE 6. Mean total water soluble NPN (as % of DM) of silages showing actual urea and ammonia fractions (Expt. 2 & 3).

(significance $P<.01$). Unidentified NPN nitrogen was slightly higher for the Pro-Sil 14 silage (not significant), but little difference was observed between the other silages in this fraction. These data support that shown for the silages used in the feeding trial.

Organic Acids: (Figure 7) Pro-Sil additions to silage increased the total organic acid content over the control and Urea-M silages by significant ($P<.01$) amounts. The total organic acid level in the control silage (9.61% of DM) was exceptionally high as compared to the control silage used in the feeding trial (8.68% of DM).

The acetic acid level in control silage (3.84% of DM) was significantly ($P<.01$) higher than that in Pro-Sil 12 (2.17%) and significantly ($P<.05$) higher than that in Pro-Sil 14 (2.80%) and Urea-M (2.95%). Lactic acid content was greater in Pro-Sil 12 (8.39% of DM) and Pro-Sil 14 (9.13%) than in control silage or Urea-M silage (5.96%). These differences were highly significant and again indicate prolonged fermentation and lactic acid production when ammonia is added at ensiling.

The Urea-M silage contained a slightly higher level of lactic acid than the control but the difference was not significant. These data closely resemble that obtained with silages used in Experiment 1.

pH levels were significantly ($P<.01$) higher for Pro-Sil treated silages than for control and urea silages.

Digestion Parameters: Means for digestion parameters are shown in Table 12 for steers fed the all silage rations. Dry matter intake was very similar for all rations and dry matter digestibility was high for all groups, Pro-Sil 14 showed the lowest digestibility but differences were not significant.

Daily nitrogen intake was similar for control, Pro-Sil 12 and

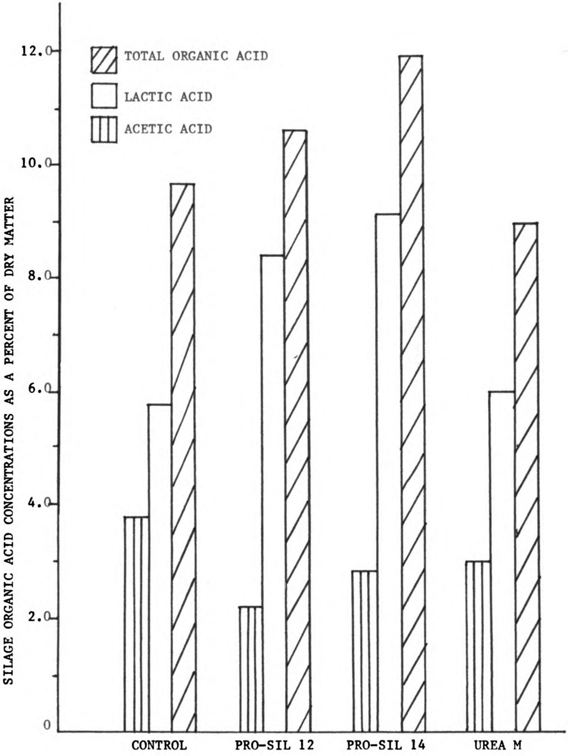

FIGURE 7. Mean organic acid fractions (as a % of DM) for the respective silages (Expt. 2 and 3).

TABLE 12

Effect of All Silage Ration on Digestion Parameters (Expt. 2)

	Treatments				
	Positive Control	Pro-Sil 12	Pro-Sil 14	Urea-M	S.E.1/
No. of Steers	4	4	4	4	
DM Intake, g. per day	6473	6332	6458	6393	218.9
DM Digested, g. per day	4722	4572	4476	4701	
Percent DM Digested, %	72.8	72.7	69.0	73.7	1.64
Nitrogen Intake, g. per day	110.0	108.8	123.7	107.1	
Nitrogen Excreted in Feces, g. per day	39.9	42.8	48.5	40.3	
Nitrogen Digested, g. per day	70.1	66.0	75.2	66.8	6.08
Percent Nitrogen Digested, %	63.7	60.7	60.8	62.4	4.53
Nitrogen Excreted in urine, g. per day	38.1	43.8	63.9	46.6	
Nitrogen Retained, g. per day	32.0	22.2	11.3	20.2	6.10
Percent Nitrogen Retained, %	29.9	20.4	10.8	19.5	
Nitrogen retained, as a Percent of Nitrogen Digested, %	45.6	33.6	15.0	30.2	8.55

S.E. 1/ = Standard Error of Means

Significance: No significant differences ($P < .10$) were found between means.

