Utilization of biuret and urea as affected by feeding interval and energy level

by Jesse George Armitage

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
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Abstract:
Biuret, urea, and soybean meal were evaluated as sources of nitro-gen for steers fed wintering rations. Trial I utilized 36 steer calves in six feed treatments fed 126 days. Three supplements were formulated to contain 20% crude protein equivalent (CPE). One was a soybean meal control, and the other two provided one-third CPE from either biuret or urea. Three pens of steers were fed 0.91 kg of one of the three supplements per head per day every day (ED). The remaining three pens received 1.81 kg supplement per head per day every other day (EOD). All pens received the same quantity of chopped grass hay per day. Weight gains were 0.6.7, 0.62, 0.63, 0.60, 0.58, and 0.57 kg per day, respectively, for steers fed the soybean meal supplement ED and EOD, the biuret supplemented ED and EOD, and' the urea supplemented ED and EOD. Weight gains, feed per kg gain or cost, per kg gain of the steers were not statistically significant by treatment.

Trial II was a metabolism study using three steers. Each steer was fed one of the three supplements,used in trial I. Digestibilities of nitrogen were greater for all steers fed ED as opposed to EOD. The urea supplement showed the greatest difference in nitrogen digestibility,. in favor of ED feeding. Digestibilities of energy of non-protein nitrogen (NPN) supplements were higher when the supplements were fed to steers ED. Digestibilities of supplemental nitrogen and energy appeared to be conversely related for NPN supplements. As nitrogen retention increased, energy retention increased for steers fed NPN supplements. The steer fed the control ration showed a decrease in energy retention as nitrogen retention increased. The overall trend of trial II favored feeding steers NPN supplements ED rather than EOD for the greatest retention of energy. Steers fed the NPN supplements appeared to retain nitrogen and energy as well as the steer fed the control supplement when steers were fed ED.

Three steers were assigned to one of three iso-caloric, iso-nitrogenous rations for a metabolism study for trial III. Two of the rations contained urea at. one-sixth and one-third of the CPE. The third ration was a soybean meal control. Energy retention and digestibility of all rations fed to steers,increased as the energy of the rations was increased. Digestibility of nitrogen decreased for the control and one-third CPE from urea-fed steers as energy consumption increased. Steers fed the control ration and the one-sixth CPE from urea ration showed increased nitrogen retention as energy increased while the steer fed the one-third CPE from Urea showed a decrease in nitrogen retention. Results of this trial indicated that one-sixth or one-third CPE of a 20% protein supplement may be supplied by urea. These supplements may be fed with straw as a source of roughage if ample readily-available carbohydrate is provided in the ration to insure maximum utilization of NPN.

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ABSTRACT

Biuret, urea, and soybean meal were evaluated as sources of nitrogen for steers fed wintering rations. Trial I utilized 36 steer calves in six feed treatments fed 126 days. Three supplements were formulated to contain 20% crude protein equivalent (CPE). One was a soybean meal control, and the other two provided one-third CPE from either biuret or urea. Three pens of steers were fed 0.91 kg of one of the three supplements per head per day every day (ED). The remaining three pens received 1.81 kg supplement per head per day every other day (EOD). All pens received the same quantity of chopped grass hay per day. Weight gains were 0.67, 0.62, 0.63, 0.60, 0.58, and 0.57 kg per day, respectively, for steers fed the soybean meal supplement ED and EOD, the biuret supplemented ED and EOD, and the urea supplemented ED and EOD. Weight gains, feed per kg gain or cost per kg gain of the steers were not statistically significant by treatment.

Trial II was a metabolism study using three steers. Each steer was fed one of the three supplements used in trial I. Digestibilities of nitrogen were greater for all steers fed ED as opposed to EOD. The urea supplement showed the greatest difference in nitrogen digestibility, in favor of ED feeding. Digestibilities of energy of non-protein nitrogen (NPN) supplements were higher when the supplements were fed to steers ED. Digestibilities of supplemental nitrogen and energy appeared to be conversely related for NPN supplements. As nitrogen retention increased, energy retention increased for steers fed NPN supplements. The steer fed the control ration showed a decrease in energy retention as nitrogen retention increased. The overall trend of trial II favored feeding steers NPN supplements ED rather than EOD for the greatest retention of energy. Steers fed the NPN supplements appeared to retain nitrogen and energy as well as the steer fed the control supplement when steers were fed ED.

Three steers were assigned to one of three iso-caloric, iso-nitrogenous rations for a metabolism study for trial III. Two of the rations contained urea at one-sixth and one-third of the CPE. The third ration was a soybean meal control. Energy retention and digestibility of all rations fed to steers, increased as the energy of the rations was increased. Digestibility of nitrogen decreased for the control and one-third CPE from urea-fed steers as energy consumption increased. Steers fed the control ration and the one-sixth CPE from urea ration showed increased nitrogen retention as energy increased while the steer fed the one-third CPE from urea showed a decrease in nitrogen retention. Results of this trial indicated that one-sixth or one-third CPE of a 20% protein supplement may be supplied by urea. These supplements may be fed with straw as a source of roughage if ample readily-available carbohydrate is provided in the ration to insure maximum utilization of NPN.

INTRODUCTION

Much of the native range of Montana is deficient in protein during the winter grazing period. Commercial supplements have been fed to provide additional protein and energy to range livestock. Non-protein nitrogen (NPN) compounds such as urea have been substituted for a portion of the natural protein to reduce the cost of these supplements.

A common management practice in recent years has been to feed twice as many pounds of the supplement every other day rather than feeding a given amount daily. The practice of feeding every other day started as a labor and time saving strategem and is especially common in areas where winter grazing is feasible. Every other day feeding has been practiced for twelve years at the Montana State University Red Bluff Research Ranch located at Norris, Montana. This method of feeding protein supplements to stock cows being wintered on the range has greatly increased desirable livestock grazing patterns.

Research at Montana State University has shown urea and biuret to be utilized effectively in range supplements as well as in wintering and fattening rations.

Two questions have arisen from this management practice: 1) What is the effect on the utilization of non-protein nitrogen in supplements fed to cattle every day versus every other day? 2) Is ample energy supplied to utilize effectively the non-protein nitrogen in the supplements fed with low quality roughages? These questions inspired an experiment to compare every day feeding versus every other day feeding of non-protein nitrogen supplements. A second experiment was designed to compare the utilization of non-protein nitrogen in conjunction with two energy levels.

LITERATURE REVIEW

History Of Non-Protein Nitrogen Research

The use of non-protein nitrogen (NPN) as a substitute for as much as one-third of the equivalent crude protein in protein supplements is not new. The discovery of nitrogen about 200 years ago brought about the first controlled experiments with nitrogen. Urea was discovered only a few years after nitrogen. After the synthesis of urea early in the nineteenth century, research on its use as a feed stuff began. The following excerpts from an excellent review by Stangel (1967) reveal the early history of non-protein nitrogens.

