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156

THE USE OF UREA IN ENSILED VERSUS NONENSILED COMPLETE FEEDS FOR LACTATING 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

Dennis B. Longmire

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ABSTRACT

Four experiments were conducted to investigate the use of urea in ensiled and nonensiled complete feeds for lactating dairy cows. All feeds were mixed in a 60:40 concentrate to forage ratio on a dry matter basis.

A fermentation study, Experiment I, was conducted to compare the nitrogen distribution in ensiled complete feeds, with or without the addition of urea at ensiling, to that of corn silage with either 0 or 1.5 percent urea added at ensiling. Results indicated that in an ensiled complete feed with corn silage as the forage, given sufficient carbohydrates, a dynamic microbial population fixed a significantly greater amount ($P < 0.05$) of ammonia nitrogen than in urea corn silage with no added carbohydrates. In neither system was there a significant loss ($P > 0.05$) of nitrogen as volatilized ammonia.

Thirty-seven cows were used in Experiment II to compare the feeding value of complete feeds containing a 3 percent urea concentrate, both ensiled and mixed at feeding, with a non-urea complete feed mixed at feeding. As in Experiment I, after ensiling in the presence of excess carbohydrate, there was a significant reduction in the urea content of the ensiled urea-containing complete feed. The dry matter intake of cows fed the ensiled urea complete feed was significantly lower than those fed a urea complete feed mixed at feeding or those fed a non-urea complete feed mixed at feeding. The cows fed the ensiled urea feed gained 9.4 pounds per week as compared to 11.4 pounds per week for those

fed the urea ration mixed at feeding and 16.2 pounds per week for those fed the non-urea ration. No significant differences ($P > 0.05$) were found in milk production, fat test, or 4 percent fat-corrected-milk (FCM) production between the three rations tested. The two urea rations had a predictable advantage in feed costs; however, this advantage was reduced in the ensiled urea feed by a non-significant reduction in salable milk production.

Experiment III was a digestion trial conducted to study nutrient digestibility in animals fed urea versus non-urea complete feeds, both mixed at feeding and at ensiling. The urea complete feeds were prepared using a 3 percent urea concentrate. The ensiled complete feeds were both significantly lower ($P < 0.05$) in intake than their counterparts mixed at feeding. The digestibilities of dry matter, nitrogen, and acid detergent-fiber (ADF) were significantly lower ($P < 0.05$) for the ensiled complete feed without urea than the ensiled urea complete feed or either of the complete feeds mixed at feeding. There were no other significant differences ($P > 0.05$) in digestibilities between treatments. The higher nitrogen content of the ADF of the ensiled non-urea ration, as well as its appearance, would indicate overheating or caramelization, which may have been responsible for the lower digestion coefficients.

Forty-one cows were used in Experiment IV to study the intake and performance of lactating cows fed one of four complete feeds: I) corn silage and a 3 percent urea concentrate mixed at ensiling; II) the same feed as I, mixed at feeding; III) corn silage and

non-urea concentrate mixed at ensiling; IV) the same feed as III, mixed at feeding. These feeds were from the same silos as those used in Experiment III. The ensiling of complete feeds significantly reduced ($P < 0.05$) intake with both urea and non-urea feeds. The weight gains were 4.7, 4.3, 3.2, and 6.1 pounds per week for Treatments I - IV, respectively. There was no significant effect ($P > 0.05$) of either ensiling or urea addition on actual milk produced. The ensiling of the complete feeds did, however, cause a significant reduction ($P < 0.05$) in fat test with a resultant significant decrease ($P< 0.05$) in 4 percent FCM production. The addition of 3 percent urea to the concentrates used in mixing the feeds had no significant effect ($P > 0.05$) on any of the production variables measured. The two urea rations had an advantage of lowering feed costs; however, this advantage was obscured with the ensiled urea feed because of the reduction in fat test. The complete feed with urea mixed at feeding resulted in a feed cost reduction while maintaining production at a level equal to that of the non-urea feeds.

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CHAPTER I

INTRODUCTION

As dairy herds have become larger, there has been increased emphasis placed on speeding up the milking procedure in order to keep labor costs at a minimum. To this end, there have been advances in parlor design, cow-handling facilities, and in the actual milking procedure. All of these have contributed to a reduction in the time cows spend in the milking parlor.

As a consequence, the time available for eating concentrates has been restricted. Many high producing cows do not have time to consume sufficient concentrates to meet their energy needs. In an effort to overcome this restriction, many dairymen have turned to feeding part or all of the concentrates outside the parlor in a mixture with the forage. The feeding of all the concentrates in a complete feed with the forage has additional advantages. One distinct advantage is the freeing of the milker from feeding the concentrate and thus allowing him to devote more time to actually milking cows. In addition, less dust and wasted feed is found in the milking area. It has also been reported by dairymen who are using a complete ration that, once cows become adjusted, they are calmer while being milked. The cows tend to move less in an attempt to reach more feed. The possibility also exists for a reduction in labor costs by feeding one complete-feed. With automated silage and grain handling at one central location, the man-hours spent feeding the herd can be decreased significantly.

At the same time that this management innovation has been taking place, changes have occurred in the feeds that dairymen are using. In order to reduce labor costs by increased automation, more and more dairy farmers are utilizing corn silage as the sole forage since it can be harvested and fed by almost totally mechanical means.

In addition to the increased use of corn silage, there has also been increased use of urea in the dairy ration. The demand for protein from the human population and a world protein shortage have caused the cost of plant protein supplements to become increasingly more expensive. Dairymen are realizing that feed costs can be lowered by utilizing the ruminants' ability to convert non-protein nitrogen into microbial protein. Research has shown that, used properly, urea can supply a significant portion of the ruminants' nitrogen requirement and thus lower feed costs while maintaining milk production.

These studies were conducted to investigate some methods of incorporating urea into complete feeds for lactating dairy cows in order to realize the cost and labor-saving advantages of these management and nutritional innovations while maintaining high milk production.

CHAPTER II

REVIEW OF LITERATURE

Urea as a Nitrogen Source for Ruminants

It has been known for many years that the ruminant animal is capable of using non-protein nitrogenous compounds for body function. The main non-protein nitrogen compound used in ruminant feeds has been urea. The enzyme urease, present in the rumen, hydrolyzes the urea molecule to ammonia and carbon dioxide (62). Ammonia is incorporated into microbial protein which is digested and assimilated later by the ruminant animal in a manner similar to protein digestion in the monogastric animal. Pearson and Smith (62) found that 100 g of rumen contents could convert 100 mg urea to ammonia in one hour. They further found that urea hydrolysis increased with temperature elevation to a maximum of 40 C. Optimum pH for hydrolysis was 7 to 9, with urease activity ceasing below 3 or above 9.5. The hydrolysis was slightly more efficient under carbon dioxide than under nitrogenous air.

There exists little information about the specific organisms possessing the urease activity. Hungate (37) concluded that a broad spectrum of bacteria contribute to the process.

Early workers (26, 27, 46) indicated that urea was used by the ruminant as a source of protein because the animals were in positive nitrogen balance while growing and producing on rations containing urea.

Efficiency of Urea Utilization by Ruminants

The major problem in the efficient use of urea is the rapid release of ammonia. Bloomfield et al. (9) reported that the release of ammonia from urea hydrolysis occurred four times faster than the uptake of ammonia, which resulted in the loss of nitrogen available for microbial protein synthesis. This rapid release was probably the limiting factor in the utilization of urea nitrogen. Most performance studies have indicated that the utilization of urea N is inferior to that of plant protein supplements. Many efforts to increase the efficiency of urea utilization have been aimed at reducing ammonia N losses by reducing the rate of urea hydrolysis, reducing the solubility of urea, increasing the ability of rumen microorganisms to incorporate available ammonia N, increasing the tissue utilization of ammonia N, or increasing the recycling of urea N to the rumen (9).

Influence of Protein Level

Several studies (39, 60, 72) have indicated that animal performance improves with time on urea-bearing rations. Schaadt et al. (72) conducted a 72-day metabolism trial with sheep and found increased N balance biological values with time. Smith et al. (74) found that when observations from 63 lambs fed a high-urea, semipurified ration in 19 digestion trials were subjected to multiple regression analyses, the retention of absorbed N was improved significantly with each 10-day feeding period. McClaren et al. (49) reported that absorbed N retention was improved by three percentage units with each 10-day period of urea feeding.

The composition of the total ration has been shown to have a definite effect on the efficiency with which the urea is utilized by the ruminant. Wegner (85, 86) indicated that the protein level of the medium inoculated with rumen microorganisms influenced both the rate and the amount of urea converted to protein.

Burroughs et al. (14) demonstrated that as much ammonia could be utilized from urea alone as from urea when used with other feed proteins. Corrections were made for ammonia of protein origin. This finding led this group (14) to suggest that the most negative influence of a protein on urea utilization would result from the competition of the ammonia from protein with that from urea in satisfying the ammonia requirements of rumen microorganisms.

In vivo utilization of urea was studied by Wegner et al. (85) who found that the utilization of urea N was decreased greatly as the crude protein of the concentrate increased above 18 percent. When the basal grain mixture was not supplemented with protein concentrates, the urea was utilized efficiently up to 4.5 percent urea (23 percent total crude protein).

Source of Carbohydrates

The essential role of carbohydrates in the conversion of ammonia to microbial protein is to furnish energy and carbon skeletons for microbial synthesis. Several in vitro studies have evaluated the utilization of the various energy sources for microbial ammonia fixation. Arias et al. (3) found that any digestible carbohydrate, whether readily available or more complex, aided in microbial urea utilization. Belasco

(7) compared several carbohydrates as energy sources for microbial use of urea. Urea utilization by rumen microorganisms *in vitro* was dependent on the amount and type of carbohydrate used. The extent of urea utilization was higher with starch than cellulose. As starch input was increased, urea utilization increased and ammonia levels decreased. Belasco (7) suggested that there are different metabolic pathways for the various carbohydrate substitutes or dynamic microbial populations changing in number and type with a change in substrate. Bloomfield *et al.* (10) found differences in urea utilization *in vitro* with starches from different sources. Cornstarch appeared to be the most efficient, supporting 98 percent utilization. Wheat starch, potato starch, and soluble starch were 81, 63, and 55 percent efficient, respectively.

Several *in vivo* metabolism studies have been conducted to study the addition of carbohydrates to urea rations. Mills *et al.* (55) found that the addition of starch to a timothy hay and urea ration lowered the ammonia level of the rumen and increased the protein content of the ingesta. Their data (55) indicated that timothy hay alone did not furnish a suitable medium for the efficient utilization of urea by the rumen microbial population. McDonald (53) reported that the supplementation of starch to the rumen of sheep would reduce high ammonia levels. This study indicated that the added starch furnished energy for the assimilation of ammonia by the rumen microorganisms. Mills *et al* (56), Bell *et al.* (8), and Oltjen and Putnam (59) demonstrated that starch was superior to soluble sugars in increasing N retention, decreasing rumen

ammonia concentrations, increasing the protein content of the rumen ingesta, and promoting growth.

The energy requirement for maximum urea utilization has been studied. Regression analysis of data obtained from N metabolism studies with sheep (49) demonstrated that the retention of absorbed N was significantly improved by two percentage units for each 100 Kcal of readily available carbohydrate in the ration. Preston et al. (66) regressed daily gain of lambs against the ratio of digestible protein to digestible energy content of the ration and found that maximum gain occurred when the ration was 22 g digestible protein to 100 Kcal digestible energy. Bloomfield et al. (11) found the in vitro fixation of urea nitrogen by rumen microorganisms to be a quantitative function of energy level. They reported that bacterial assimilation required 55 g of carbohydrate for each gram of N fixed. It was concluded (11) that the urea level in the diet is not restricted to a fixed percentage but can be fed as a function of the available energy level.

There are two studies (11, 45) which demonstrated an increased cellulose digestibility with the inclusion of urea to a corn gluten meal ration. Little et al. (45) found that the addition of urea to corn gluten meal markedly improved its value in stimulating in vitro rumen cellulose digestion and in increasing feed consumption and gains in lambs. Chalupa et al. (16) presented data showing definite trends in total cellulose disappearance as a result of an exogenous nitrogen source. Corn gluten meal resulted in no increase in cellulose disappearance over the control rumina. The substitution of 8 mg of urea N for a

portion of the corn gluten meal increased total cellulose disappearance. Maximum stimulation was noted when all 16 mg of exogenous nitrogen was derived from urea. Increases in cellulose digestion appeared to be associated with the amount of soluble nitrogen added.

Frequency of Feeding

As previously stated, a major cause of the reduction in the efficient utilization of urea is the rapid release of ammonia in the rumen (9). The possibility that feeding urea more often and in smaller quantities could increase utilization efficiency has been studied (15, 21). Campbell et al. (15) fed a 3.3 percent urea concentrate to two groups of heifers. Each group received the same amount per head per day. One group was fed six times per day, while the other group was fed only twice per day. The animals fed six times each day gained significantly more than the other group. No differences in average daily gain were observed between the non-urea ration groups on the same feeding schedule.

Conversely, Plummer (63) found no significant difference in milk production, milk protein, milk SNF, percent milk fat, dry matter intake, or body weight change in cows fed corn silage plus a concentrate which contained 2 percent urea fed twice a day versus six times a day.

