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The Use of Varying Levels of Urea in Concentrates Fed to Dairy Cattle

John Roland Plummer
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by John Roland Plummer entitled "The Use of Varying Levels of Urea in Concentrates Fed to Dairy Cattle." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

M.J. Montgomery, Major Professor

We have read this dissertation and recommend its acceptance:

Karl M. Barth, J.T. Miles, Eric W. Swanson, Robert H. Feinberg

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

July 31, 1970

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Vice Chancellor for
Graduate Studies and Research

THE USE OF VARYING LEVELS OF UREA IN CONCENTRATES FED TO DAIRY CATTLE

A Dissertation

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

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by

John Roland Plummer

August 1970

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ABSTRACT

Five experiments were conducted to investigate the use of concentrates that contained varying levels of urea for dairy cattle fed corn silage as the only forage.

Three experiments were conducted using 84 Holstein cows. Twenty-seven cows were used in Experiment I to compare a concentrate supplemented with soybean meal with a concentrate in which 2 percent urea (by weight) replaced a portion of the soybean meal on an equal nitrogen basis. Effects of frequency of feeding of concentrates containing urea were also studied. Results indicated that ration intake, body weight changes, milk production, milk protein, and milk SNF were not significantly different (P>0.05) for cows fed corn silage plus a concentrate containing either 0 or 2 percent urea (45 percent nitrogen). Milk fat percent was significantly higher (P<0.10) in the cows fed the concentrate that contained 2 percent urea. No significant differences were observed between treatments when a concentrate containing 2 percent urea was fed six times a day versus twice a day.

Thirty cows were used in Experiment II to compare a concentrate that contained soybean meal with a concentrate that contained 3 percent urea. Effect of the addition of sodium sulfate to a concentrate that contained 3 percent urea was also studied. Results indicated that silage intake, total dry matter intake, milk production, milk protein, and milk SNF were not significantly different (P>0.05) in cows fed corn silage plus a concentrate that contained either 0 or 3 percent urea. Milk fat percent was significantly higher (P<0.05) in cows that were fed

the concentrate that contained 3 percent urea. The data indicated that a ration of corn silage (0.17 percent sulfur on a dry matter basis) plus a concentrate that contained 3 percent urea (concentrate contained 0.15 percent sulfur on a dry matter basis) did not appear to be deficient in sulfur.

Twenty-seven cows were used in Experiment III to study the utilization of concentrates containing 3 percent urea with and without phosphate supplements. Results indicated that the addition of dicalcium phosphate and monosodium phosphate did not appear to improve the ration utilization of concentrates containing 3 percent urea. However, it should be pointed out that the phosphate source may be needed for purposes other than for the utilization of urea.

Two experiments using 32 Holstein heifers were conducted to study the effects of concentrates containing urea on nitrogen balances and palatability. In Experiment IV, nitrogen balances were conducted on 16 heifers fed concentrates which contained no protein supplement, soybean meal, 1.3 percent urea plus monosodium phosphate, or 1.3 percent urea without the monosodium phosphate supplement. Results indicated that nitrogen retention was directly related to nitrogen intake and digestibility. The addition of the monosodium phosphate to the concentrate containing urea did not significantly affect nitrogen balances. In Experiment V, 16 heifers were used in a palatability study of concentrates containing urea with and without phosphate supplements. A palatability study was also conducted comparing concentrates which contained either 0 or 3 percent urea. Results indicated that animals adapted to a concentrate which contained no phosphate supplements preferred concentrates which contained no dicalcium phosphate over concentrates which contained dicalcium phosphate, or dicalcium phosphate plus monosodium phosphate. If the animals were adapted to a concentrate that contained urea plus dicalcium phosphate and monosodium phosphate, the animals preferred the concentrate that contained both phosphate supplements over concentrates that contained only one of the phosphate supplements. Results indicated that the animals preferred the concentrates that contained no urea as compared to concentrates that contained 3 percent urea. However, it should be noted that animals offered concentrates that contained 3 percent urea did consume these concentrates, but at a reduced rate.

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CHAPTER I

INTRODUCTION

Increased feed costs have caused many dairymen to search for cheaper sources of nutrients for their cows. The demand for protein for human consumption, as well as for animal consumption, has caused protein to become the most expensive nutrient of many animal feeds.

The dairyman can lower feed costs by taking advantage of the ruminant's ability to synthesize protein from urea (a non-protein nitrogen source). However, nothing has been accomplished unless urea can furnish the nitrogen source cheaper without causing a decrease in milk production.

Early research indicated that rations containing urea could be utilized by lactating cows. In these investigations, several factors were observed to influence the efficient utilization of rations containing urea. Two of the most important factors were the composition of the ration and the level of urea used in the ration.

Results of these early studies indicated that lactating cows could efficiently utilize urea if sufficient energy was supplied in the ration and if the urea levels did not exceed: (1) 3 percent of the concentrate, (2) 1 percent of the total ration dry matter, or (3) 33 percent of the total ration nitrogen. These recommendations were derived from results of experiments in which the cows were producing less than 15 kilograms of milk per day.

In the last ten years, dairy cattle feeding and management have changed. Milk production per cow has increased, and animals are being fed larger quantities of concentrate. Many dairymen are also feeding corn silage as the only forage. It is quite probable that the older recommendations for urea feeding may not be applicable for the dairy cow of today.

These studies were conducted to investigate the effects of level, frequency of feeding, and mineral supplementation of rations containing urea for dairy cows fed corn silage as the only forage.

CHAPTER II

REVIEW OF LITERATURE

Utilization of Urea

When urea is placed in the rumen of ruminants, it is attacked by the enzyme urease and is hydrolyzed to carbon dioxide and ammonia. Many microorganisms are present in the rumen which are capable of utilizing the ammonia and converting it into microbial protein, which can later be utilized by the ruminant. Much of the early work with urea (28, 29, 30, 47) indicated that it was utilized by ruminants because the animals grew, produced, and had positive nitrogen retention values when urea furnished a portion of the protein requirement.

Even though substantial evidence exists indicating that the microorganisms of the rumen can utilize urea to synthesize protein, the amounts of urea that can be utilized by ruminants or the amounts of protein that can be replaced by urea are still uncertain.

Factors Affecting the Utilization of Urea

Composition of the ration has been shown to have a definite effect on how well urea is utilized by the ruminant (50, 52, 53, 74, 75). Mills et al. (52) observed that when timothy hay and urea were fed together, the amount of protein in the rumen ingesta was the same as when the hay was fed alone or in combination with starch. However, the amount of ammonia nitrogen in the rumen ingesta was higher when timothy hay and urea were fed than when timothy hay was fed alone or with starch. The addition of starch to the timothy hay and urea ration increased the amount of protein in the rumen ingesta. These data (52) indicated that timothy hay alone did not provide a suitable medium for the bacteria to utilize the urea for protein synthesis.

McDonald (50) reported that, in sheep, the addition of starch to the rumen which contained high ammonia levels would reduce the ammonia levels. These data indicated that the starch provided an energy source for the utilization of the ammonia by the rumen microorganisms. Mills et al. (53) measured the protein in the rumen ingesta when timothy hay, alone or in combination with molasses, was fed; the ingesta contained 6.5 to 7.7 percent protein. When urea was added to the timothy hay and molasses ration, the level of ingesta protein increased to 9.3 percent. When starch was added to the timothy hay, molasses, and urea ration, the ingesta protein level increased even further to 11 percent. These data indicated that starch was a better energy source than molasses for the utilization of urea by the rumen microorganisms. It was suggested (53) that the readily available sugars of the molasses may have been absorbed, passed through the rumen wall, or degraded too fast to be useful to the rumen microorganisms. Other early workers (5, 61) observed that for efficient utilization of rations containing urea, a readily available carbohydrate source was needed.

More recently, Huber et al. (34) reported that milk yields and persistency were inversely related to dietary urea and directly related to concentrate intake. These data indicated that at low concentrate intakes, the depressing effects of urea on milk yield was much less than at medium or high concentrate intakes. Huber et al. (34) suggested that energy may have been the limiting factor on production for the cows receiving small amounts of concentrate.

Van Horn et al. (69) reported that feeding concentrate mixtures containing 2.2 or 2.7 percent urea resulted in decreased intake and production. The concentrate mixtures in this experiment contained 95 percent ground shelled corn or ground corn and cob. Holter et al. (31) suggested that the decreased intakes observed by Van Horn et al. (69) might be attributed to the oversimplification of the concentrate mixture, and not necessarily due to the presence of urea. Other reports (31, 69) indicated that it was important to use a concentrate that was very palatable when the concentrate was supplemented with urea.

Wegner et al. (75) studied the influence of the level of protein in the ration on the utilization of urea by ruminants. Results indicated that some urea was converted to protein when the concentrate contained 20 to 24 percent crude protein (CP) from natural protein sources. The utilization of urea decreased rapidly as the natural protein content of the ration was increased above 18 percent. Other workers (25, 50, 51) have reported similar results which indicated the addition of urea was not beneficial if enough protein from natural sources was present to meet the nitrogen requirement of an animal.

Research on urea as a nitrogen source for the ruminant has demonstrated that lack of sulfur and/or methionine may be one of the factors which limits the efficiency of urea utilization (4, 26, 39, 42, 44, 68). William et al. (77) observed that the addition of sodium sulfate to rations containing urea fed to lambs did not improve the utilization of urea. However, other researchers (26, 46, 66, 68) have demonstrated that the addition of sodium sulfate and/or elemental sulfur increased the utilization of rations containing urea fed to sheep.

Synthesis of cystine from elemental and sulfate sulfur was demonstrated in sheep using ^{35}S as a tracer (27). Loosli et al. (49) demonstrated that sulfur containing amino acids were synthesized from non-protein nitrogen sources and inorganic sulfur. On the basis of these data, it was proposed that an inorganic sulfur source should be added to rations of dairy cattle and other ruminants when urea or ammonia furnish part of the dietary nitrogen.

Davis et al. (21) observed no significant differences in milk production between three groups of cows fed the following isonitrogenous rations: basal ration plus soybean meal, basal ration plus 2.27 percent urea, and basal ration plus 2.27 percent urea and 0.27 percent sodium sulfate.

Jones and Haag (39) demonstrated with paired feeding experiments that the addition of 1 percent sodium sulfate increased the average daily gains of dairy heifers on rations containing 3 percent urea. Brown et al. (9) fed a basal ration, basal ration plus urea and sodium sulfate, and basal ration plus soybean meal. The addition of sulfate to the concentrate containing urea resulted in increased average daily gains.

Lassiter et al. (44) studied the value of adding sodium sulfate to rations containing urea. Urea furnished 30, 50, and 70 percent of the total dietary nitrogen of the concentrates for rations 1, 2, and 3, respectively. Ration 1 contained 0.171 percent sulfur. The sulfur content of ration 2 was increased to 0.174 percent and that of ration 3 to 0.178 percent by the addition of 0.15 and 0.30 percent sodium sulfate, respectively. The animals fed the urea rations supplemented with sulfate had higher average daily gains than did animals fed the urea rations without sulfate supplementation. The higher gains were thought to have been accomplished by incorporation of the sulfur into sulfur-containing amino acids (44).

Several researchers (36, 37, 38) have indicated that sulfur deficiencies could be produced in cows fed low-sulfur rations containing urea. These researchers reported that voluntary intake and milk production were significantly increased when sulfur was added to low-sulfur rations which contained urea as a portion of the nitrogen source. However, some of the data (36) indicated that the sulfur was not efficiently utilized.

Chalupa (12) reported that the substitution of urea into a ration removed a major portion of the calcium and phosphorus sources from the diet. Conrad et al. (19) and Karr et al. (40) obtained positive results when alfalfa meal was added to urea supplements. The beneficial effects of the alfalfa meal on urea utilization were due at least partially to the minerals that the alfalfa meal contained (12). However, the amount of readily available carbohydrate and peptide nitrogen furnished by the alfalfa meal should not be overlooked. The urea supplement developed by Conrad et al. (19) also contained dicalcium phosphate to help replace the calcium and phosphorus that were removed from the ration when urea was added as a supplement.

Colovos et al. (16) fed two types of concentrate mixtures to dairy heifers: a low (5 percent) fiber and a high (10 percent) fiber. Within each fiber level, the concentrate contained either 0, 10, 20, or 40 pounds of urea per ton of concentrate. A good quality hay was fed. Results indicated that without urea, the low-fiber rations were generally superior to the high-fiber rations in net energy; but when urea in the concentrate mixtures was 40 pounds per ton, the high-fiber rations were comparable to the more expensive, low-fiber rations. Colovos et al. (16) indicated that the difference was due to the decrease in heat increment caused by the presence of urea in the ration. In a later experiment, Colovos et al. (14) fed concentrate mixtures containing 0 and 2 percent urea and 5 and 8 percent fiber to lactating dairy cows. Results indicated that urea significantly increased digestibility of fiber in the low-fiber concentrate and had the opposite effect in the high-fiber concentrate. Both the high fiber and the urea depressed ration digestibility and nutritive value, with fiber having the more pronounced effect.