As early as 1891, Hagemann and Zuntz theorized that microorganisms in the rumen could synthesize bacterial protein from non-protein nitrogen compounds such as urea and that there were differences in food value and energy of cellulose, sugars, starch, and other carbohydrates. Digestibility was also shown to be affected by the addition of the carbohydrates. Voltz, from 1907 to 1920, obtained growth of lambs on a low-protein, semi-purified diet made up of starch, alkali-washed straw, inorganic salts and urea. He was one of the first to test the theory that non-protein nitrogen could be used by rumen microorganisms to form protein useful to the host animal.

Armsby (1911) published a comprehensive review of work on the utilization of non-protein nitrogen (NPN) by ruminants and non-ruminants. Facts concerning the role of rumen microorganisms in converting NPN to protein, their subsequent digestion by the host animal;

and the conversion to protein for milk and growth were deduced. He stated that the limiting factor in the utilization of the protein formed from NPN appeared to be the extent to which the protein could be formed rather than any inferior nutritive value of the protein. It was also noted that, in the presence of adequate protein, non-protein nitrogen usually failed to contribute to an increase in the production of nitrogenous constituents of the animal.

No real interest in non-protein nitrogen research took place in the United States for the next 20 years. The bulk of the research on the role of NPN in ruminant nutrition continued to be carried on by European workers, primarily German. The commercial success of the direct manufacture of ammonia from atmospheric nitrogen and the construction of a plant in Germany in 1913 to produce synthetic nitrogen products stimulated research in the use of these non-protein compounds as protein substitutes. It was not until the 1930's that Hart et al. (1938) published the results of the first intensive research in the United States on the use of urea and ammonium bicarbonate in ruminant rations. These researchers concluded that ruminants could use simple nitrogen compounds through the action of the rumen microorganisms. Commercial production of urea in the United States began during 1935, making urea available at prices which allowed its use by the feed manufacturer. There has been little doubt that urea became the only widely used NPN source because of its commercial availability in the

United States and Europe.

In 1940, the Executive Committee of the Association of American Feed Control Officials adopted a resolution providing for the use of no more than one-third of the total nitrogen in the ration from urea and ammoniacal nitrogen. Urea and ammonium bicarbonate were accepted sources of non-protein nitrogen.

Wegner et al. (1940) reported that readily available energy stimulated the disappearance of inorganic nitrogen. Both urea and ammonium bicarbonate were shown to be converted into bacterial protein. Feeding of high total nitrogen rations with a large percentage of natural protein resulted in poor utilization of urea. It was concluded, at this time, that: 1) the rate of conversion of urea nitrogen to protein in the rumen decreased when the protein level of the rumen contents exceeded 12 percent, 2) that urea was not excreted via the skin, 3) that urea was not retained as efficiently as casein and other protein sources, and 4) that urea in the ruminant ration exerted no adverse effect on the composition, flavor and NPN content of the meat and the milk.

The extended use of urea as a nitrogen source for cattle rations lagged much behind the work of Hart et al. (1939). However, under the stress of World War II, both the feed manufacturer and the farmer became familiar with the use of urea. Not until the early 1950's was evidence shown that urea could replace 25 to 33 percent of the protein nitrogen in cattle feeds. Acceptance of this fact was not completely satisfying until the publication of research by Bell et al. (1953), Beeson et al. (1964), Garrigus (1964), Beeson and Horn (1967), and Conrad and Hibbs (1968).

Every year humans have demanded more high quality natural proteins. This demand has induced more pressure on the animal kingdom (ruminants) to utilize sources of low quality proteins and/or non-protein nitrogens. The ability for the microorganisms present in the rumen to convert non-protein nitrogen to protein for use by the ruminant has now become a widely proven and accepted fact. The question then is: which non-protein nitrogens may be fed?

Sources of Non-Protein Nitrogen

Uric acid was reported as a good source of non-protein nitrogen by Oltjen et al. (1968) and Oltjen (1969a). In the earlier work, this author reported cattle fed uric acid to have the highest nitrogen retention when compared to urea, biuret, and urea phosphate; urea phosphate had nitrogen retentions less than any of the other three non-protein nitrogens tested.

Cyanuric acid was shown to cause a conversion of a negative nitrogen balance to a positive nitrogen balance, when fed to sheep by Clark et al. (1965). Neither triuret, nor urea, nor biuret provided as great a difference in nitrogen balance as did cyanuric acid. All four non-protein nitrogen feeds caused an increase of hay consumption, with cyanuric acid having the most noticeable effect. Altona and Mackenzie

(1964) found cyanuric acid could be utilized by sheep when fed with maize and low quality supplements. These authors showed cyanuric acid to contain 32 percent nitrogen and to be non-toxic.

Davis _et al_. (1956) reported dicyandiamide fed to milk cows to have no effect on weight gains or feed consumption when compared to urea, soybean meal, and a low-protein control. Dicyandiamide reduced milk production more than urea. Both urea and dicyandiamide improved the utilization of feed when added to the low-protein control, but not significantly.

Repp, _et al_. (1955) reported ammonium formamide as an inferior product in lamb fattening rations. Ammonium propamide and urea gave equal weight gains at the 15 percent and 30 percent level of substituted nitrogen.

In vitro studies by Acord _et al_. (1966) and _in vivo_ studies by Lewis (1962) show ammonium acetate, ammonium carbonate and ammonium phosphate to be equal to urea in promoting amino acid production. These NPN sources did not have as noticeable an effect on microorganisms growth as did casein.

Ammonium bicarbonate, in presence of soluble sugars, was shown by Hart _et al_. (1939) to be as effective as urea and slightly less favorable than casein. Urea supplied 43 percent of the total nitrogen and casein supplied 66 percent of the total nitrogen in their respective rations. Moreover, Wegner (1940) used _in vitro_ studies to show ammonium bicarbonate could be used as effectively as urea to promote micro-bacterial growth in the ruminant.

Tillman and Swift (1953) reported that ammoniated condensed distillers molasses solubles, ammoniated molasses and urea in supplements were utilized as well as soybean oil meal when fed to sheep. Four years later, Tillman et al. (1957a, 1957b) reported ammoniated cane molasses to be poorly utilized and caused a negative nitrogen balance. In both reports, the ammoniated cane molasses caused adverse stimulation to rumen microflora.

As has been reported earlier, urea has been known as a non-protein nitrogen longer than any other compound. Because it has been so well known and so inexpensive to produce, urea has been the most popular of the non-protein nitrogen compounds. In recent years, a condensation product formed by heat and pressure on urea called biuret has come into being. Meiske et al. (1955) were some of the first to report biuret as a suitable nitrogen source.