Feeding Urea to Lactating Cows

There has been an extensive amount of research devoted to the feeding of urea to dairy cows, but due to variations in response, there still remains uncertainty whether or not urea can be fed without loss in

productive efficiency. The variation can be attributed to wide differences in experimental conditions. Early studies were conducted with low producing cows fed ad libitum amounts of high quality forage. Therefore, little or no additional protein N was needed to fulfill requirements. In a series of feeding trials, Archibald (2) compared urea with a combination of cottonseed meal, soybean meal, and corn gluten feed. The energy furnished by the plant protein supplements was replaced by adding corn starch to the urea ration. Urea comprised 3 percent of the total ration and 42 percent of the total N in the mixture and 2.5 percent of N in the ration. The cows consuming the urea ration produced slightly less milk and were slightly less persistent. The urea ration was less palatable, thus the intakes were lower on the urea ration. The reduced intake could have been responsible for the decreased milk production.

Bartlett and Blaxter (6) found that when urea was added to a ration already adequate in protein, milk production decreased slightly, but not significantly. Hastings (28) reported that no difference in production or composition of milk resulted from feeding a 3 percent urea ration or the control ration. Willet et al. (87) reported different results. Willet and co-workers (87) compared a low-protein (7.4 percent) basal concentrate ration with rations (13.2 to 13.4 protein) containing either soybean meal or urea (2.5 percent). They found that both supplements increased 4 percent fat-corrected milk (FCM) production. The soybean meal group produced significantly more FCM than the urea fed group.

Huber and Sandy (34) used a 3 x 3 factorial design to study the response of lactating cows to three levels of concentrate (2.99, 6.58, and 10.52 kg per day), and three levels of urea (0, 20, and 40 percent of the total requirement). Increasing urea levels significantly decreased milk production linearly. Urea level had no effect on silage intake at the two lower concentrate levels, but significantly lowered silage consumption at the highest level. Increasing urea also tended to decrease efficiency of milk production. There was no significant treatment effect on fat, protein, or solids-not-fat. In a later trial, Huber et al. (33) used four levels of urea supplementation: 0, 11, 22, 38 and 48 percent of the total N. Milk yields were markedly depressed at the two higher levels of urea. Decreases were significant at the 22 percent level. No difference was detected at the 11 percent level. Silage consumption was lowered with the higher urea levels. There were significant reductions in dry matter, crude fiber, and nitrogen-free extract digestibilities with all urea additions. There was also a decreased retention of the digested N at the 22, 38, and 48 percent levels. Huber (33) postulated that the depression of N retention and decreases in digestibilities explained the lowered efficiency of production with the increasing levels of urea.

Lassiter et al. (43) also studied the performance of lactating cows when fed varying levels of urea. They reported no significant decreases in milk production with increased urea; however, there were slight reductions in both body weight gains and milk production. Digestibility of nutrients was not influenced by the level of urea;

however, the efficiency of ration utilization tended to decrease as the level of urea increased. Results reported by several researchers (40, 79, 84) have shown that the substitution of urea for the plant protein supplements in dairy concentrates caused slight, but not significant, reductions in milk production.

Holter et al. (29) reported no effect on intake and utilization by substituting as much as 300 g of urea per cow daily for equivalent plant protein N in high quality concentrates fed with free-choice corn silage. Plummer (63) found no significant differences in ration intake, body weight changes, milk yields, milk protein, or milk SNF in cows fed corn silage plus a concentrate of either 0 or 2 percent urea. In a subsequent trial (63) a 3 percent urea concentrate was compared to a concentrate containing no urea. No significant difference was found in silage intake, total dry matter intake, milk production, milk protein, or milk SNF. Concentrate intake per 100 pounds body weight gain was significantly less with the 3 percent concentrate. There was a significant elevation in butterfat percentage with both the 3 and 2 percent urea concentrates.

Palatability of urea-containing feeds appears to be an accentuated problem with dairy cows due to the high level of protein in most dairy rations and the recent emphasis on high concentrate feeding. Although Holter (29) limited maximum concentrate feeding to 11.3 kg per day of a 1.5 percent urea concentrate, he reported discrimination against the urea-containing concentrate. Loosli and Warner (47) reported slower consumption of a concentrate containing 3 percent urea than one with

either corn distiller's grain or brewer's dried grains as protein supplements. Van Horn et al (80) reported that the addition of 2.2 percent urea to a concentrate mixture depressed intake.

Use of Urea in Silages

Early workers (88, 90) reported studies in which 10 pounds of urea was added to corn forage at ensiling time. They indicated that urea-treated silage was less palatable, but that there was no effect on milk production. There are further reports (33, 64) that treating corn silage with urea tends to reduce the palatability problem encountered with urea concentrates, due to the lesser concentration of urea per unit of feed.

Van Horn et al. (81) reported that cows fed corn silage containing 0.5 percent urea and a 1 percent urea concentrate produced significantly less milk than did cows fed the same concentrate and untreated corn silage. Polan et al. (64) fed corn silage supplemented with 0, 0.60, and 0.85 percent urea. No significant differences were found in milk production. However, the control cows and the 0.60 percent urea group were in slight negative nitrogen balance while the 0.85 percent urea group were in a large, negative nitrogen balance. Huber and Thomas (35) found that cows fed low protein rations of corn plus corn silage produced less milk and consumed less feed than those fed rations to which 0.5 or 0.75 percent urea was added to corn forage at time of ensiling. Due to the higher milk yields and a large saving in the price of nitrogen supplementation, income over feed cost was about 10 percent greater for the urea group than for the group receiving all protein supplement as soybean meal.

Effect of Urea Supplementation on Silage Fermentation

Huber et al. (36) reported studies in which urea was added to corn silage at 30, 36, or 44 percent dry matter. Corn silage with no urea supplementation ensiled at the same three dry matter levels served as controls. The urea treated silages lost more dry matter at all moisture levels than the untreated silages. The nitrogen concentrations of silages were very similar to those of the materials just prior to ensiling. The amounts of urea recovered from the silages expressed as a percent of the amounts added were 87, 81, and 31 percent from the low dry matter, medium dry matter, and high dry matter silages, respectively. Huber (36) postulated that higher temperatures or a lower organic acid content during early fermentation of the most mature silages may have explained these differences. The percent of the total nitrogen as ammonia decreased as dry matter increased. Huber (36) also reported small decreases in both ADF and lignin in urea-treated silages during the fermentation process.

Owens et al. (61) studied the influence of added urea on corn silage fermentation. After 92 days of fermentation, the final urea concentrations were low in both trials and did not reflect the amounts of urea added at ensiling time. This study concluded that substances which yield calcium or ammonium ions will buffer fermentation acids and, hence, prolong fermentation and increase the concentration of fermentation end-products in corn silage.

Everson et al. (20) investigated the nitrogen redistribution in corn silage supplemented with urea and sodium bentonite. Sodium

bentonite, an inert silica clay, is noted for its ion-exchange and water absorbing capacities. Increasing bentonite produced several changes: higher pH, increased organic acid production, increased incorporation of ^{15}N urea into microbial protein, decreased free α-amino-N, and eliminated seepage. Nitrogen-15 analysis of the liberated gasses indicated that no ^{15}N urea was lost as volatilized ammonia. There was a significant decrease in non-protein N and an increase in protein N, which appeared to be due to greater microbial protein synthesis from urea N.

Shirley et al. (73) reported a study in which urea at 0, 0.5 or 0.75 percent was added to silage of 37 to 40 percent dry matter. Acetic acid production in all silages was complete by the fifth day of fermentation, while lactic acid production continued for 25 days. The production of propionic, butyric, and lactic acids increased with increasing amounts of urea. Acetic acid was increased at the 0.75 percent level, but depressed in the 0.5 percent urea silage. Approximately 65 to 73 percent of the urea N was converted to other forms. The increase in NH_3-N accounted for 23 to 44 percent of this decrease in urea N. Shirley et al. (73) used a 3 x 3 Latin square design feeding trial with the three levels of urea silage in diets calculated to be isocaloric and isonitrogenous. Cows fed the 0 and 0.5 percent urea silages consumed more silage dry matter than the cows fed the 0.75 percent urea silage. There was no significant effect on milk production with the varying urea levels in the silages.

Use of Complete Feeds for Lactating Cows

The practice of blending forage and concentrates into one complete feed for milking cows has been an alternative used on many dairy farms, particularly large units where automated feeding systems have been used to reduce labor costs (75). Olson (58) stated that this feeding method may also be used to induce cows to consume forages and concentrates in proper proportions for maximum milk production; furthermore, when such feeds contain ingredients that are most economically purchased, transported, and stored, the maximum benefits from specialization can be realized. As milking procedures have been improved and cows spend less time in the milking parlor, it has become apparent that high producing cows are not able to consume sufficient concentrates in the parlor to support high production (78).

Ingredients for Complete Feeds

A major problem associated with the formulation of complete feeds has been the securing of available and economical sources of roughage. Many roughages have been tried in complete feeds formulation: hay (44, 65, 70, 83); pineapple hay and bran (71); corn cobs (44, 50, 51); cottonseed hulls (50, 51); and straw (23). There has also been considerable interest (23, 25, 75) in the use of silage in complete feeds. The major factors which have influenced the dairyman's choice of roughage have been non-nutritional: availability, price, and efficiency of handling. Since roughages are lower in nutrients per unit, when compared to concentrates, large procurement, transportation, and storage charges

cannot be justified (67). For these reasons corn silage has received considerable interest as the roughage source in complete feed formulation.

In order to support milk production, it has been shown that complete feeds must contain 13 to 15 percent crude protein (69). Due to the greater cost and greater adaptability to transport and storage, several studies have been conducted on sources of protein supplementation suitable for incorporation into complete feeds. As previously stated, the nitrogen content of corn silage can be raised to any desired level by the addition of urea; however, as also discussed earlier, corn silage does not contain sufficient energy to allow efficient utilization of the urea or fulfillment of the energy requirements of the lactating cow (32, 35, 64, 81, 88).

Johnson et al. (38) compared three complete feeds, all consisting of 40 percent roughage and 60 percent concentrate on a dry matter basis: 1) haylage plus soybean oil meal concentrate; 2) corn silage plus soybean oil meal concentrate; and 3) corn silage plus concentrate with urea. Milk production was significantly lower on ration 3; however, there was no difference in 4 percent FCM production, due to an increase in butterfat percentage. The solids-not-fat and protein percentages were significantly lower on ration 2 than either 1 or 3. Rumen fatty acid production was not significantly affected by the roughage or protein source. Boman et al. (12) compared the following rations: 1) corn silage plus 18 percent crude protein concentrate, 1:3; 2) corn silage plus 41 percent crude protein cottonseed meal, 1:9; 3) urea corn silage (0.5

percent urea) plus cottonseed meal and shelled corn, 1:9; 4) urea corn silage (1 percent urea) plus shelled corn and cottonsead meal, 1:9. Crude protein of silage in rations 1 and 2 averaged 9.5 percent on a DM basis, and the urea silages averaged 13.1 and 17.9 percent crude protein, respectively. No significant differences were found in 4 percent FCM production, dry matter intake (percent of live weight), or daily weight gain. Urea had no adverse effects on animal performance. Feed costs were 25 percent lower for Rations 2, 3, and 4 than those for Ration 1.

In general, the milk production and feed intake of cows fed blended or complete feeds with urea have been comparable to that of those fed the roughage and concentrate portions separately. Villavivenvio et al. (83) fed a conventional ration with concentrates and roughage offered separately and three one-percent urea feeds, containing different roughage sources, to four groups of cows for a 120-day period. The milk production levels of the various groups were not significantly different. There are numerous reports (22, 41, 52, 57, 83) comparing the feeding of complete feeds to the feeding of the same ingredients separately with no significant differences found in milk production or composition

Use of Ensiled Complete Feeds

Marshall and Browning (48) reported studies in which an ensiled complete feed was prepared by blending 26.7 kg of concentrate and 12.5 kg of water with each 100 kg of chopped, fresh corn prior to ensiling. This ensiled complete feed was compared to a complete feed made from corn silage and the same concentrate mixture blended at feeding time.

No significant differences were found in either milk production or 4 percent FCM. Dry matter intakes were very similar. The pH was 3.75 for corn silage and 3.85 for the ensiled complete ration. Fermentation dry matter losses were 8.4 percent for corn silage and 6.9 percent for the ensiled complete ration.

Derbyshire et al. (19) ensiled a complete feed using 34 percent dry matter corn forage and adding a 23 percent digestible protein concentrate at the rate of 15 percent of fresh forage weight. This was equal to a 72:28 forage-to-concentrate dry matter ratio. The ensiled complete feed was compared in a feeding trial with a complete feed of corn silage mixed with the same concentrate just before feeding. After ensiling, the control silage and the ensiled complete feed were characterized by lowered acid-detergent fiber content, cell-wall constituents cellulose and hemicellulose, and a marked increase in the percent of cell solubles. These changes were more pronounced in the control silage than in the complete feed. The fermentation process had no apparent detrimental effect on the composition or recovery of the nutrients when stored as a complete feed. There were no significant differences noted in dry matter consumption, actual milk production, or FCM production.

Hooven et al. (30) added a 27.9 percent crude protein concentrate mix to corn silage at ensiling time at a rate to attain a 60:40 forage-to-concentrate dry matter ratio. One group of cows was fed this ensiled complete ration; while a control group was fed corn silage ad libitum and the same concentrate at a rate of one pound of concentrate per three pounds of milk produced. No significant differences were found in dry matter intake or FCM production on a weekly basis.