Urea-M (110, 108.8 and 107.1 g. respectively), and considerably higher for Pro-Sil 14 (123.7 g.). This is to be expected as the first three rations mentioned were close to being isonitrogenous and Pro-Sil 14 contained a higher level of nitrogen, however differences were not significant.

For all the nitrogen metabolism data the Pro-Sil 12 and Urea-M groups are remarkably similar, and slightly inferior to the control group in respect to nitrogen digestibility, nitrogen retention and percent nitrogen retained of that digested. The Pro-Sil 14 group showed similar nitrogen digestibility to the other groups but nitrogen retention was much lower, as indicated by high amounts of nitrogen excreted in the urine. No differences, however, were significant in these data and it can be concluded that all rations were highly satisfactory as evidenced by high dry matter digestibility, high nitrogen digestibility and nitrogen retention. It is apparent that the level of nitrogen in the Pro-Sil 12 and Urea-M silages is adequate for optimum results, while the Pro-Sil 14 appears to contain excess nitrogen which is wastefully excreted.

Rumen and Blood Parameters: Mean values for plasma urea and rumen ammonia levels are shown in Tables 13 and 14 (T_0 signifies pre-feeding, T_2 - 2 hours post-feeding, etc.). Rumen ammonia levels were highest in all treatment groups at two hours post-feeding, and were particularly high for the Urea-M group (23.2 mg/100ml) and the Pro-Sil 14 group (21.9 mg/100ml). Pro-Sil 12 group showed intermediate level (15.8 mg/100ml) and Control group had the lowest concentration (11.8 mg/100ml). Differences between Urea-M and Pro-Sil 14 were not significant but both were significantly ($P < .01$) higher than control and significantly ($P < .05$) higher than Pro-Sil 12. At four hours post-feeding the Pro-Sil 14 group continued to show a high ammonia concentration (17.6 mg/100ml) whereas

TABLE 13

Means of Blood Urea Values, Expt. 2 (mg/100 ml plasma)

	Treatments				
	Positive Control	Pro-Sil 12	Pro-Sil 14	Urea-M	Overall Mean
T_0	6.0^{B}	5.7^{B}	8.2^{A}	5.8^{B}	6.4
T_2	6.8	6.6	9.4	7.1	7.5
T_4	7.1^{Bb}	7.4^{Bb}	10.8^{A}	9.4^{Aa}	8.7
T_6	6.5^{B}	6.5^{B}	10.8^{Aa}	8.1^{Ab}	8.0
T_8	6.8^{B}	6.6^{B}	9.9^{Aa}	7.1^{b}	7.6
T_{10}	7.0	6.3	9.4	7.1	7.4
Overall Mean	6.7	6.5	9.8	7.4	

Significance: A, B Values having different superscripts differ significantly ($P < .01$)
a, b Values having different superscripts differ significantly ($P < .05$)

TABLE 14

Means of Rumen Ammonia Values, Expt. 2 (mg/100 ml rumen fluid)

	Treatments				
	Positive Control	Pro-Sil 12	Pro-Sil 14	Urea-M	Overall Mean
T_0	6.0	2.0	7.1	2.8	4.5
T_2	11.8^{B}	15.8^{b}	21.9^{Aa}	23.2^{Aa}	18.2
T_4	7.2	8.0	17.6^{A}	9.6	10.6
T_6	4.6	5.4	8.3	4.2	5.6
T_8	1.9	4.5	7.4	5.8	4.9
T_{10}	2.5	4.1	5.3	5.9	4.5