Urea As A Nitrogen Source

Urea has been undoubtedly the most highly researched product of those compounds sought to be used as non-protein nitrogens. Morgan et al. (1922) stated that urea could not be used to replace any part of the protein of a ration for sheep. Sixteen years later the first work done in America by Hart et al. (1938) showed growing dairy calves could utilize urea when added to a 6 percent protein basal ration.

This study compared ammonium carbonate, casein, and urea. Urea gave gains of nearly twice as much as the basal ration and appreciably higher gains than ammonium carbonate. Casein yielded gains of 11 kg. more than did urea. Wegner et al. (1941) found urea could be utilized in ruminant rations up to 4.5 percent equivalent crude protein of a 12 percent equivalent crude protein ration when no linseed oil meal was present. When over 18 percent protein was present in a ration, the rate and extent of urea utilization was markedly reduced.

Palatability was found to be a problem by Briggs et al. (1947), when urea supplied 50 percent of the equivalent crude protein of a ration in later stages of fattening steers. McCall and Graham (1953) also found urea to be slightly less effective than natural protein when fed to fattening steers as 20 percent and 25 percent of the equivalent protein. No significant differences were present in carcass grades or dressing percentages. This same work indicated urea to be satisfactory as a protein substitute and comparable to cottonseed meal when supplying 25 percent of the total dietary nitrogen.

Lofgreen et al. (1947) fed a 10 percent protein ration in which 40 percent of the equivalent crude protein was from urea. This supplement was compared to linseed meal, urea plus methionine, and dried egg. No significant differences were found among the rations for weight gain, digestion of dry matter, or digestion of protein. Urea plus methionine fed at .02 percent of the ration increased nitrogen retention above urea only and was comparable to the nitrogen retention of linseed meal. These authors stated that protein quality may be a factor to consider in the retention of dietary nitrogen. The insignificance of the effect of urea on protein digestion was shown by Colovos et al. (1963). On the other hand, Harris et al. (1943) showed more true protein to be present in the rumen of steers fed urea than those fed low protein control rations.

McCall and Graham (1953) showed non-protein nitrogens to be satisfactory protein substitutes in supplements when they replace 40 percent of the equivalent crude protein.

Nix and Anthony (1964) fed 17.5 percent urea in a 65 percent equivalent crude protein supplement to cattle at 454 grams per head per day. Significant increases in digestibilities of dry matter and protein over cottonseed meal supplements were observed. These authors stated that urea supplements were equal to cottonseed meal supplements when fed to beef cattle and were less expensive than natural protein supplements to feed.

In research by Lowry and McCormick (1969) urea was fed as 1.3 percent of the ration to finishing steers and was found to produce gains as efficiently as cottonseed meal. These authors revealed an increase in nitrogen digestibility when urea was substituted for cottonseed meal, although nitrogen retention was about equal for both rations. Bermuda grass hay plus urea yielded significantly ($P<.05$)

less average daily gain when fed to steers than did urea plus alfalfa hay at iso-nitrogenous levels.

Increases in cellulose digestion due to the addition of urea to rations have been reported by Egan and Moir (1965), Egan (1965a,1965b), Matrone et al. (1965) and Nix and Anthony (1964). These authors indicated an increase in consumption with increases of nitrogen. Egan (1965b) stated that sheep, duodenally infused with 4.5 grams nitrogen from either casein or urea, changed nitrogen retention from negative to positive. The sheep received oat straw (0.56 percent nitrogen) *ad libitum* as roughage. Gains and efficiency of sheep fed casein based diets were slightly higher than those fed urea based diets but not significantly, reported Matrone et al. (1965). Urea was nearly as effective as casein.

When Virtanen (1966) fed lactating milk cows adapted to .27 grams urea per kilogram body weight, 1.3 to 1.4 grams urea per kilogram body weight, milk production was significantly increased. Colovos et al. (1967) reported no significant difference in milk production or ration digestibilities when lactating dairy cows were fed 1.00, 1.25, or 2.50 percent urea in concentrates.

High-energy supplements containing 32 percent protein were fed to growing beef cattle by Perry et al. (1967). Urea at 22 to 23 percent of the supplemental nitrogen compared favorably with natural protein supplements. Growing cattle gained significantly slower: steers $P<.01$

and heifers (P∠05) when fed a 64 percent protein supplement containing urea, molasses, phosphoric acid and minerals yielded gains equal to the 64 percent urea supplement fed dry.

Oltjen and Bond (1967) maintained cows on an iso-caloric purified diet. Urea was the sole source of nitrogen. The cows were maintained on the diet for 38 to 49 months. The cows calved twice with no significant differences in weights of cows or calves when compared to natural protein diets. Fat and protein of milk were lower on purified diets.

No differences in nitrogen retention were witnessed by Freitag et al. (1968), when they compared soybean meal to urea and corn in supplements. Barth et al. (1968) showed nitrogen retention to be higher for cottonseed meal supplements than for urea supplements. The non-protein nitrogen supplement contained 15 percent urea. The authors attributed the difference in nitrogen retention between the cottonseed and urea supplements to the fact that silage was fed. The silage would have a low content of readily fermentable carbohydrates, which might not allow the urea supplement to be as well utilized as if higher levels of energy were fed.

In three of four trials for weight gain, feed effiency, feed intake and carcass data, Clark et al. (1970) found urea comparable to soybean meal. Oh et al. (1969) supplemented low-quality range forage with urea alone, urea plus volatile fatty acids, urea plus caproic acid, and casein alone. All supplements increased voluntary feed consumption, microbial activity, and dry matter digestibility over unsupplemented controls, but not significantly. These increases indicated that microflora of the rumen were capable of synthesizing their cellular components from urea as a source of nitrogen.

Nelson _et al_. (1955) did not recommend urea as a source of nitrogen for wintering heifers. Urea added to a 20 percent natural protein supplement to make a 40 percent equivalent crude protein supplement did not yield as high gains as the control supplement of 20 percent protein. Trace minerals added to the 40 percent supplement increased gain over the same supplement without trace minerals. Trace minerals had no effect when added to urea supplements in trials run by Pope _et al_. (1959). In fact, trace minerals added to urea supplements tended to reduce gains of fattening yearling steers. During these trials, soybean meal supplemented steers out-gained urea supplemented cattle.

The fact that urea may replace more natural protein for rations to be fed older cattle than those rations for younger animals was reported by Kirk _et al_. (1958). Urea replaced 40 percent of the nitrogen supplied by cottonseed meal in the control supplements. Calves fed the urea supplements exhibited increased feed consumption and a highly significant ($P<.05$) reduction in gains when compared to soybean meal. The same supplements fed to yearling cattle showed no differences in gain, feed consumption, or carcass characteristics.

Drori and Loosli (1959) added ethyl alcohol plus molasses or starch to urea based rations to form iso-caloric supplements. The ethanol plus molasses and starch supplements improved utilization of urea over the basal ration but were inferior to the soybean ration.