A major problem in the efficient utilization of urea is the rapid release of ammonia (6). Some researchers (10, 24) felt that if rations containing urea were fed more frequently than twice per day, there would be a more continuous supply of ammonia available to the rumen microorganisms. Campbell et al. (10) fed a concentrate containing 3.3 percent urea to two groups of dairy heifers. Both groups of heifers were fed the same amount of feed per day, but one group was fed six times per day and the other group was fed twice per day. Data indicated that the urea ration fed six times per day gave growth and feed efficiencies similar to animals being fed a protein supplemented diet twice daily. The animals fed the ration containing urea six times daily gained significantly more than the animals fed the ration containing urea twice daily. No significant differences in average daily gain were observed between the non-urea ration fed twice per day versus six times per day.

Fletcher _et al_. (24) fed two groups of dairy heifers corn silage which contained 0.5 percent urea. One group was fed four times per day; the other group was fed twice per day. The animals fed the urea-treated silage four times per day had 18.4 percent greater gains than did the heifers fed the urea-treated corn silage twice per day. These researchers (24) suggested that although the differences in average gains were non-significant, they approached significance. Therefore, frequent feeding of grain or corn silage containing urea may be beneficial.

Levels of Urea That Can Be Used by Ruminants

In the determination of the levels of urea that can be efficiently used by ruminants, the following factors should be considered: (A) levels and methods of feeding of urea which are associated with urea toxicity, and (B) levels of urea that can be used by ruminants for maintenance and/or production.

Urea toxicity. If large enough quantities of urea are placed in the rumen, a toxic condition may occur. When urea is introduced into the rumen in a concentrated form, as would be the case if urea were fed by itself or given as a drench, it is hydrolyzed rapidly, and large quantities of ammonia are released. If larger quantities of ammonia are released than can be utilized by the microorganisms, the excess ammonia is absorbed across the rumen wall and taken up by the blood. Chalupa (12) reported that the inability of the liver to convert all the absorbed ammonia to urea is responsible for the presence of ammonia in peripheral blood which may result in toxicity. Several workers, Dinning et al. (22), Repp et al. (63), and Lewis et al. (45), have reported that toxic symptoms appear when the peripheral blood ammonia levels reach a critical value of approximately 1 to 4 milligrams per hundred milliliters. The toxic symptoms include ataxia, respiratory difficulties, salivation, incoordination, bloat, and death within 1.5 to 2.5 hours after the appearance of any of the symptoms. Lewis et al. (45) reported that changes in rumen blood ammonia concentrations were paralleled by changes in portal blood ammonia concentrations. Chalupa (12) indicated that the toxic level, which was determined by administering urea as a drench, was about 20 to 30 grams per 45 kilograms of body weight. However, when urea is fed as a part of a concentrate mixture, it is consumed more slowly, and urea toxicity is less likely to exist. Briggs et al. (8) reported that yearling steers refused to eat enough concentrate containing 8 percent urea to suffer adverse effects. Virtanen (73) has fed rations in which urea furnished essentially all of the nitrogen, and urea toxicity was not observed. From research reports it appears quite evident that urea cannot be fed in its concentrated form, but should be mixed with the ration to prevent urea toxicity. Reid (62) concluded that since urea is quite unpalatable and the quantities of urea which are usually fed are less than the toxic level, there appears to be no great concern for its toxic effect, provided that it is uniformly mixed with the feed.

Levels of urea that can be used for maintenance and production. Virtanen (73) indicated that urea may be used more efficiently for maintenance than for production. Several workers (7, 34, 48, 69) have hypothesized reasons why urea is not used as efficiently for production as it is for maintenance. They suggest that the total amount of urea that is consumed affects urea utilization instead of the percent of the ration that is made up of urea, or the percent protein equivalent furnished by urea. Low-producing cows or cows on maintenance rations would be consuming relatively low amounts of urea; whereas, cows producing large quantities of milk would be consuming more total urea.

Work of Loosli et al. (49) and Duncan et al. (23) indicated that heifers could be grown and maintained on purified rations which contained urea as the only significant source of nitrogen. Heifers and sheep reared on a ration for which urea was the sole nitrogen source did not achieve optimum growth (79).

Virtanen (73) fed four cows a purified ration in which the main nitrogen source was urea. The cows were started at a relatively low level of nitrogen to prevent urea toxicity. When no toxic symptoms were observed, the urea content in the ration was increased, resulting in enhanced milk production and general appearance of the cows. One cow produced 4,217 kilograms milk per year on the urea ration; the average production of the cows on the experiment was 3,053 kilograms milk per year. Virtanen (73) believed that energy intake may have been a limiting factor in the experiment since none of the cows had eaten over 11 kilograms of dry matter per day. These data (73) indicate that urea can be used, not only for maintenance and growth, but also for milk production. Virtanen (73) pointed out that the presence of urea in the ration may not have been, and probably was not, the main reason for the low intake of the ration. The low intakes were probably due to the composition and physical consistency of the purified ration.

Other researchers (1, 43, 64) have studied the level of urea supplementation in rations. Much of the early work with urea was conducted on cows with low milk production. Rupel et al. (64) studied the effects of feeding the following rations: (1) basal, (2) basal plus linseed meal, and (3) basal plus urea. Ration 1 contained 10 percent crude protein. Rations 2 and 3 contained 18 percent CP (when the concentrate contains urea, CP includes urea nitrogen). Three groups of five cows each were used for the experiment which ran for three years. Each group of cows received each of the rations for one entire lactation. The urea ration contained 3 percent urea (46 percent nitrogen). Average 4 percent fat-corrected-milk (FCM) yields were 6,675, 7,790, and 7,690 pounds for the basal, basal plus linseed meal, and basal plus urea rations, respectively. Fat-corrected-milk yields were not significantly different for the cows on rations 2 and 3. Cows on the linseed meal supplemented ration were receiving 0.16 pounds more digestible energy than were the cows on the urea supplemented ration. This slight difference in energy may have been the reason for the differences in milk production between these two groups (64). In this experiment, urea furnished 45 percent of the ration nitrogen. The cows receiving the urea-containing rations were consuming approximately 0.3 pounds of urea per day.

Archibald (1) fed cows a concentrate mixture in which urea furnished 45 percent of the nitrogen. The cows on the experimental urea rations produced as well as the cows on a control ration. However, it should be pointed out that only 25 percent of the total dietary nitrogen needs of the cows were from urea. These results were similar to those reported by Owens et al. (58). Lassiter et al. (43) fed a concentrate containing 4.4 percent urea in which 70 percent of the nitrogen was furnished by urea. The cows receiving the concentrate containing urea produced as well as the cows on a control ration. However, due to the low production of the cows on the experiment, intake of concentrate was quite low, and urea furnished only about 33 percent of the total dietary nitrogen.

In the 1950's, Reid (62) and Loosli and Warner (48) reported that available data indicated that urea could be fed to dairy cows up to levels that would: (1) supply 33 percent of the total nitrogen of the ration, (2) constitute up to 3 percent of the concentrate mixture, or (3) constitute as much as 1 percent of the total ration dry matter. These researchers (48, 62) felt that these recommended levels would avoid toxicity and give satisfactory performance. In 1967, Van Horn et al. (69) pointed out that the levels suggested by Loosli and Warner (48) and Reid (62) were based on experiments using cows that were producing less than 20 kilograms of milk per day. Van Horn et al. (69) suggested that higher-producing cows might respond differently.

Huber et al. (34) observed a marked depression in milk production with high-producing cows receiving rations in which 38 or 48 percent of the total ration nitrogen was furnished by urea. Knott et al. (41) fed a concentrate mixture containing 1.5 percent urea to lactating cows and observed no significant differences in milk production when the ration containing urea was compared with an isonitrogenous control ration. Colovos et al. (14) fed a concentrate mixture containing 2 percent urea to lactating cows for twelve weeks. Results indicated that the cows receiving the ration containing urea produced as well as the cows receiving a control ration. Later work by Colovos et al. (15) indicated that cows receiving an 18 percent CP concentrate containing 2.5 percent urea produced as well as cows receiving an isonitrogenous control ration.

Holter et al. (32) divided a herd of 56 cows into two groups. One group received an 18 percent CP concentrate in which soybean meal was the nitrogen supplement; the other group received an 18 percent CP concentrate in which urea replaced 3.9 percentage units of the protein. Other than the ration differences, the two groups were treated the same. At the end of the 18 month experimental period, results indicated that the cows receiving the urea-supplemented concentrate had produced as well as the cows on the soybean meal-supplemented concentrate. The cows were consuming 170 grams of urea per cow per day. The average 305 milk production for the herd was 8,044 kilograms.

Loosli and Warner (48) fed a concentrate containing 3 percent urea to lactating dairy cows. Results indicated that cows produced as well on the concentrate containing 3 percent urea as did the cows on a concentrate supplemented with either corn distillers dried grains or brewers dried grains.

The amount of urea consumed per cow per day has been studied by Huber et al. (34). Milk yields were significantly depressed when urea furnished either 48, 38, 23, 21, or 23 percent of the total dietary nitrogen. The amounts of urea consumed by these cows for the respective levels were: 355, 299, 183, 171, and 181 grams per cow per day.

Archibald (1) reported that production was not significantly depressed when urea furnished 25 percent of the dietary nitrogen. However, because of low production, intake of urea was only 152 grams per cow per day. Lassiter et al. (43) reported no milk depression when urea in the concentrate furnished 33 percent of the ration nitrogen. However, urea intake by these cows was only 140 grams per cow per day.

Reid (62) suggested that the utilization of rations containing urea could possibly be improved as the period of time which the cows were fed the urea rations was extended. In 1957, Welch et al. (76) observed an adaptation response for animals receiving rations containing urea. Virtanen (73) noted a stronger labeling of milk amino acids following a dose of ^{15}N-labeled urea after cows had been on a urea ration for six months. Van Horn et al. (69) reported that most of the spread in milk production between controls and urea-fed cows occurred during the first 20 days, after which the spread was maintained or narrowed.

In 1944, Wise et al. (78) and Woodward and Shepherd (80) reported the effects of feeding cows corn silage that had 10 pounds of urea per ton added at ensiling time. Both groups of researchers indicated that the urea-treated silage was slightly less palatable, but milk production for the cows consuming it was comparable with production of cows consuming untreated corn silage. Huber et al. (34) and Polan et al. (60) indicated that urea-treated corn silage tends to alleviate the palatability problem often encountered when urea is added to concentrate.

Van Horn et al. (70) fed lactating cows a concentrate containing 1 percent urea and corn silage that contained 0.5 percent urea, which was added at ensiling time. The cows receiving the urea-treated corn silage produced significantly less milk than did cows consuming a control ration of untreated silage. Van Horn et al. (70) also reported that urea-treated corn silage which was 31.9 percent dry matter (DM) was better utilized than urea-treated corn silage which was 46.2 percent dry matter. Huber et al. (35) studied the effects of dry matter on urea-treated corn silage. They observed lower utilization of high dry matter (44.8 percent DM) urea-treated corn silage compared to medium dry matter (36.5 percent DM) or low dry matter (30.6 percent DM) urea-treated corn silage. These workers reported that only 31 percent of the added urea nitrogen was recovered from the high dry matter corn silage as opposed to 87 percent and

81 percent recovery from the low dry matter and medium dry matter corn silages, respectively.

Conrad and Hibbs (18) pointed out that about 1 kilogram of readily fermentable carbohydrate is required per 100 grams of urea for maximum utilization of urea in an adapted cow. Coppock (20) suggested that following fermentation, corn silage which contained 0.5 percent urea may not have had sufficient available carbohydrate for efficient utilization of the urea. Conrad and Hibbs (17) reported that if urea-treated corn silage (14 pounds per ton) is fed as the total ration, inefficient use of the urea nitrogen may occur. Nitrogen balance data indicated that cows fed a sole ration of urea-treated corn silage (14 pounds per ton) utilized only 8 percent of the dietary nitrogen for milk production and body tissue retention, in comparison to 22 percent utilization for a similar group of cows fed alfalfa hay and grain.

Polan _et al_. (60) fed corn silage containing 0, 0.60, and 0.85 percent added urea. Milk production of the cows on the urea-treated silage was not significantly different from the cows receiving untreated corn silage. However, it should be noted that the cows on the control and the 0.60 percent urea-treated silage were in slightly negative nitrogen balances, while the cows on the 0.85 percent urea-treated silage were in large, negative nitrogen balances. These cows on the 0.85 percent urea-treated silage were drawing on body reserves equivalent to 794 grams of protein per day. Under these conditions, it is doubtful how long cows will continue to produce at normal levels.

Huber _et al_. (33) summarized several studies on urea-treated corn silage for dairy cattle. They concluded that feeding corn silage treated with 0.50 percent urea, with a concurrent reduction in the crude protein content of the concentrate from about 18 to 13 percent did not result in significant differences in milk yields.