No reports were found in the literature of research being conducted using an ensiled complete feed containing urea.

Least-Cost Formulation of Complete Feeds

Howard et al. (76) compared two least-cost linear programmed computer formulated feeds to a conventionally formulated ration in a 20-week continuous trial. Ration treatments were: 1) least-cost constant (LCC), formulated using the past year's prices; 2) least-cost variable (LCV), reformulated biweekly with price changes; and 3) a conventionally formulated ration using no urea. Corn silage was the only forage used in each ration. All rations were designed to be nutritionally equal, assuming feeds to be substitutable on a nutrient basis. Least-cost constant and LCV feeds were set at a maximum of 1 percent urea on an air-dried basis. Dry matter consumption, actual milk, fat-corrected milk, milk fat and solids-not-fat percentages, and body weight gains were not significantly affected by ration treatment. Abrupt ration changes did not affect animal performance. There was a significant reduction in daily feed cost on the LCC and LCV rations as compared to the control. Howard et al. (76) reported that analysis of opportunity costs revealed that the addition of urea accounted for 60 percent of the cost reduction found with the two least-cost rations. With corn silage as the forage source, both programs included the maximum level of urea (1 percent) at each formulation.

CHAPTER III

GENERAL EXPERIMENTAL PROCEDURE

Objective of Experiments

The principal objective of the study was to investigate the use of complete feeds containing urea and corn silage for lactating dairy cows. The influence of urea, in ensiled complete feeds and feeds mixed at feeding, on milk production, milk constituents, feed intake, ration digestibility and body weight change were studied. In addition, the effects of the addition of urea on nitrogen distribution, fiber content, total crude protein, and pH of corn silage and ensiled complete feeds were investigated.

Methods and Materials

Sampling. Samples of the corn fodder (whole, chopped corn plant) in Experiments II and IV were taken at the time of ensiling and moisture determined immediately. The corn fodder used in Experiment I was taken at this time. The concentrates were sampled at ensiling and the samples for Experiment I were hand-mixed and packed in glass jars.

Samples of rations fed were taken during the trial period in Experiments II and IV. Daily feed samples were taken during the collection period of Experiment III. Total feces and urine were also collected during this period.

Milk yields were weighed and recorded at each milking. A morning and evening milk sample was taken and composited for each cow once per week in Experiments II and IV.

Chemical Analyses. Dry matter content of the feeds in Experiment I was determined by the toluene distillation method (1). Dry matter content of corn silage and complete feeds was determined by drying in a forced draft oven at 50 C for 48 hours.

Feed and feces samples were analyzed for nitrogen content by the Kjeldahl method (1). Acid-detergent fiber (ADF) and lignin were determined by the method of Van Soest (82). Ammonia and urea nitrogen were determined by the method of Conway (17). Milk fat was determined by the use of the Foss Milk-O-Tester, Model Mark II.

Statistical Analyses. The results from Experiment I were analyzed using Duncan's multiple range test as outlined by Steel and Torrie (82). In Experiment III, the data were analyzed using analysis of variance and least significant difference (LSD) techniques.

The production data from Experiments II and IV were analyzed by first reducing the actual weekly production information for each cow to a polynominal describing the lactation curve. Equations were fitted in the following form:

$$\hat{Y}_i = a = b_1(wk) + b_2(wk^2) = b_3(wk^3)$$

where:

wk = the number of the week of the experimental period,

$\hat{Y}_i$ = the estimated value of the dependent production variable for each specified week,

a = the intercept value for each dependent variable at week 0,

b_1, b_2, or b_3 = the regression coefficients for each dependent variable on the independent variable: wk, wk^2, and wk^3.

These regression coefficients were then used as dependent variables in a multivariate analysis of variance (MANOVA) as described by Kramer (42) in an effort to test for treatment differences in the lactation curves. This method of analyzing repeated measurement data was similar to that used by Box (13) and Wishart (89) with growth curves. Significance was determined by use of the Generalized Variance Ratio or U-Statistic which is calculated by the formula:

$$U = \frac{|\underline{E}|}{|\underline{E} + \underline{H}|}$$

where:

$\underline{H}$ = the sum of squares (SS) and sum of products (SP) matrix for "hypothesis" or partial SS and SP due to treatment,

$\underline{E}$ = the adjusted Y'Y matrix or "error" matrix.

The calculated U value was then compared to the tabular value at a given probability with the same parameters. All statistical analyses were conducted using an IBM 360/65 computer and programs prepared by Barr and Goodnight (5).

CHAPTER IV

EXPERIMENT I

Objective of Experiment

The objective of this investigation was to compare the nitrogen distribution in ensiled complete feeds, with or without the addition of urea at ensiling, to that of corn silage, with either 0 or 1.5 percent urea added at ensiling.

Experimental Procedure

Four different corn fodder (whole, chopped corn plant) mixtures were sealed in one-quart, glass jars. The mixtures were as follows: I) corn fodder; II) corn fodder plus concentrate II, mixed at a 60:40 concentrate-to-forage ratio on a dry matter basis; III) corn fodder plus Concentrate I, mixed at a 60:40 concentrate-to-forage ratio on a dry matter basis, IV) corn fodder plus 1.5 percent urea. The composition of the concentrate mixtures is presented in Table 1. The jars were sealed to be air tight and were packed in insulation material to maintain a relatively constant temperature. Since conditions of temperature, darkness, and an anaerobic environment simulated those of a large silo, response criteria should reflect fermentation within a field scale silo. Aerobic degradation and spoilage were avoided.

Nine jars were filled with each mixture. Three fresh samples of each mixture were frozen immediately. Three other samples of each mixture were allowed to remain in insulated darkness for four days, at which time they were removed and frozen. The remaining three jars of each mixture were allowed to ferment for 16 days.

Table 1. Composition of Concentrates Used in Experiments I-IV

Ingredients	Concentrate I[a]	Concentrate II[b]
	lb/ton	
Corn	1380	1000
Oats	488	480
Soybean Meal	52	480
Urea	60	
Trace Mineralized Salt	20	20
Dicalcium Phosphate	20	20

[a]Crude Protein = 18.1 percent as fed.

[b]Crude Protein = 18.2 percent as fed.

At the end of the fermentation period, all samples were thawed and analyzed for dry matter. Crude protein was determined on the wet silage samples. The pH was determined for each silage. Ammonia and urea nitrogen were also determined for each "silo." Duplicate determinations were made for each treatment replication or jar.

Results and Discussion

The pH of the silage preparations at the three various times is given in Table 2. The pH values of the fresh samples were significantly higher ($P < 0.05$) than their respective readings at later times. Initial pH values were also significantly different from each other ($P < 0.05$). Significant differences within times are indicated in Table 2. From the table it is evident that the addition of urea or grain concentrates tended to keep the pH from falling to the levels of the silage with no additives. The addition of both urea and grain concentrates had an additive effect in keeping the pH from declining. This is in agreement with Owens et al. (61) who concluded that substances which yield calcium or ammonium ions will buffer fermentation acids and, hence, tend to stabilize pH.

The results of the dry matter, acid-detergent fiber (ADF), and lignin determinations are presented in Table 3. No significant difference ($P > 0.05$) in dry matter within treatments was found. There were slight decreases in ADF with time; however, these differences were only significant ($P < 0.05$) in the case of the non-urea complete feed. There were also decreases in lignin content with time in all cases. These decreases were significant in all treatments ($P < 0.05$). This

Table 2. pH of Silages in Experiment I

Treatment	Time		
	0	4 day	16 day
	pH[a]		
I Corn Silage	5.37[b]	3.65[b]	3.63[b]
II Complete Feed (No urea)	5.70[c]	3.93[c]	3.90[c]
III Complete Feed (1.5% urea)	7.70[d]	4.05[d]	4.00[d]
IV Corn Silage (1.5% urea)	6.80[c]	3.90[c]	3.90[c]

[a]Each value is mean of six determinations.

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

Table 3. Dry Matter, Acid-Detergent Fiber and Lignin of Silages in Experiment I

Treatment	Dry Matter	ADF	Lignin
	—— % ——	— % (DM basis) ——	
I Corn Silage			
0	36.13	22.63	3.40[a]
4 day	33.27	22.52	3.22[a]
16 day	36.60	21.89	2.48[b]
II Complete Feed			
0	52.50	17.54[a]	2.50[a]
4 day	51.50	14.99[b]	2.41[a]
16 day	52.04	14.10[b]	1.89[b]
III Complete Feed (1.0% urea)			
0	52.18	15.78	2.55[a]
4 day	50.90	15.53	2.26[ab]
16 day	53.10	15.24	2.05[b]
IV Corn Silage (1.5% urea)			
0	33.93	28.97	4.30[a]
4 day	32.37	28.58	4.03[ab]
16 day	32.97	26.85	3.91[b]

[ab]Values within treatment columns with different superscripts are significantly different ($P<0.05$).

agrees with Huber's work (36) showing decreases in both ADF and lignin in silages during the fermentation process.

The amount and partial distribution of the nitrogen content of the silage samples in Experiment I are given in Table 4. The complete feeds were prepared using two parts of corn fodder and one part of concentrate. Using this ratio, and given that Concentrate I contained 3 percent urea, Complete Feed III would contain 1 percent urea on an as-fed basis. In Treatment IV, 30 pounds of urea were added per ton of fodder, giving a 1.5 percent urea on a wet basis. In Treatment I (corn silage) there was a significant increase ($P < 0.05$) in ammonia nitrogen from day 0 to day 16. There was a small amount of urea present at day 16, but it was not significantly different from the amount present at time zero. The column in Table 4 headed, "Unaccounted-for Nitrogen," (UAN) is that fraction not specifically analyzed and presumed to be nitrates, nitrites, proteins, peptides, or any other nitrogenous compound not assayed. In corn silage the UAN was 98 percent of the total nitrogen (TN).

In Treatment II, there was a slight increase in ammonia nitrogen; however, it was not a significant increase ($P > 0.05$). In this mixture, with no urea addition, no urea was found at any time during fermentation or after. Again, the UAN accounted for approximately 98 percent of the TN, with the remainder found in the ammonia fraction. The other complete feed mixture, Treatment III, showed a significant increase ($P < 0.05$) in ammonia content with time and a highly significant ($P < 0.01$) decrease in urea over time. Over the same interval, the UAN increased from 45.8

Table 4. Nitrogen Distribution in Silage Samples in Experiment I

Treatment	Total Nitrogen	Ammonia Nitrogen	Urea Nitrogen	Urea	Nitrogen Fractions as a % of Total N: Ammonia Nitrogen	Urea Nitrogen	Unaccounted-For Nitrogen
	mg/g DM				%		
I Corn Silage							
0	14.16	0.050[a]	--	--	0.353	--	99.647
4 day	15.45	0.125[ab]	--	--	0.809	--	99.191
16 day	13.17	0.244[b]	0.004	.008	1.856	.027	98.117
II Complete Feed							
0	25.60	0.253	--	--	0.987	--	99.013
4 day	26.40	0.271	--	--	1.026	--	98.974
16 day	25.15	0.557	--	--	2.213	--	97.787
III Complete Feed							
0	26.15	0.116[a]	14.035[a]	30.118[a]	0.449	53.722	45.829
4 day	26.61	0.851[b]	7.919[b]	16.994[b]	3.260	29.731	67.009
16 day	25.60	2.622[c]	0.327[c]	.702[c]	10.246	1.260	88.494
IV Corn Silage							
0	36.21	2.592	19.549	41.951	7.168	54.033	38.800
4 day	37.49	2.242	20.553	44.105	5.977	54.826	39.197
16 day	36.89	2.497	18.794	40.331	6.761	50.988	42.251

[abc]Values within treatment columns with different superscripts are significantly different ($P<0.05$).

percent to 88.5 percent. The exact composition of this UAN was not determined; it was,however, thought to be reflective of an increase in microbial protein. In contrast, when urea (1.5 percent) was added to corn fodder alone, there was no significant decrease ($P > 0.05$) in the amount of urea present. The ammonia nitrogen level also remained fairly constant with time. The differences in the urea utilization of these two systems were thought to be due to the difference in the presence of readily available carbohydrates from the grain concentrate mixture. Several workers (3, 7, 53, 55, 56) have demonstrated the necessity of carbohydrates and the superiority of corn starch in furnishing energy and carbon skeletons for the _in vitro_ utilization of urea by microbes. It remains to be answered whether the rumen microbes used in the above studies (3, 7, 53, 55, 56) can be equated in number and type to that found in a silage fermentation system. It would appear that the 667 pounds concentrate per ton added to the corn fodder furnished adequate carbohydrate for the fixation of the 20 pounds urea (9.32 pounds N) added. Under the conditions of this trial, it can be concluded that in an anaerobic fermentation of corn silage, given sufficient carbohydrates, the dynamic microbial population is capable of fixing ammonia to a significant degree. In neither the urea silage nor the urea complete feed was any appreciable amount of urea N present after fermentation. These results are in agreement with Everson _et al_. (20) who found increased incorporation of ^{15}N urea into microbial protein and decreased ^{15}N loss as volatilized ammonia with increased dry matter and carbohydrates in a corn silage fermentation.