Significance: A, B Values having different superscripts differ significantly ($P < .01$)
a, b Values having different superscripts differ significantly ($P < .05$)

all other groups were considerably lower. The Pro-Sil 14 group declined slowly as compared to the others through six and eight hours post-feeding, however it should be noted that this group had the highest level of ammonia in the pre-feeding collection. These results were reflected in plasma urea levels, the highest levels being recorded at four hours post-feeding (T_4). Plasma urea levels were highest for the Pro-Sil 14 group at pre-feeding (T_0) and remained proportionally higher throughout the ten hour collection period. The Pro-Sil 14 and Urea-M groups showed significantly higher ($P < .01$) plasma urea levels than either control or Pro-Sil 12 groups at four and six hours post-feeding. The Pro-Sil 14 group maintained a high level through the ten hour post-feeding collection, whereas values approached normal much more rapidly for Urea-M group. The combination of rumen ammonia and blood urea data indicated a more rapid release of ammonia from urea-treated silage in the rumen, and as a result, a higher level of ammonia absorption into the blood, as compared to equinitrogenous rations of Pro-Sil 12 and protein supplemented control silages.

The Pro-Sil 14 silage contained considerably more nitrogen in the form of ammonia than the other silages, but rumen ammonia values at all times of collection indicated a slower release than the ammonia release from urea. Urea is rapidly hydrolysed to ammonia in the rumen, (high urea intake can cause ammonia toxicity) whereas the ammonia in silages is probably in the form of organic acid salts as postulated by Johnson et al. (1967). Overall means for rumen ammonia and blood plasma urea levels indicate little difference between control and Pro-Sil 12 rations, with considerably higher values for Urea-M and Pro-Sil 14, suggesting that ammonia supplementation of silage at the level used in Pro-Sil 12 is ideal in respect to rate of ammonia release and utilization by microbes in the rumen, as compared to urea supplementation of silage. Data relating to Pro-Sil 14 would suggest that higher levels of NPN may be added to the silage in the form of ammonia as compared to urea before high rumen ammonia levels are encountered.

Rumen Volatile Fatty Acids: Tables 15, 16 and 17 show means for rumen acetic, propionic and butyric acid levels. Overall means show that highest values for all acids were recorded at two hours post-feeding (T_2) and gradually declined to ten hours post-feeding (T_{10}), where they approximated pre-feeding levels (T_0). No significant differences were found in acetic acid levels between treatments within the various sampling times. The Pro-Sil 12 group had lowest values for acetic acid through all sampling periods, but the other groups were very similar.

Overall means for propionic acid levels show increased levels for all groups fed treated silages. Treatment means at each sampling time post-feeding follow the same pattern indicated by overall means. Highest values were obtained for the Pro-Sil 14 group throughout, and values for Pro-Sil 12 and Urea-M were very similar and slightly higher than control ration values.

At two hours post-feeding, Pro-Sil 14 and Pro-Sil 12 values were significantly ($P < .01$) higher than control values and Pro-Sil 14 level was significantly ($P < .05$) higher than that of Urea-M group. No other significant differences were found within sampling times.

Butyric acid levels showed the same trend throughout as propionic acid but differences were not significant. Higher propionic and butyric acid levels for treated silage groups appears to be related to lactic acid levels of those silages. It is known that lactic acid is an important intermediate in the production of propionic acid in the rumen.

TABLE 15

Mean Rumen Acetic Acid Concentrations, Expt. 2 (mM/ml)

	Treatments				
	Positive Control	Pro-Sil 12	Pro-Sil 14	Urea-M	Overall Mean
T_0	51.7	37.9	46.0	49.4	46.3
T_2	58.5	55.3	66.0	59.4	59.8
T_4	54.6	53.8	50.1	62.9	55.4
T_6	50.5	49.5	58.6	54.3	53.2
T_8	49.5	43.8	54.5	54.6	50.6
T_{10}	54.8	43.0	47.8	46.7	48.1
Overall Mean	53.3	47.2	53.8	54.6	

Significance: No significant differences were found between means.