Effects of Urea Supplementation on Ration Utilization and Ruminant Metabolism

Palatability, nitrogen retention, digestibilities, blood urea nitrogen, and volatile fatty acid production have been studied to determine the effects of urea on ration utilization and ruminant metabolism.

Urea has been shown by several researchers to be unpalatable (7, 19, 34, 62, 69). Van Horn et al. (69) suggested that when urea is added to corn silage, the palatability problem is decreased as compared to adding urea to a concentrate. Holter et al. (31) stressed the importance of using feeds that were palatable when urea was to be added.

Campling et al. (11) reported an increased voluntary consumption of low quality forage when urea was added to the ration. The increased intake was attributed to the urea nitrogen, which increased the rate of fermentation and passage.

Polan et al. (60) suggested that lactating cows consuming concentrates containing urea may fail to efficiently utilize the urea. However, through the utilization of body nitrogen sources to supplement their nitrogen requirement, milk production may equal the production of cows receiving a protein supplement. Huber et al. (34) noted that when the concentrate contained 2.2 percent urea milk production was depressed, but body weight changes were not affected. Other data (8) indicated that most changes in body weight of cows consuming concentrates containing urea were the result of feed intake. Virtanen (73) reported that cows could consume rations in which 95 percent of the dietary nitrogen came from urea and still maintain good body weights. However, milk production in Virtanen's (73) experiment averaged only 3,053 kilograms per year.

Huber et al. (34) fed lactating cows concentrates that contained 0, 1.1, or 2.2 percent urea and that furnished 0, 10, or 20 percent of the dietary nitrogen. The apparent digestibilities of dry matter, crude fiber, and nitrogen free extract were significantly lower for the rations containing urea. Polan et al. (60) fed cows corn silage supplemented with 0, 0.60, and 0.85 percent urea, adding a concentrate mixture to make each total ration isonitrogenous. Data from the experiment revealed that no significant differences existed between treatments for digestibility of dry matter, crude fiber, or nitrogen free extract.

Colovos et al. (16) reported that the inclusion of 2 percent urea in a concentrate mixture (5 percent fiber) for dairy cattle tended to increase the net energy value of the ration. This increase was apparently due to a decreased loss of energy in the heat increment. However, when Colovos et al. (13) fed concentrates containing 0, 2.0, and 2.5 percent urea to lactating cows, small decreases in metabolizable energy per unit of dry matter consumed were observed for the concentrates containing urea.

Polan *et al*. (60) ran nitrogen balances on animals consuming urea rations. Cows were fed corn silage containing 0, 0.60, or 0.85 percent urea. The nitrogen excretion of the animals receiving the corn silage containing 0.85 percent urea greatly exceeded the intake of nitrogen. The animals fed the 0 and 0.60 percent urea-treated corn silage were only in slight negative nitrogen balance. The cows on the 0.85 percent urea-treated corn silage excreted approximately twice as much nitrogen in their urine as did the cows receiving the 0 or 0.60 percent urea-treated corn silage. Work by Van Horn *et al*. (71) indicated that nitrogen balances were increased over controls when urea was fed to dairy cows.

Several workers (41, 54, 55, 60) have studied the effect of urea supplementation on blood urea nitrogen levels. Increases in blood urea nitrogen levels have been observed when urea was added to the ration (41, 60, 54). Moller (54) indicated that sharp, but not significant increases were observed in blood urea nitrogen levels when urea replaced from 20 to 40 percent of the protein equivalent. Moller *et al*. (55) fed four groups of cows rations which contained 22.5, 103.7, 201.0, and 274.8 grams urea daily; the average blood urea nitrogen levels for the respective groups were: 26.2, 28.2 to 31.7, 30.5 to 34.2, and 37.2 to 37.4 milligrams per hundred milliliters.

The effects of rations containing urea on volatile fatty acid (VFA) concentrations and proportions have been studied (15, 41, 73). Colovos *et al*. (15) fed cows concentrates containing 0, 1.25, 2.00, and 2.50 percent urea; no significant differences were observed in the molar proportions of acetic, propionic, and butyric acids for the different treatments. Huber _et al_. (34) fed lactating cows concentrates containing 0, 1.1, and 2.2 percent urea, which furnished 0, 10, and 20 percent of the total dietary nitrogen of the rations. Results indicated that VFA concentrations were not significantly affected by urea treatment.

CHAPTER III

GENERAL EXPERIMENTAL PROCEDURE

Objective of Experiments

The principle objective of the study was to investigate the use of concentrates containing urea for dairy cattle fed corn silage as the only forage. The influence of urea level, frequency of feeding, and mineral supplementation of concentrates containing urea on milk production, milk constituents, body weight change, palatability, and some metabolic factors were studied. Five experiments were conducted in the investigation.

Materials and Methods

Sampling. Samples of rations fed were taken weekly in Experiments I, II, III, and V. Dry matter analyses were made immediately on the corn silage in Experiments I, II, III, and IV. The concentrate samples were stored in air tight containers until protein and dry matter analyses were made.

Daily samples of the rations fed were taken during the experimental period of Experiment IV. Samples of rumen content were taken once per week at two, four, and six hours post-feeding during Experiment IV, and once per week at three and one-half to four and one-half hours post-feeding in Experiment III. Samples of rumen content were taken with a vacuum pump and stomach tube and were strained through cheesecloth. The rumen fluid samples were preserved with saturated mercuric chloride and refrigerated until analyses were made.

Blood samples were collected approximately three and one-half to four and one-half hours post-feeding from the cows in Experiment III. Approximately 20 milliliters of blood were taken from the jugular vein. Potassium oxalate was used as the anticoagulant.

A morning and an evening milk sample was taken and composited for each cow once a week in Experiments I, II, and III. Analyses for milk fat, solids-not-fat (SNF), and protein were made on the milk in Experiments I and II. Milk fat analyses were made on the milk in Experiment III.

Chemical analyses. Dry matter content of corn silage was determined by drying in a forced draft oven at 50°C for 48 hours. Concentrate mixtures were dried in a vacuum oven at 100°C for 24 hours.

Rumen volatile fatty acids (VFA) were determined by gas liquid chromatography (3). A five milliliter sample of rumen fluid was acidified with one milliliter of 25 percent metaphosphoric acid and used in the VFA analyses. Gas chromatographic analysis for VFA was conducted utilizing an F and M Model 810-19 Analytical Gas Chromatograph equipped with a hydrogen flame detector. The column was one-fourth inch coiled stainless steel and was packed with 15 percent Carbowax 20 M and terephthalic acid on 80/100 mesh Chromosorb W (AW-DMCS). Nitrogen was used as the carrier gas. Rumen pH was measured on the fresh rumen fluid immediately following collection with a Leeds and Northrup pH meter using a glass electrode.

Feed and milk samples were analyzed for protein content by the Kjeldahl method (2). Acid detergent fiber (ADF) was determined by the method of Van Soest (72). Milk fat was determined by the Babcock method (2), and SNF were determined by drying a two gram wet sample of milk and obtaining total solids from which milk fat was subtracted, leaving the solids-not-fat.

Blood was analyzed for blood urea nitrogen by the method described by Sigma Chemical Company (65).

Sulfur was determined by Galbraith Microanalytical Laboratory, Knoxville, Tennessee.

Statistical analyses. Statistical analyses of the data were based on the methods outlined by Steel and Torrie (67). Analyses of covariance were made, where appropriate, as outlined by Steel and Torrie (67). Portions of the data were processed with the aid of an IBM computer and auxilliary equipment.

CHAPTER IV

EXPERIMENT I

Objective of Experiment

The objective of this investigation was to compare a concentrate supplemented with soybean meal with a concentrate in which 2 percent urea (45 percent nitrogen) replaced part of the soybean meal for cows fed corn silage as the only forage. A comparison of twice versus six times a day feeding of a concentrate containing urea for cows fed corn silage as the only forage was also investigated.

Experimental Procedure

Twenty-seven Holstein cows were used in a continuous-type feeding trial which lasted a total of 17 weeks. All of the cows were in the first one-third of lactation at the beginning of the experiment. A one-week adjustment period, two-week standardization period, and a two-week changeover period preceded the 12-week experimental period. During the adjustment and standardization periods, all cows received corn silage (8.61 percent CP on dry matter basis) ad libitum and a concentrate supplemented with soybean meal fed twice per day at the rate of 1 pound per 2.5 pounds of 4 percent fat-corrected-milk (FCM). Three times during the standardization period, a morning and evening milk sample was taken and composited for each cow. The milk fat analyses from these milk samples were used to correct milk production of the cows to 4 percent FCM. At the end of the standardization period, the cows were assigned to trios based on 4 percent FCM production during the standardization period. Immediately following the assignment to the trios, the cows within each trio were assigned to treatments at random.

During the changeover period, cows on treatments that contained urea were gradually switched from the concentrate containing no urea to the concentrate containing urea.

The animals were housed in a stanchion-type barn equipped for obtaining individual feed weights of all forages and concentrates fed. Animals were allowed to exercise in an outside lot one hour daily.

One cow within each trio received one of the following treatments: (I) Concentrate I fed twice a day in equal amounts, (II) Concentrate II that contained 2 percent urea (45 percent nitrogen) fed twice a day in equal amounts, and (III) Concentrate II fed six times a day in equal amounts. Composition of the concentrates used is presented in Table I. Cows in all three treatments were fed corn silage three times a day *ad libitum*. Feed and refusal weights were recorded daily. Trace mineralized salt and water were available to the animals at all times. Concentrate allowances for the trios were adjusted every two weeks. Adjustments within each trio were based on the production of the cow with the highest persistency.

Body weights were taken for three consecutive days at the end of the standardization period and during the last three days of each two-week period following the standardization period.

Table I

Composition of Concentrates Fed in Experiment I

Components	Concentrate I[a]	Concentrate II[b]
	%	%
Corn	49.0	61.2
Oats	24.5	24.7
Soybean Meal	24.5	9.9
Urea		2.0
Salt	1.0	1.0
Dicalcium Phosphate	1.0	1.0
Monosodium Phosphate		0.2

[a]Crude Protein = 19.74% as fed.

[b]Crude Protein = 21.27% as fed.

Daily milk production was recorded, and morning and evening milk samples were collected and composited once a week from each cow. These samples were analyzed for milk fat, protein, and SNF.

Results and Discussion

The concentrates fed in the experiment were formulated to be isonitrogenous. However, as indicated in Table I, actual CP content was 19.74 and 21.27 percent for concentrates I and II, respectively.

Table II indicates the cost of the concentrates and the amount of nitrogen that was furnished by urea for the different treatments.

Individual data for the traits studied are presented in Appendix Tables XXVI through XXIX.

Adjusted means for actual milk production, milk fat percent, and FCM production are presented in Table III. Treatments had no significant effect ($P>0.05$) on actual or FCM production. Several researchers (1, 14, 43, 64) reported that no significant differences were observed between treatments when concentrates containing 2 percent urea were compared with control rations. The cows in these earlier experiments (1, 14, 43, 64) were producing less than 36.00 pounds FCM per day. The cows in the present experiment produced an average of 43.93 pounds FCM per day. This suggests that medium-producing cows, fed a concentrate containing 2 percent urea and corn silage as the only forage, utilized the urea as efficiently as it was utilized by lower producing cows.

The results of the present experiment do not agree with those obtained by Huber et al. (34). These researchers obtained

Table II

Cost of Concentrates, Percentage Nitrogen Furnished by Urea, and Average Daily Urea Consumption Per Cow in Experiment I

	Treatment		
	I	II	III
% of Concentrate N Furnished by Urea	0	26.42	26.42
% of Total Dietary N Furnished by Urea	0	21.61	21.85
Average Lbs Urea Consumed/Cow/Day	0	0.42	0.42
Cost of Concentrate[a] Per Ton, Fall 1967	$60.96	$56.32	$56.32

N = Nitrogen.

[a]Ingredient costs are presented in Appendix Table XXV.

Table III

Daily Milk Production, Fat-Corrected-Milk Production, and Milk Fat Percent for Cows in Experiment I

Treatment	Adjusted Means Actual Milk (lbs)	Milk Fat (%)	FCM (lbs)
I	49.76	3.07[a]	42.72
II	50.61	3.45[b]	45.66
III	48.84	3.20[ab]	43.40

Values within columns with different superscripts are significantly different ($P<0.10$).

significant decreases in milk production for cows fed rations in which urea furnished 21 and 23 percent of the total dietary nitrogen; these cows consumed 0.38 and 0.40 pounds of urea per day, respectively. The cows on urea treatments in the present experiment consumed 0.42 pounds of urea per day, and no decreases in milk production were observed.

Mean milk fat percent for the cows on Treatment II was significantly higher ($P<0.10$) than the milk fat percent for the cows on Treatments I or III. Huber et al. (34) observed no such increase in milk fat percent for cows consuming concentrates in which urea furnished 23 percent of the total ration nitrogen. However, work by Colovos et al. (14) indicated that cows consuming concentrates which contained 2 percent urea had a non-significantly higher milk fat percent than did cows fed rations containing no urea.