Sheep exhibited reduced consumption when fed over 6 percent urea in a ration, stated Coombe et al. (1960), even though large amounts of urea may be fed when spread over a 24 hour period. Nelson and Waller (1962) stated that urea supplements were always inferior to iso-nitrogenous supplements containing cottonseed meal for wintering beef cattle.

Oltjen et al. (1962a) found isolated soy protein to yield significantly faster ($P<.05$) gains than urea or casein with significantly greater ($P<.05$) feed efficiency. When urea furnished 98.7 percent of the nitrogen of a diet, the gains were 80 percent of that from isolated soy protein and 86 percent as good as soybean meal. These gains were considered satisfactory for urea by these authors. In other work, Oltjen and Putnam (1966) showed that nitrogen retention was significantly greater for isolated protein when the isolated soy protein or urea were the sole sources of nitrogen.

Soybean meal fed at 9 and 19 percent of the diet gave a significantly higher feed conversion than urea fed at 1.17 percent of the diet reported Clifford et al. (1967). Clifford and Tillman (1968) showed that urea as a sole source of nitrogen for lambs was approximately 70 percent as good as soybean meal. Hoar et al. (1968) found lambs fed 1 percent urea to gain 16.5 to 19.5 percent less than those fed 7 percent soybean meal. These authors also found that raising the equivalent crude protein of a 8.04 percent ration to 9.54 percent equivalent crude protein by the addition of soybean meal, urea, or sodium nitrate, almost equalized the gains of lambs.

Williams et al. (1968) reported that range supplements containing urea did not maintain weight of wintering gestating cows as well as cottonseed meal supplements. Birth weights of the calves were unaffected, but gains of the calves from cows consuming the urea supplement were less than gains of the calves whose mothers were eating cottonseed meal supplements.

A trend was shown by Theurer et al. (1968) indicating that urea was inferior to natural protein diets fed to sheep. Oltjen et al. (1969b) made a similar statement that urea tended to reduce beef cattle performance when fed over an extended period of time. Bulls were found to utilize purified diets better than heifers.

Although the use of urea may not solve the world protein shortage, it has been agreed by the majority of authors that a limited amount of urea (25 to 33 percent of total nitrogen of a ration) could be utilized by ruminant microflora.

Biuret As A Source Of Nitrogen

Biuret, a condensation product of the manufacture of urea, has become rapidly a popular source of non-protein nitrogen. Slow decomposition and lack of toxicity have been factors which have lead greater acceptance and usage of biuret.

Gaither _et_ _al_. (1955) ran studies with sheep comparing urea and biuret. Two supplements were formulated. Thirty-three percent of the nitrogen in the supplements was supplied by urea or biuret. This work showed biuret nitrogen was retained as well as urea nitrogen. Rations containing 1 percent biuret were used by Berry _et_ _al_. (1956) in comparison with cottonseed meal and urea. Gains and appetites of lambs and steers were depressed when biuret was fed rather than urea or cottonseed meal. The variable response of biuret indicated that biuret was not a dependable source of non-protein nitrogen.

Addition of nitrogen sources to rations fed to growing and fattening lambs was studied by Meiske _et_ _al_. (1955). No differences in weight gains were observed when either soybean meal, urea, or biuret were added to a basal ration.

_In_ _vitro_ studies by Ewan _et_ _al_. (1958) found biuret to depress digestibility of dry matter when compared to urea; however, this relationship was not significant. Anderson _et_ _al_. (1959) researched urea, uramite, biuret, and soybean meal in supplements which supplied up to 67 percent of the total nitrogen in iso-nitrogenous, iso-caloric diets for lambs. All levels of biuret in rations reduced crude protein digestion. Levels of biuret up to 50 percent of the total nitrogen did not alter the digestibilities or nitrogen utilization significantly. Purified soybean diets had significantly greater digestibilities than did urea, ureamite or biuret.

Hatfield et al. (1959) stated that biuret was not toxic and that growth, reproduction, and wool production were not adversely affected by feeding biuret as a source of non-protein nitrogen. However, digestion coefficients for nitrogen were significantly slower (P<.01) for biuret than for the urea and soybean meal rations. With lambs on low intake rations, nitrogen balance for biuret was significantly higher (P<.05) than urea. However, on high intake rations nitrogen balances for biuret were only slightly higher than those for urea. The animals consumed less feed when eating the urea and biuret rations. Biuret may be used as a source of non-protein nitrogen, stated Mackenzie and Altona (1964) and Hatfield et al. (1959).

Weldon and MacDonald (1962) compared urea and biuret in vitro. Nitrogen utilization of Pseudomonas aerieginosa was measured by cell reproduction. Glucose was the sole energy source. Generation time using biuret as a nitrogen source was about twice that when urea was used as the nitrogen source. Even thus, cell production was good in the biuret media.

Johnson and McClure (1963) stated that if ruminants use biuret it must be through the microflora. Microorganisms for utilization of biuret and urea were different, quoted Johnson and McClure (1964).

Even so, biuret was utilized nearly as well as urea in rations where each supplied 45 percent of the total nitrogen.

Clark et al. (1963) showed biuret to be as efficient as urea when judged by nitrogen retention, apparent nitrogen absorption, and stimulation of hay consumption. Biuret and urea were compared to each other on low protein, high roughage diets. Biuret was found to be more palatable than urea. Karr et al. (1965) indicated no significant differences in digestion of dry matter or nitrogen when urea was 3 percent of the ration and biuret was 3.5 percent of the ration.

Mies (1968) wintered steers on rations in which 1/2 the equivalent crude protein came from urea or biuret. No significance was shown in weight gains among urea, biuret, or soybean meal fed cattle. In another trial, soybean meal cattle responded more favorably ($P < .05$) than did the urea or biuret fed steers. With heifers, Mies (1968) showed urea or biuret fed at 2/3 of the equivalent crude protein to be significantly ($P < .05$) more efficient than a combination of 50 percent urea and 50 percent biuret. No effect on heifer gain or carcass characteristics was witnessed. In this study using 112 head of beef cattle, biuret was found to be equal to urea in gain production.

Raleigh and Oldfield (1968) reported no differences in calf birth weights from range cows that had been supplemented with biuret plus barley compared to barley, as a control, on high energy treatments. Biuret and cottonseed meal yielded significantly greater gain than urea or low protein controls when fed in supplements to range cows, reported Turner and Raleigh (1968). Biuret and cottonseed meal also yielded a higher economic return. Moreover, Meiske and Goodrich (1969) pointed out and summarized that biuret could be used in conditions where urea breaks down too rapidly for efficient utilization of NH_3, such as range conditions.

Effect Of Energy On Utilization Of NPNs.