TABLE 16

Mean Rumen Propionic Acid Concentrations, Expt. 2 (mM/ml)

	Treatments				
	Positive Control	Pro-Sil 12	Pro-Sil 14	Urea-M	Overall Mean
T_0	14.1	9.9	13.1	12.7	12.5
T_2	19.2^{B}	26.4^{A}	28.7^{Aa}	22.7^{b}	24.3
T_4	18.1	21.8	24.7	19.6	21.1
T_6	15.4	16.1	23.1	16.9	17.9
T_8	13.8	14.8	20.0	16.0	16.2
T_{10}	14.9	12.1	14.2	13.9	13.8
Overall Mean	15.9	16.9	20.6	17.0	

Significance: A, B Values having different superscripts differ significantly ($P < .01$)
a, b Values having different superscripts differ significantly ($P < .05$)

TABLE 17

Mean Rumen Butyric Acid Concentrations, Expt. 2 (mM/ml)

	Treatments				
	Positive Control	Pro-Sil 12	Pro-Sil 14	Urea-M	Overall Mean
T_o	11.1	8.7	9.9	9.1	9.7
T_2	12.7	14.8	15.0	14.9	14.4
T_4	12.5	14.9	13.0	14.1	13.6
T_6	12.3	14.6	14.3	13.2	13.6
T_8	11.0	11.6	13.1	12.5	12.1
T_{10}	11.1	10.1	10.7	9.4	10.3
Overall Mean	11.8	12.5	12.7	12.2	

Significance: No significant differences were found between means.

Lactic acid goes to propionic acid via the acrylate pathway. Butyric acid may be formed from lactic acid - the lactic acid gives up two electrons to form pyruvic acid which is a precursor of butyric acid in the butyric acid fermentation pathway.

Experiment 3: Means for digestion parameters are shown in Table 18 for the steers fed the 1% concentrate ration. Dry matter intake was considerably lower for the steers on the control ration (approached significance $P < .07$) and cannot be explained. Differences between the other treatment groups were small and not significant. Dry matter digestibility was high for all groups with little difference between them.

Nitrogen intake and nitrogen digestibility were highest for the Pro-Sil 14 group and very similar for Pro-Sil 12 and Urea-M groups (both being higher than values for the control group). None of the differences were significant. Percent nitrogen retained and percent nitrogen retained of absorbed, both favoured the two Pro-Sil treatment groups over the urea and control groups, but again differences were not significant. The data indicated that all rations were highly digestible and that adequate nitrogen was supplied to keep the steers in nitrogen equilibrium. It appears that the Pro-Sil 14 treatment group received more nitrogen than required as evidenced by the high nitrogen level in the urine.

Rumen and Blood Parameters: Mean values for blood plasma urea and rumen ammonia levels are shown in Tables 19 and 20. Overall means for rumen ammonia for the four treatment groups show that the control group were slightly higher in rumen ammonia production than the other treatment groups but differences were not significant. Ammonia levels peaked at two hours post-feeding and declined to normal levels rapidly. Plasma urea overall means were almost identical for control, Pro-Sil 12 and the

TABLE 18

Effect of 40% Concentrate Rations on Digestion Parameters (Expt. 3)

Treatments	Positive Control	Pro-Sil 12	Pro-Sil 14	Urea-M	S.E.[1/]
No. of Steers	4	4	4	4	
Dry matter intake, g. per day	6011	6747	6799	6949	286.8
Dry matter digested, g. per day	4601	5082	5283	5279	
Percent DM digested	76.5	75.3	77.7	76.0	1.42
Nitrogen intake, g. per day	100.0	110.4	125.5	114.0	
Nitrogen excreted in feces, g. per day	44.9	44.4	43.3	48.3	
Nitrogen digested, g. per day	55.1	66.0	82.2	65.7	7.66
Percent nitrogen digested	53.7	59.2	65.3	57.4	4.97
Nitrogen excreted in urine, g. per day	49.2	47.4	62.0	55.3	
Nitrogen retained, g. per day	5.9	18.6	20.2	10.4	5.65
Percent nitrogen retained	5.9	16.8	16.1	9.1	
Nitrogen retained as a percent of nitrogen digested	10.7	28.2	24.6	15.8	7.44

S.E. 1/ = Standard error of means.