Data in Table IV indicates that mean values for percent milk protein and SNF were not significantly different ($P>0.10$) between the three treatments. These results agree with the data reported by Huber et al. (34) and Rupel et al. (64).

Mean daily concentrate intakes were 21.02, 20.77, and 20.96 pounds, and mean daily silage intakes (as fed) were 33.38, 38.66, and 36.02 pounds for Treatments I, II, and III, respectively.

Treatment differences in feed intake and body weight increases were not significant ($P>0.05$), as is indicated in Table V. Several researchers (14, 15, 34, 64) have reported that cows fed a concentrate containing 2 percent urea consumed their feed and maintained body weight as well as cows fed control concentrates.

Table IV

Mean Milk Constituents for Cows on Experiment I

Treatment	Mean Milk Constituents Milk Fat	Protein	SNF
	%		
I	3.05[a]	3.41	9.09
II	3.45[b]	3.35	9.04
III	3.21[ab]	3.32	9.14

Values within columns with different superscripts are significantly different ($P<0.10$).

Table V

Mean Daily Dry Matter Intake and Body Weight Change for Cows in Experiment I

Treatment	Mean Daily DM Intake/100 Lbs B.W.			B.W.
	Concentrate	Silage	Total	Change/Day
	lbs			
I	1.60	0.85	2.45	1.16
II	1.45	0.97	2.42	1.13
III	1.63	0.92	2.55	1.29

No significant differences (P>0.10) were observed in actual and FCM production, milk fat percent, percent milk protein, percent milk SNF, feed intake, and body weight change per day when a concentrate containing 2 percent urea was fed twice versus six times per day. Campbell et al. (10) and Fletcher et al. (24) indicated that more frequent feedings of rations containing urea would improve average daily gains in dairy heifers. It appears from results of this experiment that feeding a concentrate containing 2 percent urea more frequently than twice per day does not improve production in lactating cows.

In evaluating the utilization of the rations which contained urea in this experiment, the actual protein requirement of the cows must be considered. According to the National Research Council (NRC) (57) requirements for crude protein and the crude protein analyses of the rations, the cows in this experiment were consuming 0.13, 0.30, and 0.45 pounds more crude protein than was needed for growth, maintenance, and production on Treatments I, II, and III, respectively. If the NRC requirements are applicable and the digestibility of protein is assumed to be the same as indicated by NRC, the cows would have needed only 0.31 and 0.26 pounds of the 0.42 pounds of urea that they were receiving on Treatments II and III, respectively. Even though these calculations suggest that the cows were consuming more nitrogen than they needed, these data also indicate that the cows were utilizing a portion of the urea to meet their protein requirements.

The rations can also be evaluated according to the amount of milk protein produced by the cows. In this evaluation, the amount of protein required for growth and maintenance was calculated from NRC requirements (57), and the amount of digestible protein required for production was considered to be 125 percent (56, 59) of the amount of milk protein produced. Assuming nitrogen digestibility to be 65 percent, the cows were consuming 0.49 and 0.52 pounds more digestible protein than they needed on Treatments II and III, respectively. Based on these values, the cows would have needed only 0.15 and 0.14 pounds of the 0.42 pounds of urea they were receiving per day on Treatments II and III, respectively. These calculations do not take into consideration the body weight gains made by the cows.

It should be noted that seven of the cows on each treatment were two years old; in calculating their maintenance requirements, additional protein was added to allow for growth. If the protein requirements had been based on mature cow maintenance, the animals would have been receiving enough nitrogen from natural sources without the addition of any urea.

CHAPTER V

EXPERIMENT II

Objective of Experiment

The objective of the study was to compare a concentrate supplemented with soybean meal with a concentrate that contained 3 percent urea (45 percent nitrogen) for lactating dairy cows fed corn silage as the only forage. A comparison of a concentrate that contained 3 percent urea with a concentrate that contained 3 percent urea and 0.45 percent sodium sulfate was also made.

Experimental Procedure

Thirty Holstein cows were used in a continuous-type feeding trial which lasted a total of 18 weeks. The selection of the cows for the experiment and the grouping of the cows into trios were the same as in Experiment I. The adjustment, standardization, and experimental periods were the same as in Experiment I. A three-week changeover period was used in this experiment to more gradually adjust the cows to the rations containing higher amounts of urea.

In Experiment II, one cow within each trio was placed on one of the following treatments: (I) Concentrate I, (II) Concentrate II, and (III) Concentrate III. The composition of the concentrates is shown in Table VI. All concentrates were fed twice daily in equal amounts.

Housing, feeding of forage, body weights, sampling and analyses of feed, sampling and analyses of milk, and feed allowance adjustments were the same as in Experiment I.

Table VI

Composition of Concentrates Fed in Experiment II

Components	Concentrate I[a]	II[b]	III[c]
	%		
Corn	49.0	68.0	67.6
Oats	24.5	24.2	24.2
Soybean Meal	24.5	2.6	2.6
Urea		3.0	3.0
Salt	1.0	1.0	1.0
Dicalcium Phosphate	1.0	1.0	1.0
Monosodium Phosphate		0.2	0.2
Sodium Sulfate			0.4

[a]Crude Protein = 18.90% as fed; Sulfur = 0.17% of dry matter.

[b]Crude Protein = 18.53% as fed; Sulfur = 0.15% of dry matter.

[c]Crude Protein = 18.99% as fed; Sulfur = 0.22% of dry matter.

Corn silage fed in the experiment contained 8.72 percent crude protein and 0.17 percent sulfur on a dry matter basis.

Sulfur was determined by Galbraith Microanalytical Laboratory, Knoxville, Tennessee.

Results and Discussion

The concentrates fed in this experiment were formulated to be isonitrogenous. However, as indicated in Table VI, the actual crude protein content was 18.90, 18.53, and 18.99 percent for Concentrates I, II, and III, respectively.

Table VII indicates the cost of the concentrates fed and the amount of nitrogen that was furnished by urea for the different treatments.

Individual data for the traits studied are presented in Appendix Tables XXX through XXXIII.

Adjusted means for actual milk production, milk fat percent, and FCM production are presented in Table VIII. No significant differences ($P>0.05$) in actual or FCM production were observed between the treatments. These results are in agreement with work reported by Rupel *et al*. (64). However, cows in the experiment by Rupel *et al*. (64) consumed only 0.30 pounds urea per cow per day and produced an average of 28.69 pounds of FCM per day. Cows on Treatment II and III of the present experiment consumed an average of 0.67 pounds of urea per cow per day and produced an average of 47.76 pounds of FCM per day.

Other researchers (1, 43) have observed no significant decreases in milk production when cows were fed concentrates that contained 3 percent urea. However, the cows in the present experiment produced

Table VII

Cost of Concentrates, Percentage Nitrogen Furnished by Urea, and Average Daily Urea Consumption Per Cow in Experiment II

	Treatment		
	I	II	III
% of Concentrate N Furnished by Urea	0	45.81	44.47
% of Total Dietary N Furnished by Urea	0	35.79	34.73
Average Lbs Urea Consumed/Cow/Day	0	0.67	0.66
Cost of Concentrate[a] Per Ton, Fall 1968	$61.99	$53.35	$53.56

[a]Ingredient costs are presented in Appendix Table XXV.

Table VIII

Daily Milk Production, Fat-Corrected-Milk Production, and Milk Fat Percent for Cows in Experiment II

	Adjusted Means		
Treatment	Actual Milk (lbs)	Milk Fat (%)	FCM (lbs)
I	52.42	3.32[a]	46.64
II	52.52	3.64[b]	47.73
III	50.60	3.60[b]	47.79

Values within columns with different superscripts are significantly different ($P<0.05$).

at higher levels and consumed more total urea per cow per day than did the cows in the earlier research (1, 43).

Loosli and Warner (48) reported that cows fed concentrates containing 3 percent urea produced as well as did cows fed concentrates supplemented with corn distillers dried grains or brewers dried grains. It should be noted, however, that cows on the present experiment consumed 0.16 pounds more urea per cow per day and produced an average of 8.0 pounds more FCM per cow per day than did the cows on the experiment by Loosli and Warner (48).

Huber et al. (34) reported that significant decreases in milk production were observed when urea furnished 21 to 23 percent of the total ration nitrogen. Cows on the experiment by Huber et al. (34) consumed an average of 0.40 pounds urea per cow per day. In the present experiment, urea furnished 35.79 and 34.73 percent of the total ration nitrogen and cows consumed an average of 0.67 and 0.66 pounds of urea per cow per day for Treatments II and III, respectively.

Adjusted mean milk fat percent for the cows on Treatments II and III were significantly higher ($P<0.05$) than the adjusted milk fat percent for cows on Treatment I. Other workers (14, 15) have observed higher, but not significant, milk fat percents for cows receiving concentrates containing 2.0 or 2.5 percent urea.

Data presented in Table IX indicate that mean values for percent milk protein and percent SNF were not significantly different ($P>0.05$) between the three treatments. Rupel et al. (64) observed no significant differences in percent milk protein or percent SNF when a concentrate containing 3 percent urea was fed.

Table IX

Mean Milk Constituents for Cows on Experiment II

Treatment	Mean Milk Constituents		
	Milk Fat	Protein	SNF
	%		
I	3.31[a]	3.55	9.26
II	3.65[b]	3.46	9.12
III	3.59[b]	3.49	9.21

Values within columns with different superscripts are significantly different ($P<0.05$).

Mean daily concentrate intakes were 24.13, 22.19, and 21.97 pounds, and mean daily silage intakes (as fed) were 38.91, 42.26, and 42.74 pounds for Treatments I, II, and III, respectively.

Mean daily dry matter intakes per 100 pounds of body weight and body weight changes for the three treatments are presented in Table X. Intake of silage and total dry matter intake per 100 pounds of body weight were not significantly different ($P>0.05$) between the three treatments. However, cows on Treatment I consumed significantly ($P<0.05$) more concentrate than did the cows on Treatments II and III. This difference in concentrate intake resulted from the cows on Treatments II and III refusing more of their daily allowances than did the cows on Treatment I. Loosli and Warner (48) reported that intake was not significantly different between cows being fed a concentrate containing 3 percent urea and a concentrate with natural protein sources. However, these workers (48) pointed out that the urea concentrate was less palatable and was consumed more slowly. It should be noted that the cows on Treatments II and III in the present experiment were consuming approximately 3.0 pounds more concentrate per cow per day than were the cows in the experiment by Loosli and Warner (48).

Body weight gains (Table X) were also significantly higher ($P<0.05$) for the cows on Treatment I as compared to Treatments II and III. This difference in body weight gain is probably the result of higher concentrate dry matter intake by the cows on Treatment I. Work by Virtanen (73) indicated that cattle maintained body weights and produced milk when fed rations in which urea furnished essentially

Table X

Mean Daily Dry Matter Intake and Body Weight Change for Cows in Experiment II

Treatment	Mean Daily DM Intake/100 Lbs B.W.			B.W.
	Concentrate	Silage	Total	Change/Day
	lbs			
I	1.74[a]	0.95	2.68	1.32[a]
II	1.52[b]	1.01	2.53	0.44[b]
III	1.47[b]	0.98	2.45	0.68[b]

Values within columns with different superscripts are significantly different ($P<0.05$).

all of the nitrogen. Briggs et al. (8) suggested that most differences in body weight change observed in cows being fed concentrates containing urea were results of decreased feed intake rather than inefficient utilization of urea.

Differences between Treatments II and III were studied to determine the affects of the addition of sodium sulfate to concentrates containing 3 percent urea. Concentrate II, fed in Treatment II, contained 3 percent urea; whereas, Concentrate III, fed in Treatment III, contained 3 percent urea and 0.4 percent sodium sulfate. Concentrate II contained 0.15 percent sulfur and Concentrate III contained 0.22 percent sulfur on a dry matter basis. The silage fed in both treatments contained 0.17 percent sulfur on a dry matter basis. The results indicated no significant differences ($P>0.05$) for treatment effects. Jacobson et al. (37) compared milk production in cows fed a low-sulfur (0.10 percent) concentrate containing 1 percent urea with production in cows fed the same concentrate supplemented with 0.9 percent sodium sulfate to give a total sulfur content of 0.18 percent. Corn silage fed by these workers contained 0.09 percent sulfur on a dry matter basis. Results (37) indicated a decreased milk production in the cows fed the low-sulfur concentrate.

Results of the present experiment indicated that the sulfur content of Concentrate II was sufficient to meet the cows' requirements. The addition of sodium sulfate to this concentrate did not appear to enhance utilization of urea.

Based on the NRC requirements (57), the cows in this experiment were consuming 0.75, 0.28, and 0.32 pounds more crude protein per cow per day than was needed for maintenance and production on Treatments I, II, and III, respectively. If these requirements are applicable and digestibility of crude protein is assumed to be the same as indicated by NRC, the cows on Treatments II and III would have needed only 0.57 and 0.54 pounds of the 0.67 and 0.66 pounds of urea per cow per day that they were receiving on the respective treatments. Here again, it should be noted that the cows were utilizing a portion of the urea that they were consuming to meet their requirements for protein.