Readily fermentable carbohydrates or other energy sources are important requisites for the proper utilization of non-protein nitrogen by rumen microflora. Early work by Honecamp et al. (1923) stated the importance of carbohydrates being present in low protein diets of milk cows when urea was fed at 150-to 200 grams per head per day. Mitchell and Hamilton (1932), Mitchell et al. (1940) and Hamilton (1942) reported that an increase in energy decreases digestibilities of crude fiber. Energy additions had the same effect on digestibilities of dry matter according to Burroughs et al. (1949). Hamilton (1942) and Burroughs et al. (1949) attributed the decreases in digestibilities of crude fiber and dry matter to the fact that micro-organisms had a greater affinity for the readily available carbohydrate than for the crude fiber of the ration. Mills et al. (1942) found urea to be utilized better with timothy hay when starch was added to the ration. The addition of casein to this diet caused a reduction in urea utilization.

Pearson and Smith (1943) stated that synthesis of protein from urea is microbial in steers and that starch stimulates this synthesis. Starch was shown to be superior to molasses for the stimulation of protein synthesis. However, a mixture of carbohydrates yielded better results than any of the individual components shown by Mill et al. (1944) and Williams et al. (1969a). Starch yielded the best utilization of urea with cellulose compared to xylan and pectin. Belasco (1956) stated, in summary, that different carbohydrates seem to have been utilized through different metabolic pathways. This evidence indicated better utilization of urea when a combination of carbohydrates was fed.

Oltjen and Putnam (1966) disclosed that the addition of starch to purified diets fed to steers significantly altered fecal and urinary nitrogen losses. Nitrogen sources for the iso-nitrogenous and iso-caloric diets were urea or isolated soybean protein. Isolated soybean protein rations had a significantly greater nitrogen retention than did the urea rations.

Feeding sheep 7 grams urea per head per day, Pierce (1951_b) found the addition of potato starch at 100 grams, 150 grams, and 200 grams per head per day to increase wool production, 7, 19, and 23 percent, respectively. In other studies by Pierce (1951a), 15 grams urea per head per day fed to sheep with a low protein, high fiber diet did not alter wool growth. Wheat gluten, rather than urea, increased total wool production 35 percent. When 15 grams urea and equivalent amounts of wheat gluten were added to the same low protein potato starch enriched diet, increases in total wool production of 32 percent and 64 percent, respectively, were witnessed. These authors stated that urea was utilized when fed with low protein, high carbohydrate rations. Lofgreen _et al._ (1951) found that increasing energy intake of dairy calves resulted in increases in nitrogen retention when moderate protein levels were fed but not with high protein rations. Corn used as energy yielded higher nitrogen retention than molasses according to Bell _et al._ (1951, 1953).

The fact that carbohydrates must be present to utilize urea has been shown by Chalmers and Synge (1954) and Kirk _et al._ (1958). They found simple sugars to be too soluble and too rapidly broken down for maximal utilization of urea. Celluloses and the hemicelluloses were broken down too slowly to add energy to the rumen. Starches yielded the best media for the utilization of urea in the ruminant. Fontenot _et al._ (1955) showed that increasing levels of cerelose, which is a highly soluble corn sugar, decreased nitrogen retention. Glucose, sucrose, or lactose had about equal influence on nitrogen utilization reported Gallup _et al._ (1954). With these simple sugars present in the rations, soybean meal ration efficiency was affected more than the urea ration efficiency, but not significantly. High levels of dextrose with cellulose inhibited cellulose digestion, but starch increased cellulose digestion according to Belasco (1956).

Availability of readily fermentable carbohydrates depressed roughage digestion when fed with urea rations in vitro reported Arias et al. (1951). Abundances of starch increased the utilization of urea and depressed cellulose digestion in studies by Hunt et al. (1954). Fontenot et al. (1955) found that a 50 percent increase in carbohydrates of a ration increased nitrogen retention 60 percent. Ellis and Pfander (1958) found by increasing cellulose levels of a ration that digestibility of ether extract increased significantly and linearly, while the digestibilities of organic matter, nitrogen-free extract, and total digestible nutrients were decreased. Daily urinary nitrogen was increased by increasing cellulose, while nitrogen balance was decreased. Elam et al. (1958) found that beef heifers fed medium levels of energy had significantly greater ($P < .01$) digestibilities of organic matter, nitrogen-free extract, and energy than did high energy (full fed) or low energy (maintenance) heifers. Smith et al. (1957) fed lambs urea in semi-purified rations containing corn cobs, wheat straw, bagasse pith, or oat-mill feed as energy sources. The source of roughage carbohydrate influenced the utilization of nitrogen of these rations in which urea supplied 67 percent of the total nitrogen. Nitrogen utilization with corn cobs was superior to wheat straw as roughage, while oat-mill feed and bagasse pith were inferior to both. Replacing various amounts of wheat straw with equal quantities of dextrose and starch increased the nitrogen utilization in urea-containing lamb rations.

The addition of ethanol to molasses increased nitrogen retention over starch based rations that were iso-caloric. In contradiction to their own work, Drori and Loosli (1959) reported that starch and starchy concentrates, such as corn, favor nitrogen retention in urea fed ruminants more than other carbohydrates, such as the sugars in molasses. These researchers stated that ethanol may help improve urea utilization of low-quality, low-protein rations when no cereal grains are fed. Ethanol added to a ration at 11.4 milliliters per 454 grams dry matter yielded a slight increase in nitrogen utilization, according to Chalupa _et al_. (1964). In this case, ethanol was useful only as a source of energy. Drori and Loosli (1961) stated that the amount of starch or glucose in a urea ration may be responsible for the poor utilization of urea by ruminants. In this study with sheep, consumption was higher on soybean meal diets than either the glucose-urea ration or the starch-urea ration. These authors theorized that the levels of carbohydrate in a ration may be as important as the levels of urea.

Chalpula (1963) stated the limiting factor in nitrogen utilization from urea was to secure comparable rates of urea hydrolysis and microbial synthesis of protein which may necessitate the co-feeding of soluble energy sources. _In vitro_ studies by Bloomfield _et al_. (1964) contended that nitrogen fixation from urea was a quantitative function of energy. For maximum assimilation, 55 grams carbohydrate should be present for each one gram nitrogen. Nitrogen retention significantly improved (2 percent units) for every 100 kilocalories readily available carbohydrate in the ration and had an effect regardless of adaptation. The same effect took place with all-urea rations fed to lambs maintained McLaren et al. (1965_a). Optimal nitrogen-free extract to nitrogen ratio was found to improve linearly from 11:1 to 28:1 with no further improvement to 55:1.