Significance: No significant differences were found between any treatment means for digestion parameters.

TABLE 19

Means of Blood Urea Values, Expt. 3 (mg/100 ml plasma)

	Treatments				
	Positive Control	Pro-Sil 12	Pro-Sil 14	Urea-M	Overall Mean
T_o	9.1	6.9	9.4	7.5	8.2
T_2	7.8	8.1	10.6	8.6	8.8
T_4	11.1	9.9	11.7	10.9	10.9
T_6	8.0	9.8	10.5	9.4	9.4
T_8	8.7	9.6	8.5	8.2	8.8
T_{10}	8.2	8.2	9.4	7.6	8.4
Overall Mean	8.8	8.8	10.0	8.7	

Significance: No significant differences were found between means.

TABLE 20

Means of Rumen Ammonia Values, Expt. 3 (mg/100 ml rumen fluid)

	Treatments				
	Positive Control	Pro-Sil 12	Pro-Sil 14	Urea-M	Overall Mean
T_o	11.4	7.6	7.0	2.5	7.1
T_2	14.2	16.0	13.9	10.1	13.6
T_4	7.4	9.5	3.8	8.3	7.3
T_6	4.0	4.2	2.3	6.1	4.2
T_8	3.5	2.3	4.4	1.8	3.0
T_{10}	3.5	1.0	1.2	0.4	1.5
Overall Mean	7.3	6.8	5.4	4.9	

Significance: No significant differences were found between means.

urea group and slightly higher for Pro-Sil 14, again no significant differences were found. Plasma urea levels peaked at four hours post-feeding (T_4) as in the previous experiment but the overall mean at (T_4) was only slightly higher than the mean of all treatments at pre-feeding (T_o) - 10.9 vs. 8.2 mg/100ml.

The effects of the silage treatments were obviously negated by the dilution of the ration with shelled corn. The general patterns of ammonia production and its effect on plasma urea values were similar to those in Experiment 2.

Rumen Volatile Fatty Acids: Mean values for rumen acetic, propionic and butyric acids are shown in Tables 21, 22 and 23. Overall means for sampling times indicate a gradual increase in levels of all acids to six hours post-feeding (T_6) and a slow decline to ten hours post-feeding (T_{10}), where levels were still considerably higher than pre-feeding levels. Overall means for treatment groups show that the Pro-Sil 12 group had highest acetic acid production with slightly less for the Urea-M control group and lowest levels produced in the Pro-Sil 14 group. This trend was consistent in treatment means for all sampling times, however, differences were small and not significant.

Overall means for propionic acid levels by treatment group showed that rations containing silages supplemented with Pro-Sil, or urea and minerals, slightly increased propionic acid production in the rumen. Increases were not significant.

Butyric acid means were very similar for the Pro-Sil 12 and control groups and both were higher than means for Pro-Sil 14 and Urea-M groups, again differences were not significant.

Trends in volatile fatty acid production were not as clear cut in

TABLE 21

Mean Rumen Acetic Acid Concentrations, Expt. 3 (mM/ml)

	Treatments				
	Positive Control	Pro-Sil 12	Pro-Sil 14	Urea-M	Overall Mean
T_0	41.4	43.5	37.1	48.8	42.7
T_2	47.9	52.3	45.1	48.4	48.4
T_4	51.5	53.0	49.3	49.0	50.7
T_6	54.6	55.5	51.3	59.5	55.2
T_8	50.8	54.3	50.9	48.2	51.1
T_{10}	48.5	55.7	45.8	52.2	50.6
Overall Mean	49.1	52.4	46.6	51.0	

Significance: No significant differences were found between means.