The rations can also be evaluated according to the amount of milk protein produced by the cows. In this evaluation, the amount of protein required for maintenance was calculated from NRC requirements (57), and the amount of digestible protein required for production was considered to be 125 percent (56, 59) of the amount of milk protein produced. Assuming nitrogen digestibility to be 65 percent, the cows were receiving 0.37 and 0.49 pounds more digestible protein per day than they needed on Treatments II and III, respectively. Based on these calculations, the cows needed only 0.47 and 0.39 pounds of the 0.67 and 0.66 pounds of urea per day that they received on Treatments II and III, respectively.

CHAPTER VI

EXPERIMENT III

Objective of Experiment

The objective of this study was to compare a concentrate supplemented with soybean meal with a concentrate that contained 3 percent urea for cows fed corn silage as the only forage. A study was also conducted comparing concentrates containing urea with and without phosphate supplementation.

Experimental Procedure

Twenty-seven Holstein cows were used in a continuous-type feeding trial. The selection of cows, trio grouping, and experimental design were the same as in Experiment I.

One cow within each trio was assigned at random to one of the following treatments: (I) Concentrate I, (II) Concentrate II, (III) Concentrate III. The composition of the concentrates is shown in Table XI. All concentrates were fed twice daily in equal amounts.

Housing, feeding of forage, concentrate allowance adjustments, body weights, sampling and analyses of feeds, and sampling of milk were the same as in Experiment I. Milk samples were analyzed for milk fat.

Blood samples were taken every two weeks during the experimental period. Twenty milliliters of blood were collected approximately three and one-half to four and one-half hours post-feeding. The blood samples were analyzed for blood urea nitrogen.

Table XI

Composition of Concentrates Fed in Experiment III

Components	Concentrate I[a]	Concentrate II[b]	Concentrate III[c]
	%	%	%
Corn	49.00	68.00	68.80
Oats	24.50	24.20	24.50
Soybean Meal	24.50	2.60	2.70
Urea		3.00	3.00
Trace Mineralized Salt	1.00	1.00	1.00
Dicalcium Phosphate	1.00	1.00	
Monosodium Phosphate		0.20	

[a]Crude Protein = 20.65% as fed.

[b]Crude Protein = 18.99% as fed.

[c]Crude Protein = 20.98% as fed.

Samples of rumen content were taken every two weeks three and one-half to four and one-half hours post-feeding and pH was immediately determined.

Silage fed in this experiment contained 10.03 percent crude protein on a dry matter basis.

Results and Discussion

The concentrates fed in this experiment were formulated to be isonitrogenous. However, as indicated in Table XI, the actual crude protein content was 20.65, 18.99, and 20.98 percent for Concentrates I, II, and III, respectively. Costs of the concentrates fed are presented in Table XII.

The percent of the concentrate nitrogen and the total dietary nitrogen furnished by urea for the treatments in this experiment are presented in Table XII.

The percent of the concentrate nitrogen and the total dietary nitrogen furnished by urea for the treatments in this experiment are presented in Table XII.

Individual data for the traits studied are presented in Appendix Tables XXXIV through XXXVII.

As indicated in Table XIII, the adjusted treatment means for actual milk production, milk fat percent, and FCM production were not significantly affected (P>0.05) by the substitution of 3 percent urea to replace natural protein in a concentrate mixture. In Experiment III, no significant differences were observed between milk fat percent. However, it should be pointed out that cows on Treatments II and III

Table XII

Cost of Concentrates, Percentage Nitrogen Furnished by Urea, and Average Daily Urea Consumption Per Cow in Experiment III

	Treatment		
	I	II	III
% of Concentrate N Furnished by Urea	0	44.68	40.14
% of Total Dietary N Furnished by Urea	0	33.01	30.21
Average Lbs Urea Consumed/Cow/Day	0	0.69	0.69
Cost of Concentrate[a] Per Ton, Fall 1969	$63.95	$55.39	$53.19

[a]Ingredient costs are presented in Appendix Table XXV.

Table XIII

Daily Milk Production, Fat-Corrected-Milk Production, and Milk Fat Percent for Cows in Experiment III

	Adjusted Means		
Treatment	Actual Milk (lbs)	Milk Fat (%)	FCM (lbs)
I	47.21	3.50	43.46
II	43.22	3.60	40.21
III	47.65	3.69	45.67

(concentrates contained 3 percent urea) did have higher milk fat percentages than did the cows on Treatment I (concentrate contained no urea).

Data presented in Table XIV indicate that there were no significant differences ($P>0.05$) between treatments in pH of the rumen fluid or blood urea nitrogen levels. Work by Van Horn et al. (71) indicated that cows fed rations which contained urea had significantly higher ($P<0.01$) blood urea nitrogen levels than did cows fed a natural protein source. The cows on the experiment (71) consumed 0.39 pounds of urea per cow per day; in the present experiment, the cows fed rations containing urea consumed 0.69 pounds urea per cow per day. Polan et al. (60) reported significant increases in blood urea nitrogen levels four to five hours post-feeding when urea furnished 25.2, 26.8, or 38.0 percent of the total dietary nitrogen; samples were taken in the present experiment three and one-half to four and one-half hours post-feeding. Work by Moller (54) indicated that urea-induced changes in blood urea levels occur after the first one and one-half hours post-feeding and return to normal after five to seven hours.

Mean daily concentrate intakes were 23.19, 22.87, and 23.04 pounds, and mean daily silage intakes (as fed) were 47.70, 46.73, and 49.86 pounds for Treatments I, II, and III, respectively.

Dry matter intakes per 100 pounds body weight and body weight changes are presented in Table XV. No significant differences ($P>0.05$) were observed in body weight changes, concentrate intake, silage intake, or total dry matter intake between the treatments. Work by Rupel et al. (64) and Loosli and Warner (48) indicated that consumption of

Table XIV

Rumen Fluid pH and Blood Urea Nitrogen Levels of Cows
in Experiment III

Treatment	Rumen Fluid pH	Blood Urea N mgs/100 mls
I	6.36	20.07
II	6.24	20.92
III	6.33	20.74

Table XV

Mean Daily Dry Matter Intake and Body Weight Change for Cows in Experiment III

Treatment	Mean Daily DM Intake/100 Lbs B.W. Concentrate	Silage	Total	B.W. Change/Day
	lbs			
I	1.45	1.09	2.55	1.19
II	1.51	1.13	2.64	0.89
III	1.49	1.18	2.67	1.15

concentrates containing 3 percent urea was equal to consumption of concentrates containing no urea. However, Loosli and Warner (48) pointed out that the concentrates which contained 3 percent urea were consumed more slowly.

Differences between Treatments II and III were studied to determine the effects of the addition of dicalcium phosphate and monosodium phosphate to concentrates containing 3 percent urea. Concentrate II, fed in Treatment II, contained 3 percent urea plus 1 percent dicalcium phosphate and 0.2 percent monosodium phosphate. Concentrate III, fed in Treatment III, contained 3 percent urea with no phosphate supplements.

No significant differences (P>0.05) between Treatments II and III were observed for the traits studied. These results suggest that Concentrate III, which contained 3 percent urea and no phosphate supplements, was sufficiently high in phosphate content for efficient utilization of the ration.

The natural protein sources fed in this experiment furnished all but 0.17 and 0.34 pounds of the NRC (57) protein equivalent requirements of the cows on Treatments II and III, respectively. These data indicate that only 0.05 and 0.12 pounds of urea were needed to meet the protein equivalent requirements for cows on Treatments II and III, respectively. A negative control, as a fourth treatment, would have been beneficial in evaluating the rations fed in Treatments II and III.

CHAPTER VII

EXPERIMENT IV

Objective of Experiment

The main objective of the study was to compare the utilization of urea fed with and without monosodium phosphate for dairy heifers fed corn silage as the only forage. During the last week of the experiment, digestibility and nitrogen balances were determined.

Experimental Procedure

Sixteen non-pregnant Holstein heifers were used in a continuous feeding trial. The average weight of the animals was 567 pounds. Animals were assigned to groups of four based on age and weight. The heifers within each group were assigned to treatments at random. A one-week adjustment period preceded a five-week experimental period. During the adjustment period, the animals that were to receive the concentrates containing urea were gradually switched to these concentrates.

The animals were housed in a stanchion-type barn equipped for obtaining individual feed weights on all forages and concentrates fed.

One animal within each group was on one of the following treatments: (I) six pounds of Concentrate I per day, (II) six pounds of Concentrate II per day, (III) six pounds of Concentrate III per day, and (IV) six pounds of Concentrate IV per day. Equal amounts of the concentrates were fed twice per day. The composition of the concentrates is presented in Table XVI. All of the heifers

Table XVI

Composition of Concentrates Fed in Experiment IV

Components	Concentrate			
	I[a]	II[b]	III[c]	IV[d]
	%			
Corn	98.00	87.00	96.70	96.50
Salt	1.00	1.00	1.00	1.00
Dicalcium Phosphate	1.00	1.00	1.00	1.00
Cottonseed Meal		11.00		
Urea			1.30	1.30
Monosodium Phosphate				0.20

[a]Crude Protein = 9.43% as fed.

[b]Crude Protein = 13.92% as fed.

[c]Crude Protein = 13.60% as fed.

[d]Crude Protein = 14.02% as fed.

were fed corn silage twice daily *ad libitum*. The corn silage fed in the experiment contained 9.94 percent CP on a dry matter basis.

Body weights were taken for three consecutive days at the end of each two-week period. Individual feed weights of the ration fed and refused were recorded daily.

During the experimental period, samples of rumen content were taken once per week at two, four, and six hours post-feeding and analyzed for volatile fatty acids.

During the last week of the experimental period, nitrogen balances were determined on all of the animals. Total collection of feces and urine was made, and representative samples of urine were preserved with hydrochloric acid. Representative samples of feces were frozen and stored. Dry matter was determined on each animal's feces each day during the collection period. Nitrogen in the feces and urine was determined by the Kjeldahl method (2).

Daily gains and the amount of nitrogen retained per pound of gain were calculated from gains made during the last two weeks of the experiment.

Results and Discussion

Individual data for the traits studied are presented in Appendix Tables XXXVIII and XXXIX.

As is indicated in Table XVII, dry-matter digestibility and acid-detergent-fiber digestibility were not significantly ($P>0.10$) different between the four treatments. These results do not agree with work reported by Huber *et al*. (34). These researchers (34)

Table XVII

Digestibility of Dry Matter, Nitrogen, and Acid Detergent Fiber; Dry Matter Intake and Gain Per Day in Experiment IV

Treatment	Digestibilities: Dry Matter	Nitrogen	Acid Detergent Fiber	DM Intake for 100 Lbs B.W.	B.W. Gain/Day
	%			lbs	
I	64.57	48.57[a]	46.95	2.38	1.88
II	61.16	53.79[ab]	48.97	2.34	1.65
III	63.49	54.84[b]	47.39	2.43	2.04
IV	63.30	57.60[b]	50.31	2.46	1.96

Values within columns with different superscripts are significantly different ($P<0.10$).

reported that the apparent digestibility of dry matter and crude fiber was significantly lower for cows fed rations containing 1.1 and 2.2 percent urea when compared to cows fed rations containing no urea. However, Polan et al. (60) noted no significant differences in digestibility of dry matter and crude fiber between treatments when corn silage, supplemented with 0, 0.60, and 0.85 percent urea, was fed to lactating cows.

Nitrogen digestibility was not significantly different (P>0.10) for rations fed in Treatments II, III, and IV. However, there was a significant decrease in nitrogen digestibility in the animals on Treatment I. These results are best explained by total nitrogen intake as shown in Table XVIII. The cows on Treatment I were consuming less total nitrogen per day than were the cows on Treatments II, III, and IV. Nitrogen digestibilities for Treatments I and II were not significantly different. Here, again, total nitrogen intake may account for the results obtained.

Mean daily silage intakes were 28.05, 26.36, 28.23, and 30.42 pounds for Treatments I, II, III, and IV, respectively.

Dry matter intakes per 100 pounds body weight were not significantly different (P>0.10) between the four treatments. Loosli and Warner (48) reported similar results. Their research indicated that concentrates containing 2 percent or less urea were readily consumed by cows.