CHAPTER V

EXPERIMENT II

Objective of Experiment

The objective of this investigation was to evaluate the performance of lactating cows fed one of three complete feeds: I) an ensiled complete feed prepared with a 3 percent urea concentrate and corn silage mixed before ensiling, II) a complete feed prepared with a 3 percent urea concentrate and corn silage mixed at feeding, and III) a control complete feed mixed at feeding with a natural-protein concentrate and corn silage.

Experimental Procedure

Thirty-seven Holstein cows were used in a continuous-type, 14-week feeding trial. All of the cows had calved in a period of two months preceding the start of the trial. The 14-week experimental period was preceded by a one-week adjustment period and a two-week standardization or preliminary period. During the preliminary period, all cows received the control feed, Treatment III. Treatment III consisted of concentrate I and corn silage mixed at feeding in a one part concentrate to two parts corn silage ratio, which was calculated to be approximately a 60:40 ratio on a dry matter basis. Weekly milk samples were collected and milk fat determined for each cow. Four percent FCM was calculated for the preliminary period. The cows were assigned to trios based on FCM production during the preliminary period, and cows within each trio were randomly assigned to one of three treatments.

The cows were housed in tie stalls equipped for obtaining individual feed consumption data. Animals were allowed to exercise approximately one hour twice daily when taken to the milking parlor. The cows were milked in a standard two-in-line, walk-through parlor. The cows received no feed in the parlor while being milked.

One cow within each trio remained on the control ration, Treatment III, for the duration of the trial. Each of the other two cows in each trio was switched to one of two treatments: I) Concentrate I and corn silage mixed at time of ensiling, II) Concentrate I and corn silage mixed at feeding. The formulas for the concentrates are given in Table 1. All cows were fed three times per day and amounts fed were weighed and recorded. Refusals were weighed and recorded each day before the morning feeding. The amounts offered were adjusted weekly so as to minimize refusals. In addition, five pounds of mixed grass-legume hay was fed to each cow every day. Trace mineralized salt and water were available at all times to the animals.

Body weights were taken and recorded for each cow on three consecutive days at the end of the preliminary period and again on the last three days of the experimental period.

Daily milk yield was recorded using the stationary weigh jars in the parlor. Once each week, morning and evening milk samples were collected and analyzed for milk fat.

Results and Discussion

The analyses of the complete feeds are given in Table 5. Although the feeds were formulated to be isonitrogenous, there was a 1 percent

Table 5. Analyses of Complete Feeds Used in Experiment II

Component	Treatment		
	I	II	III
	%		
Moisture	45.28	48.63	47.78
Crude Protein[a]	15.97	16.72	16.97
pH	3.95	4.75	4.50
Acid-Detergent Fiber[a]	15.34	16.03	16.09
Lignin[a]	2.25	2.51	3.29

[a]Dry Matter Basis.

difference between Treatments I and III at feeding. The ensiled complete feed (I) was slightly lower in ADF, although not significantly so. There was, however, a significantly lower amount of lignin in Treatment I than Treatment III ($P < 0.05$). Treatment II was not significantly different from either I or III in lignin content.

The distribution of the nitrogen within each complete feed is presented in Table 6. As was found in Experiment I, after ensiling in the presence of excess carbohydrate, there was a significant reduction in the urea content of Treatment I. There was also an increase in ammonia N concentration.

The feed intake, as well as dry matter per 100 lb body weight, is given in Table 7. On both the wet intake basis and a percent body-weight basis the intake was significantly lower ($P < 0.05$) for Treatment I than either Treatment II or III when adjusted for preliminary period intake values. There was no detectable difference between intake with Treatments II and III. The mixing of the 3 percent urea concentrate with the corn silage apparently overcame the palatability problems encountered with high urea concentrates reported by others (2, 6, 34, 65). The lowered intakes with the ensiled ration were not in agreement with other research (19, 48) which found no difference in intake between rations mixed at ensiling and those mixed at feeding. The weight gains per cow for the 14-week experimental period were 131.2, 160.1 and 226.7 lbs, respectively for Treatments I, II, and III. The weight gain for Treatment III was significantly higher ($P < 0.05$) than Treatment I. Treatment II was not significantly different ($P > 0.05$) from the other two treatments.

Table 6. Nitrogen Distribution of Complete Feeds in Experiment II

Treatment	Total N	Ammonia N	Urea N	Unaccounted-For N
	mg/gDM			
I	25.55	3.743	1.412	20.39
II	26.75	0.232	11.275	15.24
III	27.15	—	—	27.15

Table 7. Mean Weekly Intake of Cows in Experiment II

Week	Treatment I		Treatment II		Treatment III	
	Actual Intake (lb/wk)	Dry Matter Intake Per 100 lb B.W. (lb/day)	Actual Intake (lb/wk)	Dry Matter Intake Per 100 lb B.W. (lb/day)	Actual Intake (lb/wk)	Dry Matter Intake Per 100 lb B.W. (lb/day)
Preliminary[a]	326.9	1.95	338.5	1.97	337.1	2.00
1	313.5	1.85	403.9	2.35	401.4	2.38
2	322.2	1.88	435.4	2.51	400.6	2.33
3	346.4	2.03	424.0	2.42	416.4	2.38
4	365.9	2.08	426.6	2.41	443.9	2.50
5	347.5	1.95	403.5	2.25	440.8	2.44
6	333.4	1.86	411.6	2.28	452.7	2.46
7	331.3	1.84	416.2	2.28	462.4	2.49
8	325.1	1.80	454.2	2.46	464.2	2.48
9	351.2	1.94	466.0	2.50	467.9	2.48
10	334.2	1.84	455.9	2.43	465.1	2.44
11	307.9	1.69	428.3	2.28	440.8	2.29
12	338.1	1.85	416.9	2.20	455.9	2.36
13	329.3	1.80	423.1	2.22	443.0	2.27
14	322.3	1.76	423.4	2.20	437.6	2.22
Uncorrected mean	333.5[b]	1.87[b]	427.8[c]	2.34[c]	442.4[c]	2.39[c]
Adjusted mean	338.2[b]	1.92[b]	425.0[c]	2.33[c]	440.5[c]	2.40[c]

[a]Preliminary data is mean of three weeks.

[bcd]For a given variable, means with a different superscript are significantly different ($P<0.05$).

The milk yields, fat percentages, and 4 percent FCM produced are presented by weeks in Table 8. By the univariate analysis of variance methods no significant ($P > 0.05$) treatment effect on either of the three production variables was found.

As previously described, each production variable was then fitted to a regression equation with wk, wk^2, and wk^3 as the independent variables. The regression coefficients from the derived polynomial describing the production curve showed no significant treatment effects when subjected to univariate analysis of variance. There was no treatment effect on the regression coefficients for the milk, fat, or FCM production curves, which are given in Figures 1, 2, and 3, respectively. The equations for these curves are presented in Table 9. The treatment effects were then tested for equality by the multivariate analysis of variance using the likelihood ratio test of significance. The analysis of variance tables are presented in Appendix Tables 19, 20, and 21. With this method, also, no significant treatment effect ($P > 0.05$) was found for the actual milk, fat percent, or FCM curves. The lack of a treatment effect on milk production agrees with the work of Hastings (28) and Lassiter (43) with a 3 percent urea concentrate and Plummer (63) with a 2 percent urea concentrate. However, the lack of a treatment effect on butterfat percentage is in conflict with Plummer's (63) work in which a significant elevation was found with the 2 and 3 percent urea concentrates. Neither Hastings (28) nor Huber (33) found a butterfat increase while feeding a 3 percent urea concentrate.

The costs of the concentrates and the complete feeds are given in Table 10. The feed cost per cow per week is also given in this table.

Table 8. Mean Weekly Milk Production, Fat-Corrected-Milk Production, and Milk Fat Percentage for Cows in Experiment II

Week	Treatment I			Treatment II			Treatment III		
	Actual Milk (lbs)	Milk Fat (%)	FCM (lbs)	Actual Milk (lbs)	Milk Fat (%)	FCM (lbs)	Actual Milk (lbs)	Milk Fat (%)	FCM (lbs)
Preliminary[a]	355.9	3.00	301.0	369.0	3.02	312.4	365.3	2.51	282.5
1	368.7	3.62	345.1	371.3	3.73	352.3	372.4	3.20	323.2
2	370.1	3.05	313.9	375.2	3.34	334.5	370.3	2.75	299.5
3	361.2	3.40	325.9	373.1	3.65	349.2	373.0	3.09	320.7
4	369.5	3.18	322.2	369.9	3.71	351.6	378.8	3.17	332.9
5	360.3	3.08	308.0	365.0	3.65	341.7	373.4	3.07	322.9
6	364.1	3.36	327.4	368.3	3.75	351.8	371.5	3.35	336.4
7	350.9	3.51	323.9	361.2	3.80	348.8	368.4	3.42	337.4
8	348.9	3.03	296.0	352.7	3.39	318.7	361.9	2.98	308.8
9	335.9	3.28	297.9	352.1	3.54	325.8	352.7	3.26	315.9
10	338.7	3.40	306.7	356.3	3.54	329.9	349.6	3.33	317.8
11	323.1	3.35	291.3	344.4	3.90	337.8	342.1	3.08	294.7
12	322.6	3.33	288.7	343.1	3.61	321.7	336.9	3.42	306.8
13	314.8	3.71	299.7	337.2	3.78	323.1	334.2	3.48	305.7
14	288.0	4.40	287.6	327.2	3.88	319.0	325.6	3.35	290.9
Uncorrected mean	344.1[b]	3.41[b]	309.6[b]	356.9[b]	3.66[b]	336.1[b]	357.9[b]	3.21[b]	315.3[b]
Adjusted mean	350.1[b]	3.32[b]	307.4[b]	352.5[b]	3.56[b]	325.2[b]	356.4[b]	3.39[b]	327.2[b]

[a]Preliminary data is mean of three weeks.

[b]For a given variable, means with different superscripts are significantly different ($P<0.05$).

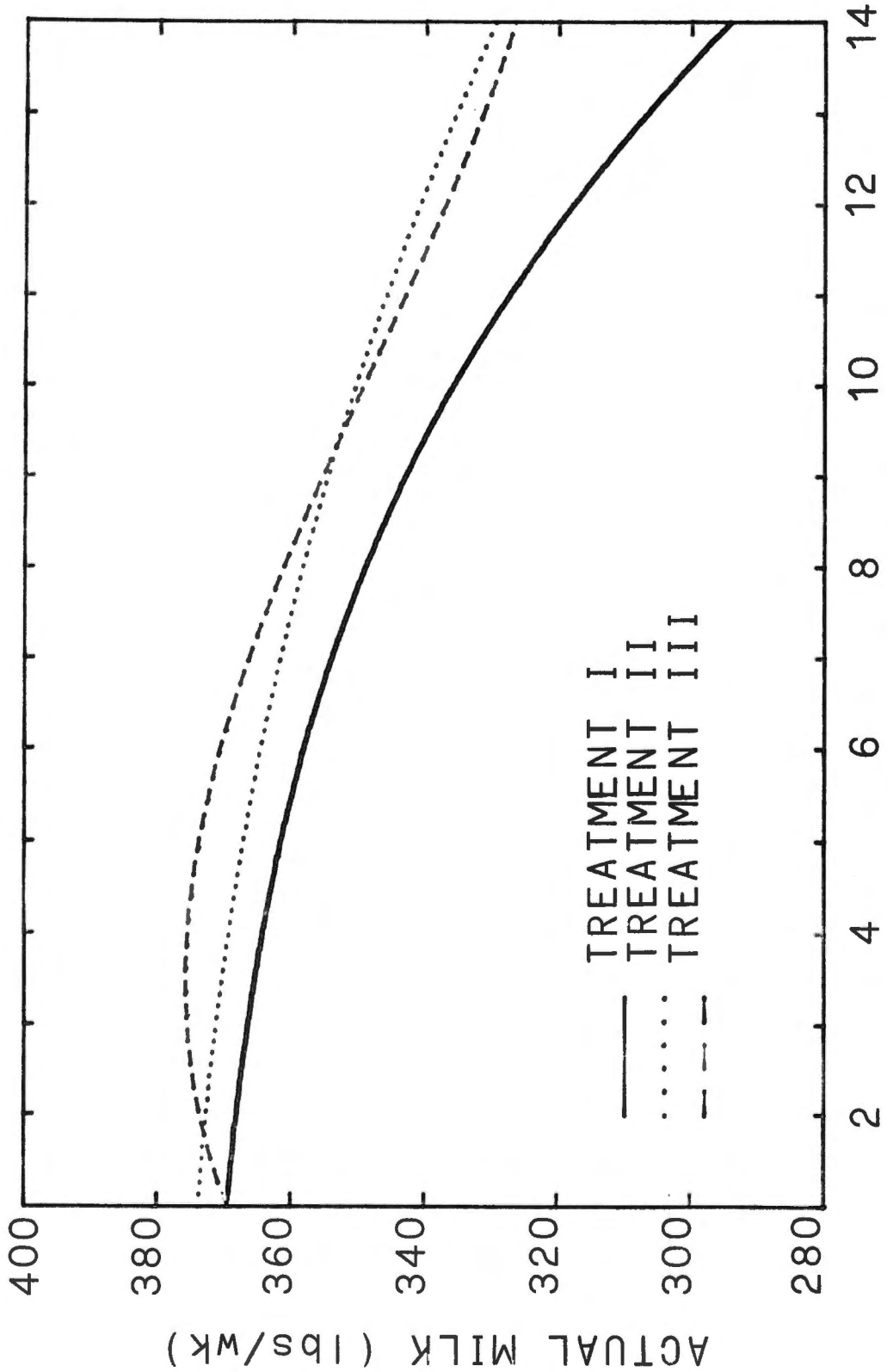


Figure 1. Trinomial regression curves for milk production of cows on Experiment II.