Success of urea is dependent on composition of the carbohydrates fed, contend Conrad and Hibbs (1968). These authors indicated that approximately 1 kilogram readily available carbohydrate (2/3 starch) was needed per 100 grams of urea fed to adapted cattle. With this ratio of carbohydrate to urea, efficiency of urea was compared equally with plant protein, when milk production and body tissue were considered. Feed consumption increased when urea was fed above 0.45 grams per kilogram body weight. In contradiction, a review by Conrad (1968) reported a definite decrease in feed intake when cattle were fed 0.4 to 0.5 grams NPN per kilogram body weight.

Sucrose added to straw-urea rations for sheep had no effect on intake, revealed Faichney (1965). Crude fiber digestion was decreased as sucrose increased, because of competition for nitrogen. This author asserted that there was no need for added energy in the straw-urea rations. Milligan (1967) contradicted this statement. He showed that rumen microbes reproduced using NH_3 as the only source of nitrogen.

This author stated that only a small portion of the feed energy became available to the microbes and that energy was the limiting factor when microbes utilized NH_3 for production. McAtee et al. (1967) substantiated this work by feeding wethers. These authors found that 50 to 80 percent of the corn starch that was fed escaped rumen fermentation and was digested posteriorly to the rumen.

Campling, et al. (1962) infused intraruminally into dairy cows 75 grams or 150 grams urea. The infusion of either level increased the consumption of oat straw 40 percent. The addition of 500 grams sucrose to the urea had no further effect on consumption. At the 150 gram urea 500 gram sucrose level, dry matter digestion was improved from 40 percent to 53 percent over the 150 gram urea level.

Straw was used as a source of energy by Lofgreen and Christensen (1962) along with alfalfa. When straw replaced 1/2 the energy in the ration of beef steers, intake and gains were depressed, although reticulo-rumen fill was increased.

Barth (1962) reported that increasing readily available carbohydrates 50 percent in all-urea lamb rations from maintenance resulted in a linear increase in nitrogen utilization of approximately 60 percent

Oltjen et al. (1962_b) fed 4.2 percent urea with 30, 40, and 50 percent cellulose to sheep. Their work showed gains of sheep fed 30 percent cellulose to have been greater ($P < .05$) than those fed 50 percent cellulose. Sheep fed the 30 percent cellulose ration showed less ($P < .05$) feed per kilogram gain than those sheep fed 50 percent cellulose ration.

Hemsley and Loir (1963) reported no necessity for readily available carbohydrate energy to enhance utilization of urea-supplemented, low-quality, cereal hay diets fed to sheep. Donefer et al. (1963), on the other hand, showed that as the barley content of the rations fed ewes was increased, the digestion of energy had a nearly linear increase. Conrad (1968) indicated nitrogen utilization to be a linear function of digestibilities of energy input regardless of body weight.

Starch substituted for roughage carbohydarate increased the rate of NH_3 utilization, according to Tagari et al. (1964) and impaired protein utilization. Lewis (1962) disagreed with this statement and reported the addition of starch to depress the liberation of NH_3. Tagari et al. (1964) found that increases in starch of diets for sheep increased the ruminal concentration of amino acids. Starch added to the sheep rations increased protein digestion but, at the same time, decreased nitrogen retention in the body. Indicating that increased protein digestion did not mean an increase in protein utilization. Along this same line, Miller and Payne (1961) stated that on low energy diets with ample protein, a protein deficiency may appear because energy was preferential to protein and the protein was used for energy.

Stone and Fontenot (1965) indicated no significant differences in nitrogen retention among low, medium, and high energy natural protein rations fed to Angus steers. Digestibilities of dry matter, organic matter, energy and nitrogen-free extract significantly ($P < .01$) increased with increased energy. Digestibility of crude fiber increased significantly ($P < .01$), also.

The heat increment was lower for 10 to 15 percent equivalent crude protein rations containing urea than for rations containing all natural protein. In this same research, Cock et al. (1966) indicated that energy digestion increased with an increase in dietary nitrogen when fed to ruminants.

Growth and reproduction of heifers fed high urea supplements (2/3 dietary N from urea) was compared to soybean meal supplements by Bond et al. (1967). The urea plus corn starch supplement was equal to soybean meal supplement when average daily gain of heifers was considered. Urea supplements caused slightly longer estrous cycles; however, no significant differences in conception rate or post-parturate estrus were observed. In feeding urea, biuret or cottonseed meal supplements to cattle on native range, Turner and Raleigh (1968) showed a significant gain advantage with added energy of the high energy supplements. High energy supplements yielded a $4.47 economic advantage over the low energy supplements. As urea increased up to 6 percent in range supplements, performance tended to decrease, according to Clanton et al. (1968).

Smith 1968) attacked the problem of energy availability and simultaneous NH_3 release in a different manner. Finely ground corn, sorgham, barley, or other starch was mixed with urea and then gelatinized with heat and pressure. This starch-controlled urea compound, called

Starea, had good handling and storage properties and, most important, released NH_3 more slowly than other conventional urea feeds. Starea compared favorably to soybean meal rations when fed to lactating dairy cows. Grain intake and milk production were similar for both rations. Conventional urea rations reduced both grain intake and milk production and caused the cows to lose weight. A starch-controlled urea product was superior to an equivalent amount of urea supplement and equal to the same quantity of soybean meal for lactating cows according to Deyoe et al. (1968).

High urea (15 percent urea) rations compared favorably to cottonseed meal based supplements when high levels of concentrate were fed, in work done by Barth et al. (1968). When steers were fed high-silage rations, cottonseed meal based supplements were superior to the high urea supplements.

Wilson et al. (1969) fed Angus-Holstein cows 150 percent of N.R.C. requirements for protein and 85 percent or 115 percent of N.R.C. requirements for energy. High energy significantly ($P < .01$) influenced cow weight loss, cow and calf condition, calf conformation score, and calf gain. Cows on high energy levels maintained their weight, while low energy level cows lost 54.4 kilograms, which was approximately 12 percent of the on test body weight. Optimum energy to urea ratios have been hard to find for range cattle on poor-quality forages, quoted Williams et al. (1969_b). These workers fed 1362 grams of a 21 percent protein supplement containing 4 percent urea. Birth weights and weaning weights of calves from urea supplemented corn showed a trend to be lighter than those calves whose mothers received a cottonseed meal supplement. Simultaneous provision of adequate and readily available energy has been imperative for efficient utilization of peanut-cake and urea nitrogen for cattle according to Miara and Ranhotra (1969).

The general trend for most authors discussing non-protein nitrogen utilization by ruminants has been that a source of readily available carbohydrate is essential. Exact levels of energy to non-protein nitrogen as yet have not been well established, particularly for range cattle conditions. Probably the biggest factor to consider has been that of economics when using non-protein nitrogens as a portion of a ration.