Nitrogen balance data are presented in Table XVIII. These data indicate that there were no significant differences (P>0.10) in the percent of total nitrogen consumed that was excreted in the feces or

Table XVIII

Nitrogen Balance Data

Treatment	Nitrogen Intake/Day (g)	Total Nitrogen Intake: Excreted In Feces	Total Nitrogen Intake: Excreted In Urine	Total Nitrogen Intake: Retained In Body	Nitrogen Balance Average/Day	Nitrogen Retained/Lb Gain
		%			g	
I	109.91[a]	57.43[a]	34.63[a]	13.94[a]	15.54[a]	9.12
II	123.73[b]	46.21[ab]	35.69[a]	18.10[ab]	22.28[ab]	13.80
III	127.30[b]	45.17[b]	30.78[b]	24.06[b]	30.72[b]	21.53
IV	134.05[b]	42.41[b]	33.60[ab]	24.00[b]	32.32[b]	19.17

Values within columns with different superscripts are significantly different ($P<0.10$).

the percent of total nitrogen intake that was retained in the body between Treatments II, III, and IV. Treatment differences for these traits were not significant between Treatments I and II. These results can best be explained by the total nitrogen intake (Table XVIII) and nitrogen digestibilities (Table XVII, page 59) of the rations fed in the four treatments. Work by Van Horn _et al_. (71) indicated that nitrogen digestibility was essentially the same in cows receiving the same amount of total nitrogen from either a control or urea-supplemented ration. Polan _et al_. (60) attributed lower nitrogen digestibility of concentrates containing urea to lower total nitrogen intake for the animals consuming the urea concentrates. In the present experiment, nitrogen intake and digestibility were directly related to the grams of nitrogen retained per pound of gain and to the percent of total nitrogen consumed that was retained in the body.

Data presented in Table XVII indicate that average daily gains or grams of nitrogen retained per pound of gain were not significantly different ($P>0.10$) between the four treatments.

Based on NRC requirements (57), calves weighing 567 pounds need 0.89 pounds of digestible protein per day to gain 1.43 pounds. Calves in the present experiment were gaining 1.88, 1.65, 2.04, and 1.96 pounds per day on Treatments I, II, III, and IV, respectively. Based on nitrogen digestibility and nitrogen intake, the animals were receiving 0.74, 0.92, 0.96, and 1.06 pounds of digestible protein per day for Treatments I, II, III, and IV, respectively. These data suggest that the animals on Treatment I were not receiving enough digestible protein per day to meet the NRC requirements.

However, it should be noted that all of the animals were gaining at a rate exceeding 1.43 pounds per day.

As indicated in Table XVIII, page 61, all of the animals in this experiment were in positive nitrogen balance. However, the animals fed the concentrates containing urea had higher nitrogen retentions than did the animals fed the unsupplemented concentrate. These results are in agreement with work reported by Van Horn et al. (71). However, Polan et al. (60) reported negative nitrogen balances for animals fed corn silage which contained 0.60 and 0.85 percent urea.

The percent of nitrogen intake that was excreted in the urine was significantly less ($P<0.10$) for the animals in Treatment III than for the animals on Treatments I and II. No significant differences were observed for this trait between Treatments I, II, and IV. These results differ from the results of Polan et al. (60), which indicated that percent nitrogen excreted in the urine increased significantly when corn silage containing 0.85 percent urea was fed.

Treatment means for the volatile fatty acids in rumen fluid are presented in Table XIX. Results indicate no significant differences ($P>0.10$) between the four treatments in total volatile fatty acid production. At four hours post-feeding, percent acetic acid of total VFA's was significantly lower for Treatment III than for Treatments I or IV. At six hours post-feeding, butyric acid was significantly higher for Treatment III than for Treatments I or IV.

Results of the experiment indicate that the addition of 0.2 percent monosodium phosphate to a concentrate containing 1.3 percent urea had no significant effect on nitrogen digestibility, grams of

Table XIX

Rumen Fluid Volatile Fatty Acid Data

Rumen Fluid VFA	Concentrate			
	I	II	III	IV
Total mgs/100 mls				
2 hr post-feeding	711.84	698.88	695.08	744.07
4 hr post-feeding	681.46	729.45	765.32	764.52
6 hr post-feeding	681.37	716.89	644.00	710.72
Acetic (% of total)				
2 hr post-feeding	65.23	64.38	62.78	64.25
4 hr post-feeding	64.11^{a}	60.12^{b}	58.06^{b}	65.11^{a}
6 hr post-feeding	64.87	63.07	62.36	65.79
Propionic (% of total)				
2 hrs post-feeding	19.84	20.90	22.09	21.67
4 hrs post-feeding	21.90	24.48	25.03	20.88
6 hrs post-feeding	20.21	19.93	19.79	20.03
Butyric (% of total)				
2 hrs post-feeding	12.24	11.31	11.91	11.52
4 hrs post-feeding	11.46	12.16	14.01	12.08
6 hrs post-feeding	12.17^{a}	14.51^{bc}	15.05^{c}	12.93^{ab}

Values within rows with different superscripts are significantly different ($P<0.05$).

nitrogen retained per pound of gain, or the percent of the nitrogen intake that was retained in the body or excreted in the feces or urine.

CHAPTER VIII

EXPERIMENT V

Objective of Experiment

The main objective of this investigation was to study the effect of mineral supplements and ingredient components on palatability of concentrates containing urea. Five trials were conducted in the experiment.

Experimental Procedure

Sixteen non-pregnant Holstein heifers were used for the experiment. The animals were housed in loose housing with facilities equipped for individual feeding of concentrates. For the entire experiment, all heifers were fed 15 pounds per heifer per day of a soybean-pearl millet hay. The offering of hay was limited to ensure consumption of the concentrate.

A four-week adjustment period preceded a five-week experimental period. Five one-week trials were conducted during the experimental period.

In Trials I, II, and III, four concentrates were studied. The composition of these four concentrates is presented in Table XX. For these three trials, the animals were equally divided according to age and weight into two groups.

During the adjustment period, animals in Group I were fed Concentrate I and animals in Group II were fed Concentrate II. The first three trials for Groups I and II were conducted as follows:

Table XX

Composition of Concentrates Fed in Trials I, II, and III of Experiment V

Components	Concentrate I	II	III	IV
	%			
Corn	96.0	94.8	95.8	95.0
Salt	1.0	1.0	1.0	1.0
Urea	3.0	3.0	3.0	3.0
Dicalcium Phosphate		1.0		1.0
Monosodium Phosphate		0.2	0.2	

Group I:

Weeks 1-4	Adjustment to Concentrate I
Week 5	Offered a choice of Concentrate I or II
Week 6	Offered a choice of Concentrate I or III
Week 7	Offered a choice of Concentrate I or IV

Group II:

Weeks 1-4	Adjustment to Concentrate II
Week 5	Offered a choice of Concentrate II or I
Week 6	Offered a choice of Concentrate II or III
Week 7	Offered a choice of Concentrate II or IV.

Animals were allowed freedom of the loose housing except during feeding of the concentrates. When concentrates were being fed, the animals were tied for 30 minutes in individual stanchions. Weights of refused concentrates were taken immediately.

The animals were fed in special boxes which were 36 inches by 24 inches. The boxes were divided down the center to form two 18 inch by 24 inch portions. During the adjustment period, five pounds of the concentrate the animal was being adjusted to was placed in each portion of the box. During the experimental period, five pounds of the concentrate the animal had been adjusted to was placed in one portion of the box, and five pounds of the concentrate being studied in that trial was placed in the other portion of the box. The positions of the concentrates were switched each day to prevent the animals from eating due to location.

In Trials IV and V, four concentrates were used. The composition of these concentrates is presented in Table XXI. In these two

Table XXI

Composition of Concentrates Fed in Trials IV and V of Experiment V

Components	Concentrate			
	V	VI	VII	VIII
	%			
Corn	99.0	96.0	74.0	71.0
Salt	1.0	1.0	1.0	1.0
Oats			25.0	25.0
Urea		3.0		3.0

trials, the 16 animals were used as one group. In Trial IV, the animals were offered a choice of Concentrate V or VI for a one-week period. In Trial V, the animals were offered a choice of Concentrate VII or VIII for a one-week period.

Individual records of the amounts of each concentrate that was consumed during the 30-minute feeding period were recorded.

Results and Discussion

Individual data for the five trials are presented in Appendix Tables XL through XLII.

The results of Trials I, II, and III presented in Table XXII indicate that the animals in Group I (adjusted to Concentrate I) preferred Concentrate I over Concentrate II or IV. There was no significant difference ($P>0.10$) in the preference of Concentrate I or III for animals in Group I. As is indicated in Table XXIII, the animals in Group II (adjusted to Concentrate II), preferred Concentrate I over Concentrate II, and preferred Concentrate II over either Concentrate III or IV.

Overall results of Trials I, II, and III indicate that the animals preferred Concentrate I, which contained no dicalcium phosphate, over Concentrates II and IV, which contained dicalcium phosphate. No preference was observed between Concentrate I and Concentrate III (III contained 0.2 percent monosodium phosphate).

Results of Trials IV and V, presented in Table XXIV, indicate that the animals in both trials preferred the concentrates which contained no urea (Concentrates V and VII). It should be

Table XXII

Mean Daily Concentrate Intake of Animals in Group I

Trial	Concentrate I	Concentrate II	Concentrate III	Concentrate IV
	lbs			
I	2.54^{a}	1.10^{b}		
II	1.53		1.12	
III	1.77^{a}			1.17^{b}

Values within rows with different superscripts are significantly different ($P<0.10$).

Table XXIII

Mean Daily Concentrate Intake of Animals in Group II

Trial	Concentrate I	II	III	IV
	lbs			
I	3.34[a]	0.32[b]		
II		2.08[a]	0.96[b]	
III		2.42[a]		1.86[b]

Values within rows with different superscripts are significantly different (P<0.10).

Table XXIV

Mean Daily Concentrate Intake of Animals in Trials IV and V

Trial	Concentrate			
	V	VI	VII	VIII
	lbs			
IV	4.11[a]	1.34[b]		
V			4.13[a]	1.15[b]

Values within rows with different superscripts are significantly different ($P<0.05$).

pointed out that these animals had been consuming concentrates that contained 3 percent urea for a period of seven weeks and were, therefore, well adapted to concentrates containing urea.

Oats were added to the concentrates fed in Trial V to ascertain if the oats would aid in overcoming the palatability problem often encountered when urea is added to the concentrate. Results indicated that the animals preferred the concentrate containing oats and corn over the concentrate containing oats, corn, and urea. A comparison between concentrates containing corn and urea or corn, oats, and urea was not studied. If this comparison had been studied, a better evaluation of the ability of oats to aid in the alleviation of palatability problems with concentrates containing urea could have been made.

CHAPTER IX

SUMMARY

1. Ration intake, body weight changes, milk production, milk protein, and milk SNF were not significantly different (P>0.10) in cows fed corn silage plus a concentrate containing 0 or 2 percent urea (45 percent nitrogen). The urea furnished 26.42 percent of the concentrate nitrogen and 21.61 percent of the total dietary nitrogen.

2. Milk fat percent was significantly higher (P<0.10) for cows fed a concentrate which contained 2 percent urea as compared to a concentrate which contained no urea.

3. Milk production, milk protein, milk SNF, percent milk fat, dry matter intake, and body weight changes were not significantly different (P>0.10) in cows fed corn silage plus a concentrate which contained 2 percent urea fed twice a day versus six times a day.

4. Silage intake, total dry matter intake, milk production, milk protein, and milk SNF were not significantly different (P>0.05) in cows fed corn silage plus a concentrate that contained 0 or 3 percent urea. In the urea treatment, urea furnished an average of 45 percent of the concentrate nitrogen and 35.26 percent of the total dietary nitrogen.

5. Percent milk fat was significantly higher (P<0.05) in two groups of cows fed concentrates that contained 3 percent urea than in cows fed a concentrate that contained no urea.

6. Concentrate intake per 100 pounds body weight and body weight change per day were significantly less (P<0.05) in cows

fed a concentrate that contained 3 percent urea as compared with a concentrate that contained no urea.

7. The addition of 0.4 percent sodium sulfate to a concentrate that contained 3 percent urea did not appear to improve the utilization of the urea. However, it should be pointed out that the level of sulfur was 0.15 percent on a dry matter basis before the addition of the sodium sulfate.

8. Milk production, milk fat percent, rumen fluid pH, blood urea nitrogen level, dry matter intake, and body weight changes were not significantly different ($P>0.05$) in cows fed concentrates that contained 3 percent urea with or without sodium sulfate supplementation.

9. Milk production, milk fat percent, rumen fluid pH, blood urea nitrogen level, dry matter intake, and body weight changes were not significantly different ($P>0.05$) in cows fed corn silage plus concentrate that contained no urea, 3 percent urea with phosphate supplementation, or 3 percent urea without phosphate supplementation. However, according to NRC requirements, the cows on this experiment were consuming more protein than was needed for maintenance and production. For a more valid evaluation of the rations, a negative control treatment would have been beneficial.

10. Results of the first three experiments indicate that urea can be fed at levels up to 3 percent to lactating dairy cows fed corn silage as the only forage without causing a significant decrease in milk production. In two of the three experiments, the

inclusion of urea in the concentrate resulted in significantly higher milk fat percent.

11. The inclusion of 0.4 percent sodium sulfate in a concentrate that contained 3 percent urea and 0.15 percent sulfur on a dry matter basis did not appear to be beneficial for urea utilization.

12. The addition of 1 percent dicalcium phosphate and 0.2 percent monosodium phosphate to a concentrate that contained 3 percent urea did not appear to improve the utilization of the urea. However, it should be pointed out that the phosphate sources may be needed for purposes other than the utilization of urea.