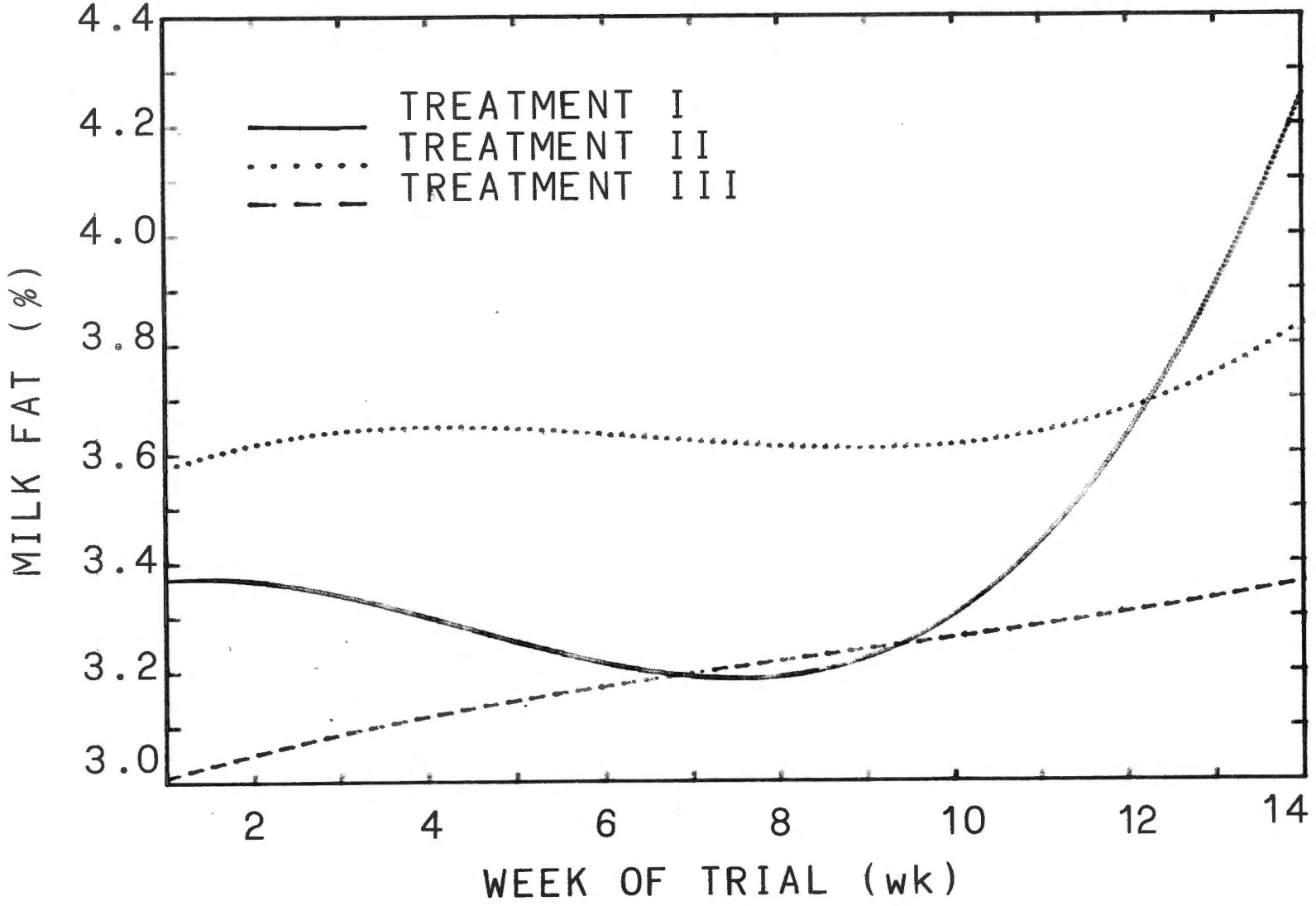


Figure 2. Trinomial regression curves for fat percentage of cows on Experiment II.

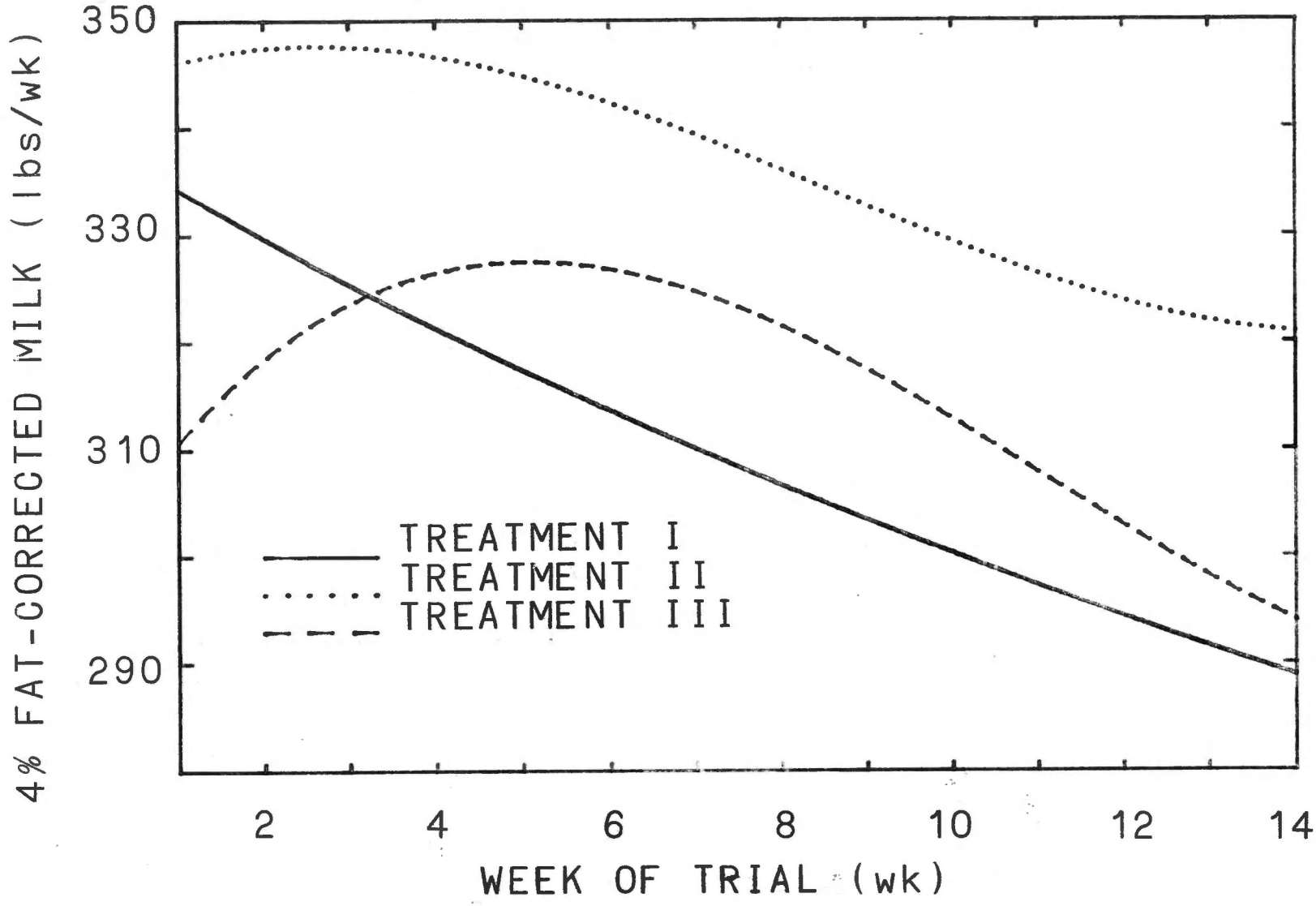


Figure 3. Trinomial regression curves for 4 percent fat-corrected-milk production of cows on Experiment II.

Table 9. Regression Coefficients for Production Functions[a] in Experiment II

Treatment	Regression Coefficients			
	a	$b_1(wk)$	$b_2(wk^2)$	$b_3(wk^3)$
I				
Milk	270.713	-1.099	-0.055	-0.018
Fat	3.340	0.050	-0.022	0.002
FCM	339.090	-4.904	0.123	-0.002
II				
Milk	374.835	-0.712	-0.150	-0.002
Fat	3.506	0.082	-0.014	0.001
FCM	343.238	3.617	-0.819	0.032
III				
Milk	363.134	7.888	-1.368	0.044
Fat	2.962	0.051	-0.003	0.000
FCM	300.353	11.897	-1.521	0.046

[a] $\hat{Y}_i = a + b_1(wk) + b_2(wk^2) + b_3(wk^3)$, where $\hat{Y}$ = production variable and wk = week of experimental period.

Table 10. Cost of Concentrates[a] and Complete Feeds[b] Used in Experiment II

Treatment	Concentrate Cost/T	Complete Feed Cost/T	Cost/cow/week
I	$63.72	$27.95	$4.66
II	63.72	27.95	5.98
III	75.70	31.95	7.07

[a]Prices based on ingredient cost as of August 31, 1972.

[b]Computed using concentrate cost and $10/T as cost of all corn silages.

The obvious cost advantage of the addition of urea is evident from this table by comparing Treatments II and III, where there was no difference in milk produced. The lower cost of feeding the cows on Treatment I was partially offset by a statistically non-significant, yet economically detectable, decrease in milk production.

In evaluating these three complete feeds, it was evident that there were no differences between Treatments II and III as to either intake or performance. The lowered intake with Treatment I would be difficult to justify on a urea basis. The sustained production and weight gains of the cows on Treatment I would indicate that their protein and energy requirements were being met adequately, and that cows receiving Treatments II and III were consuming above their requirements as evidenced by their greater body weight increases. The urea feed, when ensiled, apparently possessed some factor restricting luxury intake.

It can be concluded from the data presented here that, when incorporated into a complete feed, a 3 percent urea concentrate has no adverse effects on intake or production of lactating cows.

CHAPTER VI

EXPERIMENT III

Objective of Experiment

The objective of this investigation was to evaluate the difference, if any, in nutrient digestibility and nitrogen balance of animals fed four complete feeds: I) an ensiled complete feed prepared with a 3 percent urea concentrate and corn silage mixed before ensiling, II) a complete feed prepared with a 3 percent urea concentrate and corn silage mixed at feeding, III) a complete feed prepared from a non-urea, natural-protein concentrate and corn silage mixed before ensiling, and IV) a complete feed prepared from a non-urea, natural-protein concentrate and corn silage mixed at feeding.

Experimental Procedure

Eight yearling Holstein steers averaging 796.5 lbs were allotted to four treatment groups and placed in individual metabolism crates where total feces and urine collection was possible. The animals were given a one-week adjustment period and a two-week period to adapt to their respective ration. Treatments I and II consisted of Concentrate I (Table 1) and corn silage. Treatment I was mixed at ensiling; Treatment II was mixed at feeding. Treatments III and IV consisted of Concentrate II (Table 1) and corn silage. Treatment III was mixed at ensiling; Treatment IV was mixed at feeding. All feeds were mixed on a one part concentrate to two parts silage basis, which was calculated to give a 60:40 concentrate to forage ratio on a dry matter basis. The animals were fed

equal parts of the total ration intake twice daily, with refusal weighed before each feeding. The amounts fed were adjusted so as to minimize refusals. Water and trace-mineralized salt were provided ad libitum. The animals were weighed on the first day of the adaptation period and again on the last day of the collection period. After the adaptation period, a five-day collection period was conducted. After the first collection period, the two urea-fed pairs switched rations as did the non-urea pairs. Another adaptation period was allowed before another five-day collection period.

Feces were collected daily and a 5 percent sample from each animal was composited and refrigerated at 5 C in jars containing thymol to retard mold formation. Total daily urine excretion of each steer was collected in jars containing 25 ml of 6N HCl and 5 g of thymol to prevent spoilage. Ten percent of the daily sample was taken, composited for each steer with 6N HCl and thymol, and refrigerated until analyzed.

Fecal samples from each animal were dried for 72 hours in a forced-air oven at 65 C. The samples were allowed to air-equilibrate for 48 hours, reweighed, and ground through a medium mesh screen (2 mm) in a Wiley Mill.

Samples of feeds and feces were analysed as previously outlined, and urine was analyzed in triplicate for nitrogen according to A.O.A.C. (1) methods.