TABLE 22

Mean Rumen Propionic Acid Concentrations, Expt. 3 (mM/ml)

	Treatments				
	Positive Control	Pro-Sil 12	Pro-Sil 14	Urea-M	Overall Mean
T_0	11.0	11.8	11.1	13.6	11.9
T_2	17.1	17.4	20.3	15.5	17.6
T_4	17.4	19.3	19.7	17.3	18.4
T_6	19.6	19.4	19.5	22.1	20.2
T_8	16.5	17.9	20.6	16.9	18.0
T_{10}	15.2	17.0	19.0	17.6	17.2
Overall Mean	16.1	17.1	18.4	17.2	

Significance: No significant differences were found between means.

TABLE 23

Mean Rumen Butyric Acid Concentrations, Expt. 3 (mM/ml)

	Treatments				
	Positive Control	Pro-Sil 12	Pro-Sil 14	Urea-M	Overall Mean
T_o	12.2	10.3	7.6	11.5	10.4
T_2	13.7	14.3	11.3	11.5	12.7
T_4	14.4	15.8	12.3	12.8	13.8
T_6	19.8	17.7	14.0	16.4	17.0
T_8	15.8	18.0	14.0	13.3	15.3
T_{10}	15.0	17.9	12.6	13.9	14.9
Overall Mean	15.2	15.7	12.0	13.2	

Significance: No significant differences were found between means.

this experiment. No significant differences were found. Peak acid production in the rumen was at six hours post-feeding indicating a slower breakdown of feed energy, which contained considerable amounts of starch, and also lower ammonia levels than were found with the all silage rations.

V. SUMMARY

The value of a liquid suspension of anhydrous ammonia, minerals and molasses (Pro-Sil), as an additive to corn silage at ensiling was studied in a feeding trial and two metabolism trials with yearling steers.

Pro-Sil additions increased crude protein content of the silages in amounts proportional to the level of addition, recovery of ammonia nitrogen added was high (approx. 95%). NPN added was recovered mainly as ammonia in Pro-Sil silages and as ammonia and urea in urea-treated silage. All treated silages had increased true protein levels and slight increases in unidentified nitrogen compounds. Total organic acid content was significantly ($P < .01$) higher for all treated silages, due to the increased lactic acid fraction. Pro-Sil treated silages showed significantly ($P < .01$) higher lactic acid levels than both urea-treated silage and control silage. However, Pro-Sil 12 and Pro-Sil 14 silages showed significantly ($P < .05$) lower levels of acetic acid.

Increased lactic acid can be explained by considering the neutralizing effect of ammonia which extends the fermentation and thereby prolongs the lactic acid production phase. The acetic acid producing phase appears to have been curtailed in the high Pro-Sil silages and the reason for this is not known. The trends in silages used for the metabolic studies were identical. Steer performance on the all silage rations was significantly ($P < .01$) improved, as measured by rate of gain and feed efficiency, for positive control, Pro-Sil 12 and urea-treated silages as compared to the negative control silage. Dry matter intake was higher for all treated silages and the control silage with protein supplement as compared to unsupplemented control silage. Feed cost per 100 Kg. gain favored the Pro-Sil 12 ration ($23.58) as compared to the urea-treated silage ration ($24.53) and control silage plus protein supplement ($29.35).

These results indicate that Pro-Sil added to corn silage at ensiling at the rate of 25 Kg. per 1000 Kg., can adequately supply the necessary crude protein equivalent and minerals to maximise gain in yearling steers on an all silage ration. The addition of 13.7 Kg. Pro-Sil per 1000 Kg. was not adequate to meet the known protein requirements of steers, and 35 Kg. Pro-Sil added had an intake depressing effect which requires further investigation.

Steer performance on the 40% concentrate rations was slightly superior for the group receiving urea-treated silage, over Pro-Sil 12 and the Positive control silage (differences not significant). However all three were superior to the negative control, Pro-Sil 10 and Pro-Sil 14.