13. Dry matter intake per 100 pounds body weight, pounds of gain per day, dry-matter digestibility, and acid-detergent-fiber digestibility were not significantly different ($P>0.10$) in dairy heifers fed corn silage plus a concentrate that contained either 0 or 1.3 percent urea.

14. Nitrogen digestibility was directly related to the nitrogen intake of animals consuming concentrates that contained either 0 or 1.3 percent urea.

15. The percent of the total nitrogen intake that was retained in the body was directly related to nitrogen intake and digestibility.

16. Nitrogen retention values (grams per day) were positive for the animals fed the negative control as well as the animals fed the concentrates that contained urea. However, the animals on the concentrate that contained 1.3 percent urea had higher nitrogen retention values than did the animals consuming the negative control concentrate.

17. The grams of nitrogen retained per pound of gain were directly related to total nitrogen intake and nitrogen digestibility.

18. The addition of 0.2 percent monosodium phosphate to a concentrate that contained 1.3 percent urea did not appear to improve the utilization of the urea.

19. Animals preferred a concentrate that contained 3 percent urea with no phosphate supplements over concentrates that contained 3 percent urea supplemented with either 1 percent dicalcium phosphate or 1 percent dicalcium phosphate and 0.2 percent monosodium phosphate.

20. If animals were adjusted to a concentrate that contained 3 percent urea supplemented with 1 percent dicalcium phosphate and 0.2 percent monosodium phosphate, they preferred the concentrate with both of the phosphate supplements over concentrates that contained only one of the phosphate supplements.

21. Animals preferred concentrates that contained no urea over concentrates that contained 3 percent urea. However, it should be pointed out that if the animals were offered only the concentrates that contained urea, they did consume these concentrates, but at a slower rate.

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APPENDIX

Table XXV

Cost of Concentrate Ingredients

Ingredient	1967-68	1968-69	1969-70
		$/lb	
Corn	0.024	0.024	0.025
Oats	0.028	0.028	0.027
Urea	0.047	0.040	0.040
Soybean Meal	0.045	0.047	0.050
Monosodium Phosphate	0.151	0.151	0.151
Sodium Sulfate	0.044	0.044	0.044
Dicalcium Phosphate	0.063	0.063	0.063
Trace Mineralized Salt	0.023	0.023	0.023

Table XXVI

Individual Daily Milk Production, Fat-Corrected-Milk Production, and Milk Fat Percent for Cows in Experiment I Standardization Period

Treatment	Animal	Actual Milk (lbs)	Milk Fat (%)	FCM (lbs)
I	353	57.58	3.70	54.99
	346	58.46	3.15	51.01
	339	54.86	3.40	49.94
	328	48.72	3.30	43.64
	366	49.39	3.20	43.46
	64	61.97	3.20	54.53
	305	68.94	3.40	62.74
	379	54.10	3.40	49.24
	383	51.15	3.30	45.79
	Mean	56.13	3.34	50.59
II	374	59.73	3.45	54.81
	342	63.91	2.80	52.41
	336	50.27	3.45	46.13
	364	49.84	3.20	43.87
	367	47.26	3.35	42.66
	309	58.12	3.65	55.07
	116	62.67	3.50	58.90
	381	50.41	4.20	52.33
	380	53.16	3.10	45.99
	Mean	55.04	3.41	50.24
III	357	62.34	3.55	58.13
	347	59.19	3.30	52.99
	363	52.35	3.45	48.03
	388	50.48	3.25	44.80
	376	49.68	3.15	43.34
	297	53.52	3.70	51.11
	175	69.76	3.60	65.57
	385	49.36	4.10	50.44
	370	54.72	2.90	46.10
	Mean	55.71	3.44	51.17

Table XXVII

Individual Daily Milk Production, Fat-Corrected-Milk Production, and Milk Fat Percent for Cows in Experiment I Experimental Period

Treatment	Animal	Actual Milk (lbs)	Milk Fat (%)	FCM (lbs)
I	353	49.60	3.53	46.06
	346	54.27	3.15	47.36
	339	52.01	2.29	38.76
	328	42.65	3.34	38.44
	366	40.55	3.27	36.23
	64	57.21	2.77	42.89
	305	61.09	3.48	56.26
	379	54.36	3.14	47.29
	383	40.27	2.52	31.26
	Mean	50.22	3.05	42.73
II	374	55.91	3.55	52.14
	342	59.82	3.00	50.79
	336	47.36	3.55	44.15
	364	43.49	3.54	40.44
	367	43.57	3.73	41.69
	309	47.42	3.88	46.55
	116	47.58	3.53	43.99
	381	56.01	2.89	46.71
	380	49.47	3.04	45.01
	Mean	50.07	3.45	45.72
III	357	58.68	3.10	50.77
	347	51.06	3.22	45.43
	363	47.35	3.03	41.83
	388	43.81	3.05	37.68
	376	41.81	3.37	38.18
	297	48.16	3.20	42.38
	175	43.33	3.38	39.28
	385	56.60	3.52	52.57
	370	49.41	2.99	41.90
	Mean	48.91	3.21	43.34

Table XXVIII

Individual Mean Milk Constituents for Cows on Experiment I

Treatment	Animal	Mean Milk Constituents Protein	SNF
		%	
I	353	3.34	8.98
	346	3.40	8.97
	339	3.39	8.90
	328	3.43	9.03
	366	3.60	9.11
	64	3.45	8.48
	305	3.21	9.19
	379	3.40	9.43
	383	3.50	9.72
	Mean	3.41	9.09
II	374	3.51	8.70
	342	3.07	8.92
	336	3.45	9.09
	364	3.33	8.78
	367	3.58	9.56
	309	3.54	9.01
	116	3.39	9.31
	381	3.02	8.93
	380	3.23	9.04
	Mean	3.35	9.04
III	357	3.19	8.85
	347	3.45	9.40
	363	3.53	9.77
	388	3.33	9.30
	376	3.56	9.11
	297	3.29	9.20
	175	3.31	8.85
	385	3.10	9.14
	370	3.09	8.62
	Mean	3.32	9.14

Table XXIX

Individual Daily Dry Matter Intake and Body Weight Change for Cows in Experiment I

Treatment	Animal	Mean Daily DM Intake/100 Lbs B.W. Concentrate	Silage	Total	B.W. Change/Day
		lbs			
I	353	1.66	1.15	2.81	0.69
	346	1.69	1.07	2.76	1.42
	339	1.72	0.73	2.45	1.21
	328	1.06	0.98	2.04	2.05
	366	1.46	0.69	2.15	2.11
	64	1.44	0.80	2.24	0.49
	305	1.57	0.82	2.39	1.10
	379	2.34	0.74	3.08	0.45
	383	1.44	0.70	2.14	0.96
	Mean	1.60	0.85	2.45	1.16
II	374	1.96	0.91	2.87	1.04
	342	1.41	0.85	2.26	0.76
	336	1.31	1.49	2.80	1.68
	364	1.47	0.96	2.43	1.60
	367	1.41	0.92	2.33	2.00
	309	1.41	1.16	2.57	1.13
	116	1.39	0.94	2.33	-0.25
	381	1.22	0.76	1.98	0.64
	380	1.49	0.76	2.25	1.57
	Mean	1.45	0.97	2.42	1.13
III	357	1.83	1.32	3.15	1.20
	347	1.37	0.87	2.24	1.63
	363	1.69	0.89	2.58	1.31
	388	1.47	0.59	2.06	1.65
	376	1.54	0.79	2.33	1.81
	297	1.37	0.93	2.30	0.98
	175	1.59	1.18	2.77	0.80
	385	2.34	1.07	3.41	0.54
	370	1.46	0.64	2.10	1.69
	Mean	1.63	0.92	2.55	1.29

Table XXX

Individual Daily Milk Production, Fat-Corrected-Milk Production, and Milk Fat Percent for Cows in Experiment II Standardization Period

Treatment	Animal	Actual Milk (lbs)	Milk Fat (%)	FCM (lbs)
I	325	72.76	3.60	68.39
	371	69.94	3.00	59.45
	367	63.89	3.20	56.22
	309	53.28	3.40	48.48
	388	58.56	2.70	47.14
	423	49.01	3.60	46.07
	329	82.56	3.90	81.21
	276	70.71	3.60	65.94
	394	63.66	3.60	59.84
	439	53.18	2.30	39.21
	Mean	63.76	3.29	57.20
II	301	77.66	3.20	68.34
	342	74.19	2.90	61.95
	363	64.98	2.80	53.28
	387	47.81	4.10	48.53
	357	58.83	2.60	46.48
	427	51.21	3.70	48.91
	266	74.76	4.00	74.19
	305	82.89	2.80	67.97
	59	64.55	3.20	56.33
	362	46.29	3.90	45.24
	Mean	64.32	3.32	57.12
III	346	76.96	3.00	65.42
	312	70.93	3.40	64.55
	376	59.45	3.30	53.21
	328	53.28	3.60	50.08
	383	53.34	2.80	43.74
	401	53.50	3.60	50.29
	302	83.29	3.10	71.41
	236	73.85	3.60	69.44
	326	64.32	2.90	53.24
	408	51.91	3.60	48.79
	Mean	64.08	3.29	57.02

Table XXXI

Individual Daily Milk Production, Fat-Corrected-Milk Production, and Milk Fat Percent for Cows in Experiment II Experimental Period

Treatment	Animal	Actual Milk (lbs)	Milk Fat (%)	FCM (lbs)
I	325	62.09	3.30	55.95
	371	60.70	3.20	53.86
	367	48.30	3.30	43.50
	309	31.50	3.70	30.51
	388	55.10	2.80	46.22
	423	41.30	4.10	41.67
	329	63.10	3.70	59.83
	276	56.60	3.50	52.53
	394	48.20	3.30	42.67
	439	54.10	2.20	39.96
	Mean	52.10	3.31	46.67
II	301	67.30	3.40	61.30
	342	60.40	3.10	52.08
	363	51.90	3.50	47.96
	387	31.40	4.20	32.49
	357	49.20	3.40	45.57
	427	63.80	3.60	40.05
	266	52.40	4.20	54.78
	305	65.90	3.50	60.36
	59	46.30	3.80	44.80
	362	39.50	3.80	37.99
	Mean	52.81	3.65	47.74
III	346	63.56	3.40	58.15
	312	59.50	3.50	59.44
	376	37.90	3.90	37.38
	328	43.20	3.60	40.61
	383	45.30	3.40	40.94
	401	45.70	3.90	45.14
	302	57.20	3.20	50.44
	236	54.80	3.60	51.03
	326	55.70	3.50	51.71
	408	43.50	3.90	42.67
	Mean	50.64	3.59	47.75

Table XXXII

Individual Mean Milk Constituents for Cows on Experiment II

Treatment	Animal	Mean Milk Constituents	
		Protein	SNF
		%	
I	325	3.44	9.21
	371	3.48	9.29
	367	3.66	9.51
	309	3.76	9.48
	388	3.61	9.79
	423	3.65	8.89
	329	3.62	9.06
	276	3.42	8.88
	394	3.44	8.91
	439	3.43	9.86
	Mean	3.55	9.29
II	301	3.14	8.76
	342	3.22	8.91
	363	3.64	9.54
	387	3.80	9.49
	357	3.39	8.82
	427	3.65	9.45
	266	3.50	9.16
	305	3.14	8.87
	59	3.67	8.96
	362	3.49	9.29
	Mean	3.46	9.13
III	346	3.33	9.04
	312	3.71	9.56
	376	3.78	9.36
	328	3.65	9.36
	383	3.51	9.03
	401	3.58	9.53
	302	3.03	8.41
	236	3.41	9.22
	326	3.38	8.69
	408	3.48	9.61
	Mean	3.49	9.18

Table XXXIII

Individual Daily Dry Matter Intake and Body Weight Change for Cows in Experiment II

Treatment	Animal	Mean Daily DM Intake/100 Lbs B.W. Concentrate	Silage	Total	B.W. Change/Day
		lbs			
I	325	1.66	0.90	2.56	0.61
	371	2.33	1.15	3.48	1.02
	367	1.37	0.69	2.06	2.01
	309	1.14	1.21	2.35	2.38
	388	1.65	0.73	2.38	2.25
	423	1.81	1.11	2.92	1.48
	329	2.28	1.26	3.54	-0.42
	276	1.71	1.03	2.74	1.05
	394	2.07	0.69	2.76	1.37
	439	1.33	0.72	2.05	1.44
	Mean	1.74	0.95	2.68	1.32
II	301	1.89	0.90	2.79	0.29
	342	1.88	0.97	2.85	1.64
	363	1.51	1.09	2.60	1.07
	387	1.14	0.69	1.83	1.17
	357	1.42	1.35	2.77	1.07
	427	1.64	1.16	2.80	0.10
	266	1.62	1.22	2.84	-0.80
	305	1.59	0.72	2.31	0.50
	59	1.31	1.10	2.41	-0.07
	362	1.23	0.87	2.10	-0.52
	Mean	1.52	1.01	2.53	0.44
III	346	1.56	1.13	2.69	0.36
	312	1.78	0.84	2.62	0.40
	376	1.43	0.76	2.19	1.62
	328	0.91	1.01	1.92	0.86
	383	1.29	0.81	2.10	2.06
	401	1.20	1.19	2.39	1.54
	302	1.83	0.86	2.69	-0.80
	236	1.68	1.25	2.93	0.45
	326	1.56	0.88	2.44	0.20
	408	1.49	1.05	2.54	0.13
	Mean	1.47	0.98	2.45	0.68