Results and Discussion

The analyses of the four complete feeds are given in Table 11. The distribution of the nitrogen within each complete feed is presented

Table 11. Analysis of Feeds Used in Experiments III and IV

Component	Complete Feed				Hay
	I	II	III	IV	
	%				
Dry Matter	54.3	52.8	56.0	52.1	93.7
Crude Protein[a]	14.7	15.6	14.0	16.0	13.9
pH	4.05	4.85	3.95	4.65	
Acid-Detergent Fiber[a]	14.7	16.9	15.7	15.9	37.1
Lignin[a]	2.4	2.5	3.8	2.4	6.2

[a]Dry Matter Basis.

in Table 12. The fermentation changes were very similar to those discussed in Experiment II. It was evident from organoleptic examination that Treatment III had been overheated or caramelized during fermentation. This was confirmed by a significantly higher ($P < 0.05$) N content of Treatment III ADF.

The intakes for the four treatments are given in Table 13. Although urea addition had no significant effect ($P > 0.05$ on intake, the process of ensiling significantly reduced ($P < 0.05$) intake. Both ensiled treatments, I and III, were significantly lower ($P < 0.05$) in intake than their non-ensiled counterparts. This does not agree with work by Derbyshire et al. (19) and Marshall and Browning (48) who found no differences in dry matter intake between ensiled complete feeds and the same feeds mixed at feeding.

As shown in Table 11, Treatment I was significantly lower in ADF content than Treatment II which agrees with the results of Experiment I and the work of Gordon et al. (24) who suggested the conversion of cellulose or hemicellulose to a simpler form of dry matter. The apparent increase in lignin content of Treatment III may have been an artifact of the high temperatures which caused the caramelization of Treatment III.

Apparent digestion coefficients were calculated for dry matter, crude protein, and acid-detergent fiber. The addition of urea had a significant effect ($P < 0.05$) on dry matter digestibility (DMD). The DMD of Treatment I was significantly higher than Treatment III. No other differences were statistically significant ($P > 0.05$). The nitrogen digestibility for Treatment III was significantly lower ($P < 0.05$)

Table 12. Nitrogen Distribution of Complete Feeds in Experiments III and IV

Treatment	Total N	Ammonia N	Urea N	Unaccounted-For N	ADF-N[a]
	mg/gDM				
I	23.52	3.341	1.234	18.945	1.030
II	24.96	0.333	11.117	13.510	1.782
III	22.40	0.486	0.233	21.681	2.135
IV	25.60	--	--	25.600	1.595

[a]Nitrogen recovered from ADF fraction.

Table 13. Collection Period Intake of Steers on Experiment III

Intake	Treatment			
	I	II	III	IV
Complete Feed (lbs/wk)	110.5	176.5	150.1	175.4
Adjusted[a]	112.1	178.2	148.5	173.8
Dry Matter/100 lbs B.W.	1.49	2.24	2.08	2.33
Adjusted[a]	1.51	2.26	2.08	2.31

[a]Adjusted for preliminary intake.

than any of the other three treatments. Acid-detergent fiber digestibility followed the same pattern as nitrogen digestibility. The decrease in nitrogen availability in overheated silage has been reported by Gordon et al. (24).

Nitrogen balance data are presented in Table 14. These data indicate that there were no significant differences ($P > 0.05$) between Treatments II and IV in the percent of total nitrogen consumed that was excreted in the feces or urine, or the percent of total nitrogen intake that was retained in the body. Van Horn et al. (80) indicated that nitrogen digestibility was essentially equal for cows receiving the same amount of total nitrogen from either a control or urea-supplemented ration. Plummer (63) found nitrogen intake and digestibility to be 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.

The digestibilities for Treatment I were very similar to those of Treatments II and IV; however, there was a significantly higher ($P < 0.05$) percentage excreted in the urine and a significantly lower ($P < 0.05$) percentage retained in the body. The increased urinary excretion could indicate three things: 1) a loss of nitrogen from proteins being deaminated for energy from the highly significantly lowered ($P < 0.01$) intakes of the animals on Treatment I; or 2) the quality of the digested protein in Treatment I was low enough to cause a reduction in retention; or 3) there was insufficient available energy in the rumen contents of these animals to furnish energy for N fixation of ammonia released during fermentation. The fact that these animals were losing weight would

Table 14. Effect of Treatment on Nutrient Digestibility and Nitrogen Balance in Experiment III

Item	Treatment			
	I	II	III	IV
Number of animals	4	4	4	4
Weight change, 16/day	-1.03	1.35	1.95	0.25
Apparent Digestibility (%)				
Dry Matter	75.4[a]	71.9[ab]	67.8[b]	70.6[ab]
Nitrogen	75.3[a]	75.3[a]	59.8[b]	73.7[a]
ADF	44.2[a]	43.4[a]	27.3[b]	39.3[a]
N Balance, g/day				
Intake N	128.08	211.24	171.04	212.44
Fecal N	31.97	52.72	68.96	56.10
Urinary N	91.01	112.42	74.80	112.94
Retained N	5.10[a]	46.10[b]	27.28[b]	43.40[b]

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

lend credence to the first postulation, which would predispose a palatability problem with Treatment I.

The animals on Treatment III excreted a higher percentage ($P < 0.05$) of their ingested N intake in the feces as indicated by the lower digestibility coefficient for N. There was no significant difference ($P > 0.05$) between urinary N percentage of Treatment III and either II or IV.

Results of the experiment indicate that the ensiling of a complete feed with urea will reduce intake. The data show no effect of urea addition at mixing on either DMD, N digestibility, or N balance. The caramelization and lowered digestibilities of the non-urea feed would appear to indicate an advantage of urea over soybean meal as a nitrogen additive in an ensiled complete feed both on a keeping-quality standpoint and a cost basis; however, the moisture content difference in Treatments I and III may have confounded the difference.

CHAPTER VII

EXPERIMENT IV

Objective of Experiment

The objective of this investigation was to evaluate the performance of lactating cows fed one of four complete feeds: I) an ensiled complete feed prepared from a 3 percent urea concentrate and corn silage mixed before ensiling, II) a complete feed with the same ingredients as I mixed at feeding, III) an ensiled complete feed prepared from a natural protein concentrate and corn silage, IV) a complete feed with the same ingredients as III mixed at feeding.

Experimental Procedure

Forty-one Holstein cows were used in a continuous-type, 12-week feeding trial. The selection of cows, grouping, and experimental design were the same as in Experiment II.

One cow within each foursome was assigned at random to one of the following treatments: 1) a complete feed mixed at ensiling from Concentrate I and corn silage, 2) a complete feed mixed at feeding from Concentrate I and corn silage, 3) an ensiled complete feed mixed at ensiling from Concentrate II and corn silage, 4) a complete feed mixed at feeding from Concentrate II and corn silage. All feeds were mixed on a wet basis from one part concentrate and two parts forage, which was calculated to give approximately a 60:40 concentrate-to-forage ratio on a dry matter basis. The composition of the concentrates is shown in Table 1, page 24.

Housing, feeding schedules and adjustments, body weight measurement, sampling and analyses of feeds and milk were the same as in

Experiment II. As in Experiment II, all cows received a 5 lb allotment of mixed grass and alfalfa hay each day. The composite analysis of the hay is given in Table II, page 47.

Results and Discussion

The analyses of the complete feeds are given in Table 11. These feeds were from the same silos as those used in Experiment III. As in Experiment II, even though the feeds were formulated to be isonitrogenous, there was considerable variation between the feeds on an as-fed basis.

The distribution of the nitrogen within each complete feed is shown in Table 12, page 49. As in Experiments I and II, after ensiling in the presence of excess carbohydrate, there was a significant reduction ($P<0.05$) in the urea content of Treatment I feed. The analyses of these four feeds is discussed in detail in Experiment III, Chapter VI.

The feed intake and dry matter intake per 100 lbs body weight are given in Table 15. There was a significant depression ($P<0.05$) of intake due to ensiling. Treatment IV intake was significantly higher ($P<0.05$) than either Treatment I or Treatment III. Treatment II was also significantly higher than Treatment I. There were no significant differences ($P<0.05$) in intake due to urea addition when adjusted for preliminary intakes. The lowered intakes with the ensiled rations were in conflict with earlier reports (19, 48) which found no difference in intake between rations mixed at ensiling and those mixed at feeding.

The weight gains for the period were 56.2, 51.6, 38.4, and 73.2 lbs for Treatments I through IV, respectively. Treatment IV gains were significantly higher (P 0.05) than any of the other three Treatments.

Table 15. Mean Weekly Intake of Cows in Experiment IV

Week	Treatment I		Treatment II		Treatment III		Treatment IV	
	Intake lb/wk	DM Intake/ 100 lb B.W. lb/day	Intake lb/wk	DM Intake/ 100 lb B.W. lb/day	Intake lb/wk	DM Intake/ 100 lb B.W. lb/day	Intake lb/wk	DM Intake/ 100 lb B.W. lb/day
Preliminary[a]	327.8	1.90	311.8	1.74	296.2	1.84	310.7	1.73
1	444.7	2.57	391.7	2.19	388.3	2.41	383.7	2.14
2	351.4	2.03	388.6	2.17	360.2	2.22	403.9	2.24
3	365.4	2.10	378.1	2.10	347.7	2.15	410.9	2.26
4	340.3	1.95	360.6	2.00	346.0	2.14	403.2	2.21
5	337.5	1.93	373.6	2.07	332.4	2.05	389.0	2.12
6	336.6	1.91	377.9	2.08	340.0	2.09	382.6	2.08
7	333.7	1.89	363.9	2.00	329.1	2.02	396.4	2.15
8	341.9	1.93	389.6	2.14	361.4	2.21	415.1	2.24
9	316.8	1.78	368.8	2.02	340.5	2.08	385.0	2.07
10	301.8	1.69	370.5	2.02	349.4	2.13	393.1	2.10
11	300.7	1.68	351.2	1.91	328.1	1.99	394.2	2.10
12	299.8	1.67	342.8	1.86	311.5	1.89	401.9	2.13
Uncorrected mean	339.2[b]	1.93[b]	371.4[cd]	2.05[cd]	344.6[bd]	2.12[bd]	396.6[c]	2.15[c]
Adjusted mean	330.4[b]	1.87[b]	371.6[cd]	2.04[cd]	353.4[bd]	2.16[bd]	397.3[c]	2.15[c]

[a]Preliminary data is mean of three weeks preliminary period.

[bcd]For a given variable, means with different superscripts are significantly different ($P<0.05$).

Treatment III gains were significantly lower ($P<0.05$) than Treatment IV, but were not different from either I or II.

The milk yields, fat percentages, and 4 percent FCM are presented by weeks in Table 16. By the univariate analysis of variance method, no significant differences ($P > 0.05$) were found in milk production when adjusted for preliminary yields. There was a significant effect ($P < 0.05$) on fat test due to ensiling. Urea inclusion had no effect on fat test. The fat test of the cows on Treatment I was significantly lower ($P < 0.05$) than Treatment IV. The butterfat test difference was also evident in the significant effect of ensiling on 4 percent FCM production. When adjusted for preliminary production, Treatment II was significantly higher ($P < 0.05$) than Treatment I. The yields on Treatment II were higher than both Treatments III and IV, although not significantly ($P > 0.05$).

As in Experiment II, the production variables were fitted to polynomial time equations. The regression coefficients from these equations, presented in Table 17, were analyzed by univariate analysis of variance. There was no significant urea or ensiling effect ($P > 0.05$) on any of the coefficients in the milk equations. There was a significant ensiling effect on the intercept values and the B_1 values for fat percentage; however, this effect was not sufficient to cause any significant difference ($P < 0.05$) in 4 percent FCM production. The treatment effects were tested for equality by the multivariate analysis of variance using the likelihood ratio test of significance. The multivariate analysis of variance tables are given in Appendix Tables 22 and 24.

Table 16. Mean Weekly Milk Production, Fat-Corrected-Milk Production, and Milk Fat Percentage for Cows in Experiment IV

Week	Treatment I			Treatment II			Treatment III			Treatment IV		
	Actual Milk	Milk Fat	FCM	Actual Milk	Milk Fat	FCM	Actual Milk	Milk Fat	FCM	Actual Milk	Milk Fat	FCM
	(lbs)	(%)	(lbs)	(lbs)	(%)	(lbs)	(lbs)	(%)	(lbs)	(lbs)	(%)	(lbs)
Preliminary[a]	404.5	3.65	379.8	417.0	3.40	380.8	385.8	3.45	353.5	407.5	3.42	373.8
1	444.7	3.55	378.5	412.5	3.25	367.3	386.3	3.44	352.5	403.0	3.29	358.7
2	397.2	3.25	349.2	408.8	3.43	375.4	381.5	3.38	344.6	395.5	3.22	350.7
3	402.3	3.08	342.3	410.2	3.23	363.0	379.9	2.81	309.8	386.1	3.45	355.0
4	393.3	2.95	327.7	404.0	3.41	367.2	371.0	3.25	330.3	382.2	3.28	341.5
5	378.7	2.72	302.6	397.9	3.37	361.2	367.0	3.21	321.0	376.9	3.43	344.9
6	379.8	2.78	309.7	396.1	3.11	344.4	365.2	3.05	312.2	371.8	3.22	329.2
7	372.3	2.72	295.6	393.7	3.19	348.4	361.0	3.14	311.6	365.6	3.31	328.0
8	341.5	3.08	293.9	384.9	3.16	338.3	354.8	2.87	292.9	361.4	3.30	324.1
9	344.6	3.13	298.7	385.1	3.24	341.4	340.2	3.09	289.2	358.0	3.46	329.5
10	339.3	2.77	275.2	379.4	3.03	325.6	344.4	2.93	287.1	349.8	3.31	314.1
11	340.7	2.82	278.7	378.7	3.02	325.8	345.4	2.89	284.4	352.7	2.99	298.9
12	337.0	2.90	282.6	368.0	3.06	318.5	333.6	2.92	275.9	349.9	2.88	292.3
Uncorrected means	372.6[b]	2.98[b]	311.2[b]	393.3[b]	3.21[bd]	348.0[c]	360.9[b]	3.08[bd]	309.3[bc]	371.1[b]	3.26[cd]	328.3[bc]
Adjusted mean	369.0[b]	2.88[b]	306.5[b]	384.2[b]	3.26[bd]	342.7[c]	373.0[b]	3.10[bd]	320.7[bc]	368.5[b]	3.30[cd]	329.6[bc]

[a]Preliminary data is the mean of the three preliminary weeks.