Importance Of Adaptation Periods Of Ruminants To Non-Protein Nitrogen Feeds

Welsh et al. (1957) fed lambs non-protein nitrogen for 35 days. As days on trial increased, greater utilization of urea and biuret was observed. After 35 days, no further increase in utilization of nitrogen occurred. Urea levels of 25 to 45 grams per head per day caused a toxic effect to sheep, reported Coombe and Tribe (1958). With an adaptation period, no toxic symptoms occurred at urea levels of 100 grams per day in lambs. Positive nitrogen balances were observed in steers, by Hatfield _et al_. (1959), after an 18 day adaptation to biuret. A drench containing 275 grams biuret was administered by stomach tube in this study. Nitrogen retention improved significantly with adaptation reported by Smith _et al_. (1960). Urea was fed to provide two-thirds of the total nitrogen of a ration composed basically of straw and molasses. Differences of 2 percentage units increase in nitrogen retention accompanied each 10-day collection period, reported Smith _et al_. (1960) and Chalupa (1968). No measurable changes occurred in digestibility of organic matter or crude fiber. Smith _et al_. (1960) and McLaren et al. (1965_a) reported a significant improvement of 3 percent in nitrogen retention for every 10-day collection period in their work with urea fed to lambs. Lewis (1960) stated that 7 days were necessary for organisms to adapt to large quantities of NH_3 in ruminants.

In vitro studies by Barth _et al_. (1961) indicated some adaptation of sheep to urea, up to 48 days. _In vivo_ studies corresponding to the _in vitro_ studies showed utilization of urea increased from 36 to 51 percent. Johnson and McClure (1963, 1964) found sheep to adapt to biuret when digestibilities were studied. No differences in nitrogen retention were observed with adaptation by Johnson and McClure (1965_a 1965_b) and Schaadt _et al_. (1966). Campbell _et al_. (1963_b) reported a 3 to 4 week adaptation improved the utilization of biuret fed to ruminants. Clark _et al_. (1963) contended this period should be 6 to 8 weeks, when comparing biuret to urea in sheep rations. A two-week adaptation period was found ample by Smith (1968) for the starch enriched urea product, Starea.

Significant increases in nitrogen retention were observed by Farlin et al. (1968) for an adaptation to biuret for 51 days. These authors stated that at least a 9-day adaptation period is essential. Clifford and Tillman (1968) indicated that during metabolism studies with sheep fed urea rations, urinary nitrogen increased sharply, then decreased after 10 days, indicative of the importance of at least a 10-day adaptation period to urea. An adaptation period of more than 19 days was associated with the accelerated conversion of ammonia to urea in the liver by Conrad (1968).

The addition of diethylstilbestrol (DES) to ruminants fed non-protein nitrogen has been beneficial in reducing adaptation time. Welch et al. (1957) indicated that DES reduced the adaptation period to urea and biuret from 35 days to 25 days. Biuret and urea utilization was improved more rapidly by the presence of DES in lambs, reported McLaren et al. (1959) and Karr et al. (1965). Mies (1968) observed DES implanted steers gained significantly ($P < .01$) more than non-implanted steers fed urea or biuret in fattening rations.

Frequency of feeding had no effect on urea utilization reported Dinning et al. (1949) and Blaxter et al. (1961). Dinning et al. (1949) fed range steers and range ewes a supplement in which urea supplied 25 or 50 percent of the total nitrogen. These authors found no differences in urea utilization when the animals were fed twice daily, daily, or on alternate days. Feeding Guernsey heifers urea rations six times daily yielded slightly better nitrogen utilization than feeding two times daily, contended Campbell et al. (1963a).

The overall indication of these studies was that at least a 10-day adaptation to non-protein nitrogen was essential before optimal performance could be expected by the ruminants to non-protein nitrogen feeds. Longer periods of 30 to 49 days may have been better for the most efficient utilization of non-protein nitrogen.

Additives To Non-Protein Nitrogen Diets

Although the requirements for microorganisms of the rumen are relatively simple, minerals were one of the important factors most often overlooked, stated Burroughs et al. (1951a). Burroughs et al. (1951b) confirmed that iron and phosphorus stimulated urea utilization, as did sodium, potassium, calcium, magnesium, chlorine, and sulfur. Conrad (1968) found the necessity for large amounts of phosphorus and sulfur in rations for optimum utilization of urea and NH_3.

Trace minerals added to urea rations fed to heifer calves by Nelson et al. (1955) increased gains. Thomas et al. (1953) found no significant difference in weight gains of steers fed a soybean meal supplement over steers fed a urea supplement when trace minerals and phosphorus were added to both rations. Adequate phosphorus significantly increased gain of steers over steers fed low-phosphorus rations. Gossett et al. (1962) indicated no effect of trace minerals in fattening rations for steers. Pope et al. (1959) reported decreased gains with the addition of trace minerals. Oltjen (1962b) stated that high mineral levels significantly ($P < .05$) improved gains of lambs.

Sulfur may have been the single most important element considered as far as common commercial diets were concerned. Thomas et al. (1951) found the absence of sulfur to inhibit growth in lambs and especially wool growth. Poor urea utilization was indicated by a negative nitrogen balance which was positive after the addition of sulfur to the rations. Sulfur significantly ($P < .001$) improved gains and wool growth no matter what the source, according to Starks et al. (1954). Black et al. (1951), Hale et al. (1953) and Hunt (1954) all agreed that sulfur added to rations was beneficial to urea utilization.

Alfalfa meal was shown by Burroughs et al. (1950_a) to increase the digestibility of corn cobs in steer rations. This increase in digestibility was attributed to unidentified factors in alfalfa ash. Dyer and Roberts (1956) confirmed that alfalfa meal increased gains ($P < .01$) of pregnant heifers fed non-protein nitrogen rations. Alfalfa ash added to the same urea supplements also significantly ($P < 0.5$) increased gains. The effect of alfalfa meal and alfalfa ash was observed in weights of the calves from these heifers. Bell et al. (1953), Beeson et al. (1964), Beeson and Horn (1967), Garrigus (1964), and Conrad and Hibbs (1968) revealed urea utilization in supplements could be improved with the addition of dehydrated alfalfa meal. Biuret utilization was not increased as greatly as was urea utilization by the addition of dehydrated alfalfa meal (DEHY), according to Karr et al. (1965). Horn and Beeson (1969) show a significant ($P < .05$) increase in nitrogen retention of urea nitrogen fed beef cattle when dehydrated alfalfa meal or distillers dried grains with solubles (DDGS) were present. Beeson (1969) remarked that two good sources of unidentified urea-protein factors were DEHY and DDGS, although others may have been just as acceptable.

Toxicity

Toxicity to non-protein nitrogen products has been a serious problem. Urea seems to have been the worst offender, while biuret showed little or no toxic problem. Gallup et al. (1953) fed adapted ruminants 100 grams of urea per 45.4 kilograms body weight with no ill effects. Levels of urea from 25 to 45 grams per day fed to unadapted sheep caused toxic symptoms in studies by Coombe and Tribe (1958). With adapted sheep, 100 grams per day were fed with no ill effects. Coombe et al. (1960) reported an ample supply of energy to reduce toxicity of urea. The starch-controlled product tested by Deyoe et al. (1968) was claimed to reduce the danger of toxicity.