Feed costs per 100 Kg. gain, also favored the urea-treated silage group ($29.52) by a small amount over the Pro-Sil 12 group ($29.79). Both of these treatments lowered costs considerably as compared to the conventional protein supplementation of silage at feeding ($33.64).

Steer groups on all silage rations gained significantly ($P < .01$) slower than those on the 40% concentrate rations, due to lower dry matter intake, as feed efficiency was similar. No significant carcass differences were found, but beef production per hectare was considerably higher (2228 Kg.) for the all silage rations as compared to the 40% concentrate

(1331 Kg.).

The metabolism study using all silage rations showed very similar apparent dry matter digestibility, and nitrogen digestibility for control, Pro-Sil 12 and Urea-Mineral treated silage. Nitrogen retention was greater on control silage but differences were not significant.

Rumen ammonia levels were higher for groups fed treated, compared to control silages but overall means were not significantly different. A similar trend was apparent in blood urea levels. Rumen volatile fatty acid production did not differ significantly between rations, but propionic and butyric acid levels were increased slightly in treated-silage groups. Little difference was seen between rations, and none of the treatments significantly affected parameters studied. The metabolism study using 40% concentrate rations showed no significant differences between rations for all parameters examined. As expected, apparent dry matter digestibility was lower for the all silage rations than for the high concentrate rations.

The Pro-Sil 12 and urea-treated silage supported steer performance equally as well as protein-supplemented corn silage for all parameters measured in this study.

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APPENDIX I

SAMPLE CALCULATION

SAMPLE CALCULATION

Experiment 2 - Metabolism Study

Silage Acetic Acid

Analysis of Variance

Source	d.f.	Mean Square	F	Approximate level of Significance
Between silages	3	4.3071	6.0464	0.002
Within silages (Error)	32	0.7123		
TOTAL	35			

Standard Error $= \sqrt{\frac{0.7123}{9}} = 0.2812$

Duncan New Multiple Range Test

Critical Values (P .01)		1.09	1.14	1.17
Critical Values (P .05)		0.81	0.85	0.88
Ranked Means:	3.84	.89*	1.04*	1.67**
	2.95	.15	.78	
	2.80	.63		
	2.17			

** Significance (P .01)
 * Significance (P .05)

APPENDIX II

DESIGN OF EXPERIMENTS

APPENDIX II - TABLE 1

Experiment 1 - Feeding Trial, Design of Experiment

(6 x 2 Factorial Design:
12 lots of cattle of 9 head each
= 108 steers.)

Lot No.	Silage Treatment	Concentrate Level
35	Negative control	0%
39	Positive control	0%
37	Urea-treated	0%
36	Pro-Sil 12	0%
38	Pro-Sil 14	0%
41	Pro-Sil 16	0%
42	Negative control	40%
40	Positive control	40%
34	Urea-treated	40%
44	Pro-Sil 12	40%
33	Pro-Sil 14	40%
43	Pro-Sil 16	40%

APPENDIX II - TABLE 2

Experiment 2 - Metabolism Study, Design of Experiment

	Steer No.			
Period	3	5	1	4
1	5*	1	3	9
2	3	9	5	1
3	1	3	9	5
4	9	5	1	3

* Each value denotes the silo number fed during the respective periods.

Treatment	Silo No.
Control silage	1
Pro-Sil 12 silage	3
Pro-Sil 14 silage	5
Urea-Mineral silage	9

APPENDIX II - TABLE 3

Experiment 3 - Metabolism Study, Design of Experiment

	Steer No.			
Period	8	10	15	11
1	5*	3	1	9
2	9	5	3	1
3	1	9	5	3
4	3	1	9	5

* Each value denotes the silo number fed during the respective periods.

Treatment	Silo No.
Control silage	1
Pro-Sil 12 silage	3
Pro-Sil 14 silage	5
Urea-Mineral silage	9