[bcd]For a given variable, means with different superscripts are significantly different ($P<0.05$).

Table 17. Regression Coefficients for Production Functions[a] in Experiment IV

Treatment	a	$b_1(wk)$	$b_2(wk^2)$	$b_3(wk^3)$
I				
Milk	399.991	6.905	-2.767	0.147
Fat	4.039	-0.531	0.074	-0.003
FCM	401.166	-27.304	2.291	-0.072
II				
Milk	415.720	-2.622	-0.105	0.001
Fat	3.219	0.091	-0.0193	0.001
FCM	369.153	2.215	-1.113	0.049
III				
Milk	389.222	-2.836	-0.364	0.019
Fat	3.568	-0.190	0.024	-0.001
FCM	361.792	-18.689	0.950	-0.040
IV				
Milk	409.296	-7.160	0.056	0.011
Fat	3.362	-0.076	0.022	-0.002
FCM	367.187	-8.539	0.922	-0.061

[a] $\hat{Y} = a + b_1(wk) + b_2(wk^2) + b_3(wk^3)$, where $\hat{Y}$ = production variable and wk = week of experimental period.

The milk production, fat percentage and 4 percent FCM curves are given in Figures 4, 5, and 6, respectively. With this method, there was a significant difference ($P < 0.05$) in the coefficients of the fat and 4 percent FCM production curves due to ensiling. Urea addition had no significant effect ($P > 0.05$) on any of the three production curves. Neither was there any significance found for the urea-ensiling interaction. The lack of a urea effect agrees with work by Hastings (28) and Lassiter (43) with a 3 percent urea concentrate and Plummer (63) with a 2 percent urea concentrate. The ensiling effect on fat production does not agree with the work of Marshall and Browning (48) and Derbyshire et al. (19) who found no difference in performance of lactating cows fed an ensiled complete feed or one mixed at feeding. There was a decrease in ADF with ensiling which may have been contributory to the reduction in fat percentage. A redistribution of the volatile fatty acids during the ensiling process is also a possibility which would require further investigation.

The costs of the concentrates and the complete feeds are given in Table 18. The feed costs per cow per week are also given in this table. Obviously, Complete Feeds I and II have a substantial advantage in feed cost; however, the fat reduction with Treatment I would decrease returns from milk sales. The savings from Treatment II would have been realized since both milk and fat production were maintained at a level equal to that of the non-urea groups.

It can be concluded from the data that a 3 percent urea concentrate can be incorporated in a complete feed and fed to lactating dairy

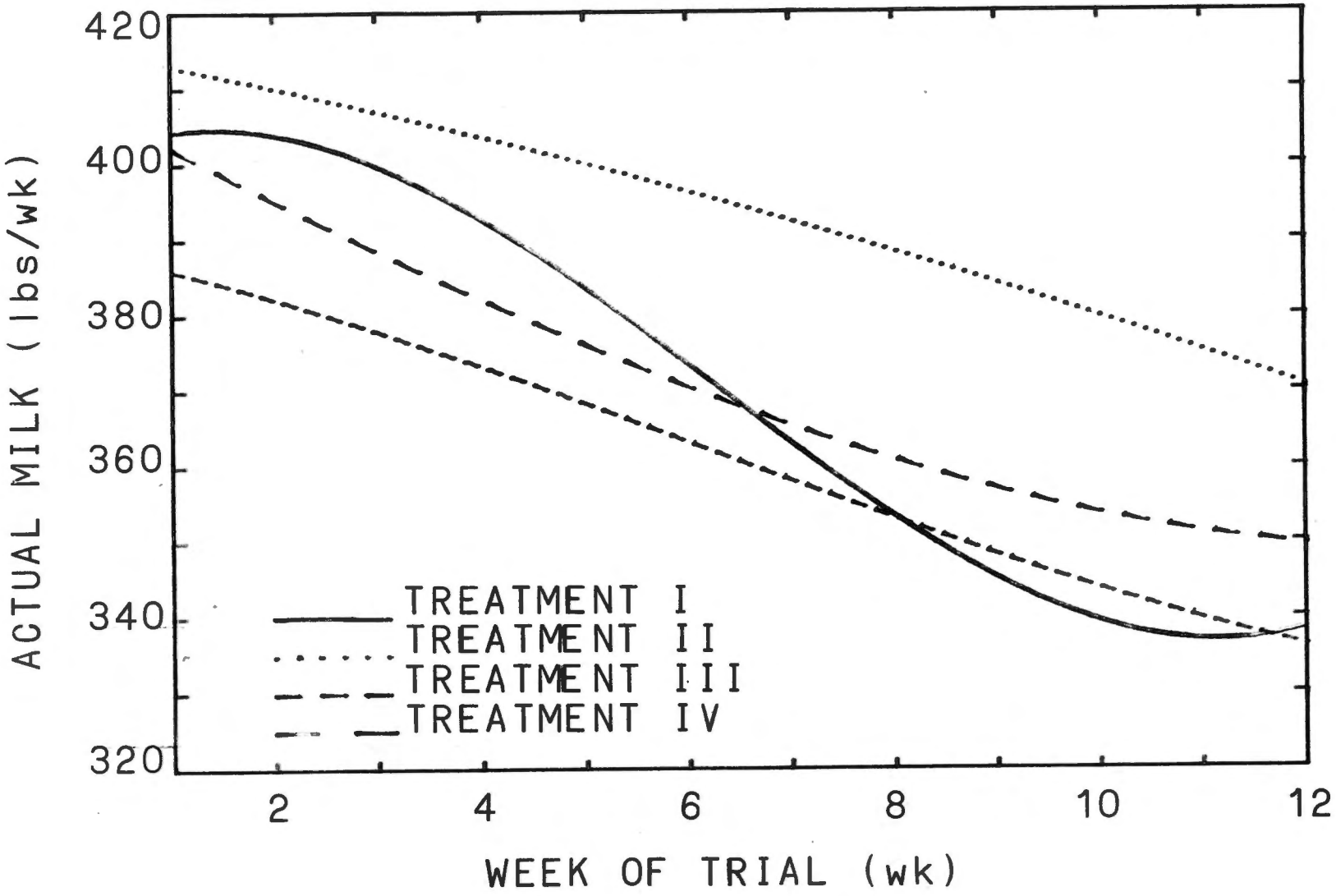


Figure 4. Trinomial regression curves for milk production of cows on Experiment IV.

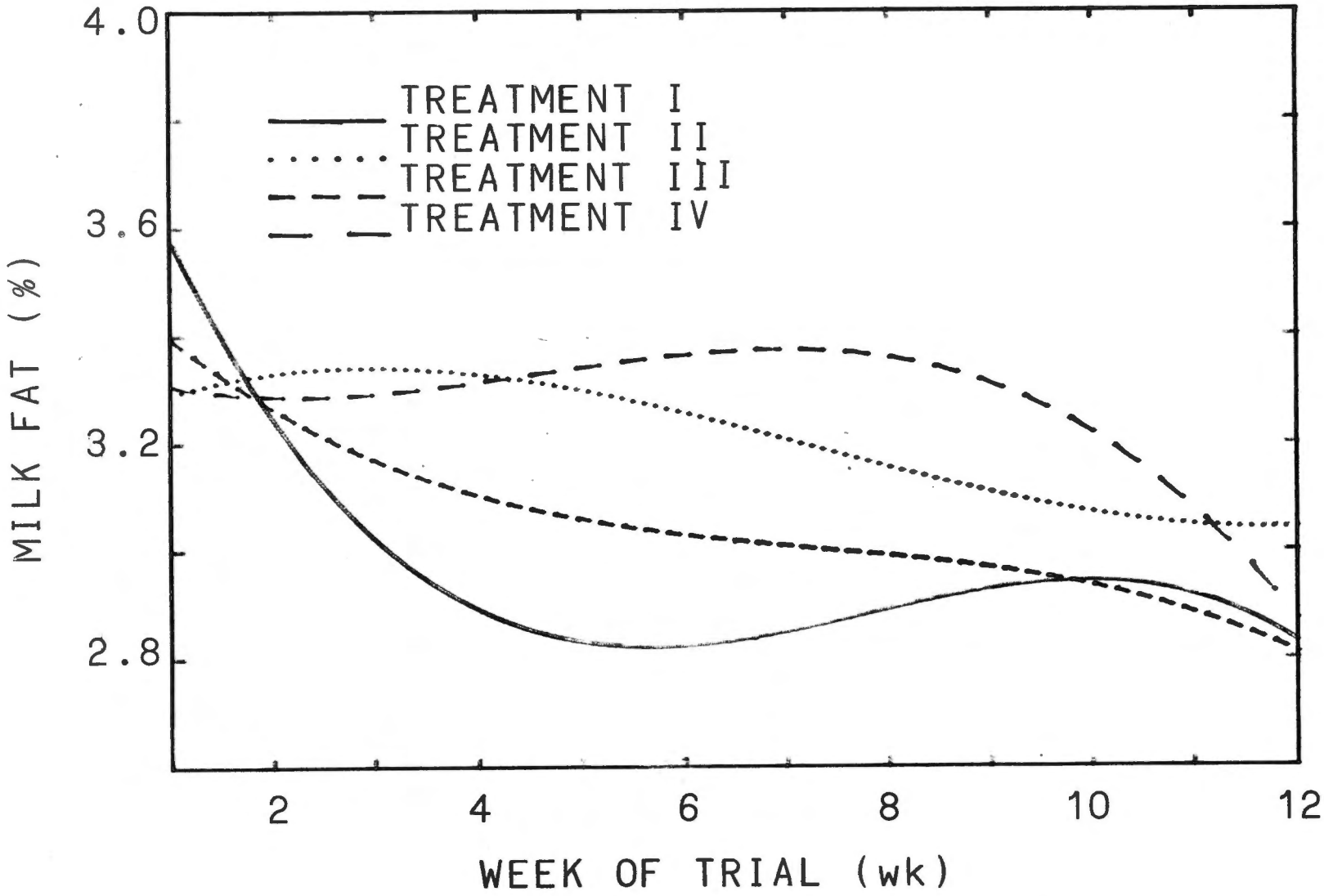


Figure 5. Trinomial regression curves for fat percentage of cows on Experiment IV.

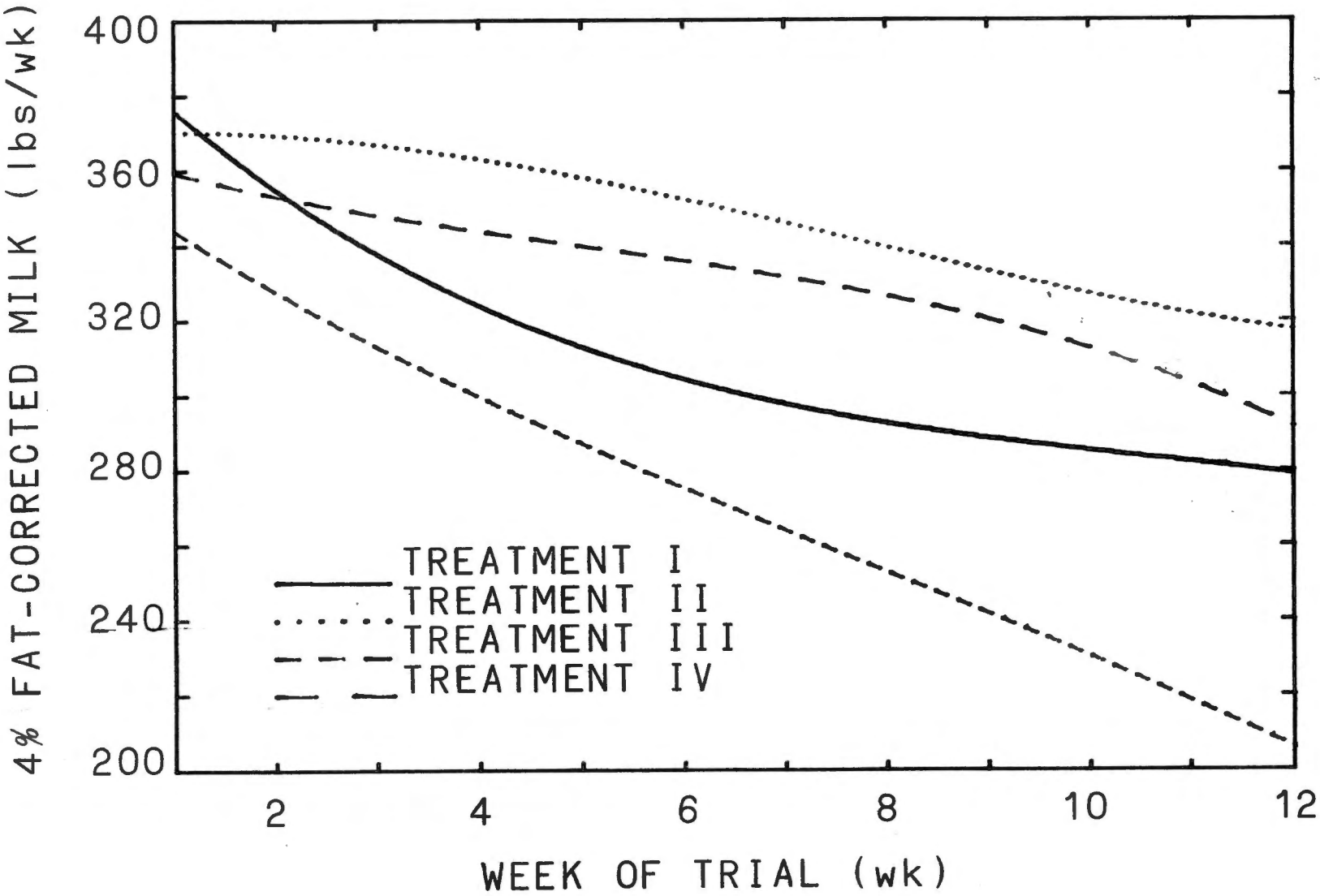


Figure 6. Trinomial regression curves for 4 percent fat-corrected-milk production of cows on Experiment IV.