Table XXXIV

Individual Daily Milk Production, Fat-Corrected-Milk Production, and Milk Fat Percent for Cows in Experiment III Standardization Period

Treatment	Animal	Actual Milk (lbs)	Milk Fat (%)	FCM (lbs)
I	471	48.23	3.30	43.17
	443	46.01	4.10	46.70
	420	51.37	3.70	49.06
	357	59.73	3.50	55.25
	302	63.41	3.20	55.80
	276	59.85	3.60	56.26
	404	61.73	3.80	59.88
	362	71.30	3.70	68.09
	388	71.88	3.80	69.72
	Mean	59.28	3.63	55.99
II	475	50.79	3.20	44.70
	426	53.66	3.50	49.64
	435	50.35	3.70	48.08
	376	54.67	4.00	54.67
	423	58.08	3.70	55.47
	408	61.22	3.70	58.47
	439	63.93	3.50	59.14
	363	64.89	3.80	62.94
	371	75.12	3.50	69.49
	Mean	59.19	3.62	55.84
III	470	47.16	3.60	44.33
	457	49.14	3.80	47.67
	431	58.14	3.30	52.04
	430	58.22	3.50	53.85
	126	61.58	3.40	56.04
	325	58.32	3.80	56.57
	427	64.83	3.60	60.94
	329	66.09	3.70	63.12
	383	73.13	3.70	69.84
	Mean	59.62	3.60	56.04

Table XXXV

Individual Daily Milk Production, Fat-Corrected-Milk Production, and Milk Fat Percent for Cows in Experiment III Experimental Period

Treatment	Animal	Actual Milk (lbs)	Milk Fat (%)	FCM (lbs)
I	471	40.52	3.23	35.83
	443	34.87	3.95	34.49
	420	47.95	3.72	45.91
	357	50.57	3.27	45.01
	302	51.40	3.50	47.49
	276	39.19	3.53	36.45
	404	40.52	3.40	36.73
	362	61.31	3.53	57.02
	388	57.78	3.38	52.51
	Mean	47.12	3.50	43.49
II	475	45.56	3.25	40.45
	426	26.53	4.00	26.59
	435	34.01	3.98	33.92
	376	35.93	3.85	35.06
	423	41.12	3.75	39.72
	408	43.50	3.60	40.84
	439	49.82	2.85	40.94
	363	51.73	3.43	47.25
	371	49.08	3.65	55.93
	Mean	43.03	3.60	40.08
III	470	39.14	2.65	31.26
	457	37.14	4.03	37.29
	431	53.35	3.48	49.21
	430	45.02	3.68	42.88
	126	48.14	3.55	44.89
	325	57.52	3.72	55.08
	427	52.71	3.92	52.05
	329	47.61	4.70	52.58
	383	50.74	3.47	46.63
	Mean	47.93	3.69	45.76

Table XXXVI

Individual Rumen Fluid pH and Blood Urea Nitrogen Levels of Cows in Experiment III

Treatment	Animal	Rumen Fluid pH	Blood Urea N mgs/100 mls
I	471	6.40	20.36
	443	6.23	20.35
	420	6.40	18.40
	357	6.60	18.39
	302	6.20	19.43
	276	6.50	17.55
	404	6.30	22.05
	362	6.33	19.88
	388	6.28	24.24
	Mean	6.36	20.07
II	475	6.13	19.79
	426	6.38	20.39
	435	6.40	18.09
	376	6.25	21.76
	423	6.25	22.00
	408	6.33	20.84
	439	6.05	22.09
	363	6.08	21.85
	371	6.28	21.43
	Mean	6.24	20.92
III	470	6.10	20.32
	457	6.20	19.49
	431	6.50	22.23
	430	6.70	20.40
	126	6.38	18.59
	325	6.35	21.72
	427	6.40	23.15
	329	6.07	19.28
	383	6.25	21.52
	Mean	6.33	20.74

Table XXXVII

Individual Daily Dry Matter Intake and Body Weight Change for Cows in Experiment III

Treatment	Animal	Mean Daily DM Intake/100 Lbs B.W. Concentrate	Silage	Total	B.W. Change/Day
		lbs			
I	388	1.68	0.83	2.51	1.37
	471	1.30	1.25	2.55	1.46
	443	1.01	0.93	1.94	1.51
	420	1.28	1.18	2.46	1.30
	357	1.14	1.50	2.64	1.36
	302	1.48	0.92	2.40	1.33
	276	1.34	1.21	2.55	1.55
	404	1.99	0.93	2.92	1.21
	362	1.85	1.10	2.95	-0.38
	Mean	1.45	1.09	2.55	1.19
II	475	1.31	1.26	2.57	1.33
	426	1.05	0.97	2.02	1.88
	435	1.13	0.97	2.10	1.25
	376	1.16	1.07	2.23	1.93
	423	1.79	1.22	3.01	1.67
	408	1.57	1.16	2.73	0.35
	439	2.14	1.02	3.16	0.33
	363	1.64	1.08	2.72	0.26
	371	1.83	1.40	3.23	-0.99
	Mean	1.51	1.13	2.64	0.89
III	470	1.33	0.81	2.14	1.93
	457	1.03	1.21	2.24	1.50
	431	1.47	1.27	2.74	0.60
	430	1.10	1.25	2.35	4.38
	126	1.56	1.20	2.76	0.44
	325	1.48	1.28	2.76	2.62
	427	1.99	1.35	3.34	0.77
	329	1.78	1.40	3.18	-0.56
	383	1.66	0.86	2.52	-1.32
	Mean	1.49	1.18	2.67	1.15

Table XXXVIII

Individual Digestibility of Dry Matter, Nitrogen, and Acid Detergent Fiber; Dry Matter Intake and Gain Per Day in Experiment IV

Treatment	Animal	Digestibilities Dry Matter	Nitrogen	ADF	DM Intake Per 100 Lbs B.W.	Gain/Day
		%			lbs	
I	470	64.56	44.86	40.74	2.37	0.85
	474	63.12	55.33	51.92	2.72	1.92
	479	63.17	46.24	48.62	2.28	2.15
	497	67.43	47.85	46.51	2.16	2.62
	Mean	64.57	48.57	46.95	2.38	1.88
II	465	55.25	54.19	49.25	2.20	1.46
	469	60.46	50.06	48.32	2.37	2.08
	473	66.47	55.20	49.41	2.22	1.38
	482	62.47	55.72	48.91	2.56	1.69
	Mean	61.16	53.79	48.97	2.34	1.65
III	466	63.55	55.15	50.12	2.19	1.77
	471	61.16	51.02	46.25	2.29	3.23
	477	66.87	59.11	49.29	2.53	0.69
	486	62.36	54.06	43.90	2.69	2.46
	Mean	63.49	54.84	47.39	2.43	2.04
IV	464	69.14	63.19	52.38	2.39	1.23
	467	66.80	54.55	51.05	2.31	2.92
	472	58.39	54.48	50.49	2.58	1.23
	475	58.87	58.16	47.30	2.55	2.46
	Mean	63.30	57.60	50.31	2.46	1.96

ADF = Acid Detergent Fiber.

Table XXXIX

Individual Nitrogen Balance Data

Treatment	Animal	Nitrogen Intake/Day (g)	Total Nitrogen Intake: Excreted In Feces	Total Nitrogen Intake: Excreted In Urine	Total Nitrogen Intake: Retained In Body	Nitrogen Retained/Day	Nitrogen Retained/Lb Gain
			%	%	%	g	g
I	497	98.32	52.15	34.84	13.01	12.79	4.88
	470	115.47	55.14	36.18	8.68	10.02	11.79
	474	120.65	44.67	32.62	22.70	27.39	14.27
	479	105.18	53.76	34.89	11.35	11.94	5.55
	Mean	109.91	51.43	34.63	13.94	15.54	9.12
II	465	123.70	45.81	36.15	18.04	22.31	15.28
	469	135.52	49.94	35.41	14.65	19.85	9.54
	473	115.57	44.80	38.37	16.83	19.45	14.09
	482	120.13	44.28	32.84	22.88	27.49	16.27
	Mean	123.73	46.21	35.69	18.10	22.28	13.80
III	466	125.37	44.85	32.02	23.13	29.00	16.38
	471	120.40	48.98	30.25	20.77	25.01	7.74
	477	132.55	40.89	34.50	24.61	32.61	47.26
	486	130.89	45.94	26.35	27.71	36.27	14.74
	Mean	127.30	45.17	30.78	24.06	30.72	21.53
IV	464	139.98	36.81	34.10	29.09	40.72	33.11
	467	139.08	45.45	32.25	22.30	31.02	10.62
	472	125.63	45.52	35.75	18.73	23.52	19.12
	475	131.50	41.84	32.30	25.86	34.01	13.83
	Mean	134.05	42.41	33.60	24.00	32.32	19.17

Table XL

Individual Mean Daily Concentrate Intake of Animals in Group I

Trial	Animal	Concentrate I	Concentrate II	Concentrate III	Concentrate IV
		lbs			
I	507	3.84	0.47		
	509	3.57	1.46		
	502	3.70	1.01		
	488	3.41	0.21		
	501	0.67	1.96		
	503	0.21	2.41		
	494	2.56	0.23		
	497	2.31	1.07		
	Mean	2.54	1.10		
II	507	1.01		1.90	
	509	0.64		2.34	
	502	3.23		0.31	
	488	2.31		0.16	
	501	1.47		0.91	
	503	1.57		0.20	
	494	0.76		1.63	
	497	1.21		1.50	
	Mean	1.53		1.12	
III	507	2.07			0.67
	509	2.17			0.90
	502	2.39			1.29
	488	1.86			0.99
	501	0.76			1.90
	503	0.94			1.01
	494	1.90			1.43
	497	2.07			1.14
	Mean	1.77			1.17

Table XLI

Individual Mean Daily Concentrate Intake of Animals in Group II

Trial	Animal	Concentrate I	Concentrate II	Concentrate III	Concentrate IV
		lbs			
I	505	4.04	0.23		
	489	3.23	0.11		
	495	3.46	0.47		
	510	2.91	0.41		
	492	3.59	0.07		
	487	3.56	0.54		
	498	2.87	0.31		
	493	3.09	0.43		
	Mean	3.34	0.32		
II	505		1.04	2.39	
	489		0.44	1.77	
	495		2.61	0.70	
	510		2.09	0.16	
	492		1.64	1.09	
	487		3.13	0.79	
	498		3.10	0.40	
	493		2.56	0.41	
	Mean		2.08	0.96	
III	505		2.46		2.00
	489		2.34		1.01
	495		2.73		1.80
	510		2.04		1.61
	492		2.11		2.50
	487		3.29		2.29
	498		2.63		1.70
	493		1.76		1.99
	Mean		2.42		1.86

Table XLII

Individual Mean Daily Concentrate Intake of Animals in Trials IV and V

Animal	Trial IV		Trial V	
	Concentrate			
	V	VI	VII	VIII
	lbs			
501	3.56	0.80	2.69	1.24
507	4.30	1.77	3.23	1.74
509	3.40	1.27	3.99	1.16
505	4.59	2.54	4.70	1.53
489	4.69	0.36	3.26	0.60
502	4.37	1.49	4.74	1.03
488	4.39	1.96	4.31	1.54
495	3.81	1.04	4.51	0.60
510	4.06	0.49	4.42	0.59
503	2.50	0.89	3.34	0.79
492	3.84	1.80	4.60	1.06
487	4.01	1.76	3.70	2.43
494	4.43	1.59	4.64	1.33
497	4.69	1.44	4.64	1.46
498	4.79	0.96	4.71	0.60
493	4.34	1.33	4.53	0.69
Mean	4.11	1.34	4.13	1.15

VITA

John Roland Plummer was born in Montgomery County, Tennessee, on November 21, 1942. He attended elementary schools in that county and was graduated from Montgomery Central High School in 1961. The following September he entered Austin Peay State University, and in August, 1965, he received a Bachelor of Science degree in General Agriculture. In the fall of 1965, he accepted a research assistantship at The University of Tennessee and began study toward a Master's degree. He received this degree in December, 1967. He continued graduate studies at The University of Tennessee and received the Doctor of Philosophy degree with a major in Animal Sciences in August, 1970.

He is a member of the American Dairy Science Association, Gamma Sigma Delta, and Phi Kappa Phi.

He is married to the former Maxine Lyle of Jonesville, Virginia.