Rumsey et al. (1969) infused 100 grams urea into adapted 454 kilogram steers by means of ruminal fistula. Toxicity occurred with recovery after the administration of 5 percent acetic acid drench.

Signs of toxicity were observed by Whitehair et al. (1955) and Fraser (1963) in steers that had eaten 20 grams urea per 45.4 kilograms body weight. Symptoms of uneasiness and incoordination progressed until staggering, muscular convulsion, increased respiration, excessive salivation, and bloat were observed. Death could follow 30 minutes to one hour after ingestion of the urea.

Mieske et al. (1955) and Berry et al. (1956) reported no toxic symptoms from biuret, a strong point in favor of feeding this compound rather than urea.

Although urea poisoning has been associated with the aforementioned symptoms, Warren (1962) observed similar symptoms in ruminants on spring pasture, high in non-protein nitrogen. Clark et al. (1951_a) also substantiated this effect with sudden increases in natural protein.

Whitehair et al. (1955) concluded that conditions that led to urea toxicity were as follows:

a) starving or fasting cattle before feeding urea;

b) animals with "hoggish" or aggressive appetities;

c) unadapted animals;

d) improperly mixed feed or feeds too high in urea;

3) high levels of urea fed with poor quality, high roughage rations.

METHODS AND PROCEDURES

Trial I - Nitrogen Source, Wintering Study

These experiments were conducted at the Montana State University Agricultural Experiment Station, Nutrition Center, Bozeman, Montana. All animals used in this trial were Angus-Hereford crossbred or Hereford steers from Red Bluff Research Ranch at Norris, Montana, the U. S. Range Livestock Experiment Station, Miles City, Montana and the campus at Montana State University, Bozeman. The calves were born the spring of 1969. Upon arrival at the Nutrition Center, all cattle were vaccinated for Blackleg, Malignant Edema, Para-Influenza 3, Infectious Bovine Rhinotracheitis, Enterotoxemia (Type D), and Bovine Virus Diarrhea. All calves were treated with Ruelene for grub control and later sprayed with Korlan for lice control. The steers were identified by individual eartag numbers.

Thirty-six steer calves were stratified by source, weight, and breed, and randomly assigned in groups of six to each of six pens. Calves were weighed on test after approximately two months of preconditioning. Individual initial and final weights were taken after an overnight shrink (15 hours) without feed and water. The cattle were weighed without shrink every 28 days from the initial weight to final weight.

The pens were located with the fenceline bunks under an open shed. Half of the pens were partially slotted, the other half of the six pens being concrete located on the south side of the open shed. The other three pens were sloped concrete slabs, located on the north side of the open shed. Pens were 5.49 meters by 7.62 meters, allowing 6.97 square meters per calf. Water was available from thermostatically-controlled, electric, self-filling waterers. Salt was available *ad libitum.* Supplement was fed at the morning feeding on the days it was fed. Hay was fed twice daily.

Three supplements were formulated to contain 20 percent protein from soybean meal, biuret and urea. The control supplement was the soybean meal supplement. Biuret or urea provided one-third of the crude protein equivalent of the remaining two supplements (Table I).

TABLE I. SPECIFICATION OF SUPPLEMENTS FOR WINTERING STEERS

MSU Formula No.	608	609	610
Ingredients:		Percent of Ration	
Biuret	----	2.77	----
Urea	----	----	2.35
Barley	46.26	61.35	62.00
Soybean meal	23.25	5.25	5.00
Alfalfa, dehydrated	10.00	10.00	10.00
Wheat millrun	10.00	10.00	10.00
Molasses	6.50	6.50	6.50
Monodosium phosphate	3.00	3.00	3.00
Trace minerals	0.50	0.50	0.50
Gypsum	0.50	0.50	0.50
Limestone	----	0.15	0.15
Vitamin A[a]	x	x	x
	100.0	100.0	100.0

[a] Vitamin A added to provide 15,000 I.U. per lb.

Each of the six pens of cattle was randomly assigned to one of six feeding regimes. Three pens of cattle were fed 0.91 kg supplement per head per day once a day, with each pen receiving one of the three supplements. The remaining three pens received 1.81 kg of one of the supplements per head on every other day. Grass hay was chopped through a 5.5 cm screen in a hammermill, and fed to all pens daily, the amount being controlled by the pen consuming the least. Using this procedure, all cattle consumed equal quantities of feed on a two-day basis. Protein of all rations was calculated to be equal to NRC requirements for normal growth for steers on a long term basis.

All pens of cattle were allowed 28 days on their particular feed regime for an adaptation period prior to being weighed on test, January 20, 1970. The steers were shrunk and weighed after they were fed 98 days and 126 days on this wintering ration; they were weighed off test May 26, 1970. The steers had an average weight of 227 kg on test and an average weight of 286 kg off test.

Trial II - Nitrogen Source, Metabolism Study

A metabolism study was conducted to supplement the study of every day or every other day feeding of supplements with different sources of nitrogen. Steers used in the study were born in the fall of 1968 and were from one herd. They were vaccinated for Blackleg and Malignant Edema and drenched with Thiobenzole for internal parasite control. Three steers, weighing approximately 240 kg were randomly assigned to receive one of the three supplements described in Trial 1. The steers, previously adapted to non-protein nitrogen feeds, were allowed a 10-day adjustment period to the supplements and placed in the metabolism stalls. Seven additional days were allowed to adjust to the stalls and stabilize intake and excretion. The stalls were similar to those used by Nelson et al. (1954).

The sequence of feeding for the three phases of the metabolism study was as follows: 1) 0.91 kg supplement every day plus grass hay (basal ration) 2) 1.82 kg supplement every other day plus basal and 3) basal ration only. The basal (grass hay only) ration was fed last in the sequence of metabolism studies to allow continuity in the feeding of non-protein supplements. If the digestibility of basal ration had been studied first, the necessity to re-adapt the steers to their respective non-protein supplements for a second time would have been time-consuming. The basal ration study provided a basal nitrogen balance. The nitrogen balance of the supplements was then determined by differences between the hay ration and the hay and supplement rations as described by Cramptom and Harris (1969).

Steers were fed 80 percent grass hay (basal) and 20 percent supplement in a ration calculated to be slightly above the net energy maintenance requirement reported by Gill (1968). Steers were fed to gain 0.14 kg per head per day according to their net energy requirements calculated from their metabolic body size (weight $_{kg}^{0.75}$). The total equivalent crude protein intake was calculated to equal that suggested by NRC for normal growth of steers. Values for the feeds were