Table 18. Cost of Concentrates[a] and Complete Feeds[b] Used in Experiment IV

Treatment	Concentrate Cost/T	Complete Feed Cost/T	Feed Cost cow/week
I	$63.72	$27.95	$4.60
II	63.72	27.95	5.01
III	75.70	31.95	5.51
IV	75.70	31.95	6.35

[a]Prices based on ingredient costs as of August 31, 1972.

[b]Calculated using concentrate cost and $10/T as cost of all corn silage.

cows with no adverse effects or sacrifice of milk or fat production. It has been shown that the ensiling of complete feeds with urea lowered the palatability of the feed significantly and may have a depressing effect on butterfat test.

CHAPTER VIII

SUMMARY

1. A significantly greater ($P < 0.05$) amount of urea was hydrolyzed and fixed by microorganisms in a corn-silage complete feed with carbohydrate added than in corn silage with urea as the only additive.

2. There was no significant ($P > 0.05$) loss of volatilized nitrogen from either the corn silage plus urea or the ensiled complete feed with urea added at ensiling.

3. In both ensiled complete feeds and corn silage, there was a significant ($P < 0.05$) reduction in lignin during ensiling.

4. Complete feed intake and dry matter intake per 100 lb body weight were significantly lower ($P < 0.05$) for complete feeds mixed at ensiling with 3 percent urea concentrate than either a complete feed with urea mixed in at feeding or complete feed without urea when fed to lactating cows or yearling steers.

5. With complete feeds mixed at feeding, there was no difference ($P > 0.05$) in intake with cows fed a complete feed with or without 3 percent urea in the concentrate.

6. Lactating cows fed a complete feed with no urea mixed at feeding had significantly higher ($P < 0.05$) weight gains than those fed an ensiled complete feed containing a 3 percent urea concentrate.

7. Milk production was not significantly different ($P > 0.05$) in cows fed complete feeds either ensiled or mixed at feeding, with or without urea at 3 percent in the concentrate.

8. Milk fat percentage was significantly lower ($P < 0.05$) in cows fed an ensiled complete feed with a 3 percent urea concentrate mixed at ensiling than in cows fed a complete feed mixed at feeding from corn silage and a 3 percent urea concentrate.

9. The ensiling of complete feeds composed of corn silage and concentrate with either 0 or 3 percent urea caused a significant reduction ($P < 0.05$) in intake when compared to the same feeds mixed at feeding.

10. The addition of 3 percent urea to the concentrates used in complete feeds either mixed at ensiling or at feeding had no significant effect ($P > 0.05$) on milk or fat production of lactating cows.

11. The use of a 3 percent urea concentrate in complete feeds with corn silage mixed at feeding significantly reduces ($P < 0.05$) the cost of feeding the lactating cow while maintaining production.

12. The use of a 3 percent urea concentrate in a complete feed mixed at ensiling significantly reduces ($P < 0.05$) the cost of feeding the lactating cow, but a reduction in fat test may lower the milk price sufficiently to offset the reduction in feed cost.

13. There was no significant difference ($P < 0.05$) in digestibility of dry matter or nitrogen in complete feed with a 3 percent urea concentrate mixed at ensiling or feeding.

14. The dry matter and nitrogen digestibilities were significantly lower ($P < 0.05$) in non-urea complete feed mixed at ensiling than a non-urea complete feed mixed at feeding.

15. A multivariate analysis of variance using the regression coefficients of production-time curves was shown to be an accurate means of testing for differences in the shapes of lactation response curves.

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APPENDIX

Table 19. Multivariate Analysis of Variance Table for Experiment II Regression Coefficients for Milk Production[a]

Source	Treatment	Error	Total
df	2	34	36
$SS_{(a)}$	885.63	209492.19	210377.82
$SP_{(a)(b_1)}$	-705.18	-18931.64	-19636.82
$SP_{(a)(b_2)}$	100.46	1251.05	1351.51
$SP_{(a)(b_3)}$	-4.02	-33.17	37.19
$SS_{(b_1)}$	652.04	11212.35	11865.20
$SP_{(b_1)(b_2)}$	-94.01	-1511.19	-1605.20
$SP_{(b_1)(b_3)}$	4.07	62.25	66.32
$SS_{(b_2)}$	13.55	233.77	247.32
$SP_{(b_2)(b_3)}$	-0.59	-10.29	-10.88
$SS_{(b_3)}$	0.03	0.47	0.50

[a]Calculated U-value = 0.7939.

[b]$U_{(4, 2, 34)(0.05)} = 0.6151$; accept H_o, no significant difference.

Table 20. Miltivariate Analysis of Variance Table for Experiment II Regression Coefficients for Fat Production[a]

Source	Treatment	Error	Total
df	2	34	36
$SS_{(a)}$	1.961	17.288	19.249
$SP_{(a)(b_1)}$	0.091	-5.435	-5.344
$SP_{(a)(b_2)}$	-0.050	0.584	0.534
$SP_{(a)(b_3)}$	0.003	-0.019	-0.016
$SS_{(b_1)}$	-0.008	5.467	5.475
$SP_{(b_1)(b_2)}$	-0.001	-0.836	-0.837
$SP_{(b_1)(b_3)}$	-0.000	0.037	0.037
$SS_{(b_2)}$	0.002	0.139	0.141
$SP_{(b_2)(b_3)}$	-0.000	-0.006	-0.006
$SS_{(b_3)}$	0.000	0.000	0.000

[a]Calculated U-value = 0.6553.

[b]Tabular $U_{(4, 2, 34)(0.05)}$ = .6151; accept H_o, no significant difference.

Table 21. Multivariate Analysis of Variance Table for Experiment II Regression Coefficients for 4 Percent FCM Production[a]

Source df	Treatment[b] 2	Error 34	Total 36
$SS_{(a)}$	14147.737	87314.394	101462.131
$SP_{(a)(b_1)}$	-4103.744	-6521.770	-10625.514
$SP_{(a)(b_2)}$	380.153	667.378	1047.531
$SP_{(a)(b_3)}$	-9.713	-30.296	-40.009
$SS_{(b_1)}$	1761.889	13621.616	15383.505
$SP_{(b_1)(b_2)}$	-172.145	-1941.775	-2113.920
$SP_{(b_1)(b_3)}$	4.981	76.008	80.989
$SS_{(b_2)}$	16.914	310.963	327.877
$SP_{(b_2)(b_3)}$	-0.495	-13.095	-13.590
$SS_{(b_3)}$	0.015	0.579	0.594

[a]Tabular $U_{(4,\ 2,\ 34)(0.05)} = 0.6151$.

[b]Calculated U-value = 0.6950423; reject H_o, no significant difference.

Table 22. Multivariate Analysis of Variance Table for Experiment IV Regression Coefficients for Milk Production[a]

Source	Urea[b]	Ensiling[c]	Urea Ensiling[d]	Error	Total
df	1	1	1	37	40
$SS_{(a)}$	756.172	3279.296	48.290	197159.108	201242.866
$SP_{(a)(b_1)}$	627.967	-1268.54	57.839	-34047.779	-34630.513
$SP_{(a)(b_2)}$	-112.680	282.166	-24.934	4341.379	4485.931
$SP_{(a)(b_3)}$	5.186	-14.191	1.528	174.131	-181.608
$SS_{(b_1)}$	521.514	490.713	69.276	33086.894	39168.397
$SP_{(b_1)(b_2)}$	-93.577	-109.151	-29.864	-6353.406	-6585.998
$SP_{(b_1)(b_3)}$	4.307	5.490	1.830	290.082	301.709
$SS_{(b_2)}$	16.791	24.279	12.874	1105.867	1159.811
$SP_{(b_2)(b_3)}$	-0.773	-1.221	-0.789	-51.341	-54.124
$SS_{(b_3)}$	0.036	0.061	0.048	2.403	2.548

[a] Tabular U-value$_{(4, 1, 37)(0.05)}$ = .7589.

[b] Calculated U-value for urea effect = .9701 (P>0.05).

[c] Calculated U-value for ensiling effect = .9192 (P>0.05).

[d] Calculated U-value for interaction = .8467 (P>0.05).

Table 23. Multivariate Analysis of Variance Table for Experiment IV Regression Coefficients for Fat Production[a]

Source df	Urea[b] 1	Ensiling[c] 1	Urea Ensiling[d] 1	Error 37	Total 40
$SS_{(a)}$	0.275	2.689	0.966	20.550	24.480
$SP_{(a)(b_1)}$	-0.146	-1.929	-0.797	-10.514	-13.386
$SP_{(a)(b_2)}$	0.006	0.248	0.144	1.721	2.119
$SP_{(a)(b_3)}$	0.000	-0.009	-0.007	-0.080	-0.096
$SS_{(b_1)}$	0.077	1.385	0.657	9.531	11.650
$SP_{(b_1)(b_2)}$	-0.003	-0.178	-0.118	-1.630	-1.929
$SP_{(b_1)(b_3)}$	-0.000	0.007	0.006	0.078	0.091
$SS_{(b_2)}$	0.000	0.023	0.213	0.288	0.524
$SP_{(b_2)(b_3)}$	0.000	-0.001	-0.001	-0.014	-0.016
$SS_{(b_3)}$	0.000	0.000	0.000	0.001	0.001

[a]Tabular U-value $_{(4, 1, 37)(0.05)}$ = 0.7589.

[b]Calculated U-value for urea effect = .8533 (P>0.05).

[c]Calculated U-value for ensiling effect = .7033, significant (P<0.05).

[d]Calculated U-value for interaction = .9248 (P>0.05).

Table 24. Multivariate Analysis of Variance for Experiment IV Regression Coefficients for 4 Percent FCM Production[a]

Source df	Urea[b] 1	Ensiling[c] 1	Urea Ensiling[d] 1	Error 37	Total 40
$SS_{(a)}$	4371.846	1812.442	3579.686	196578.342	206342.316
$SP_{(a)(b_1)}$	226.199	-2701.138	-1853.494	-50283.69	-54612.123
$SP_{(a)(b_2)}$	-73.415	233.643	323.110	7383.248	7866.586
$SP_{(a)(b_3)}$	8.204	-6.756	-13.648	-323.406	-335.606
$SS_{(b_1)}$	11.704	4025.591	959.704	42407.119	47404.118
$SP_{(b_1)(b_2)}$	-3.798	-348.205	-167.300	-6882.548	-6882.548
$SP_{(b_1)(b_3)}$	0.424	10.069	7.067	319.454	337.014
$SS_{(b_2)}$	1.233	30.119	29.165	1267.522	1328.039
$SP_{(b_2)(b_3)}$	-0.138	-0.871	-1.231	-59.972	62.212
$SS_{(b_3)}$	0.015	0.025	0.052	2.287	2.379

[a] Tabular U-value $_{(4, 1, 37)(0.05)} = 0.7589$.

[b] Calculated U-value for urea effect = 0.8542 ($P>0.05$).

[c] Calculated U-value for ensiling effect = 0.7018, significant ($P<0.05$).

[d] Calculated U-value for interaction = 0.9553 ($P>0.05$).

VITA

Dennis B. Longmire was born on June 4, 1944, in Dayton, Ohio. At the age of 10 years, he moved with his family to a dairy farm in Knox County, Tennessee. He attended public schools in that county and June, 1962, was graduated from Karns High School. That same month he entered the University of Tennessee, and in June, 1966, received a Bachelor of Science degree in Dairying. For the next three years, he was employed by Mayfield Dairy Farms, Athens, Tennessee, as an assistant herdsman. In September, 1969, he accepted a research assistantship at the University of Tennessee to study toward a Master's degree. In September, 1970, he received an NDEA Fellowship for further graduate work. The Master of Science degree was awarded in August, 1971. He continued graduate studies at the University of Tennessee and received the Doctor of Philosophy degree with a major in Animal Science in August, 1973.