PROTEIN AND ENERGY STUDIES WITH BEEF CATTLE

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INTRODUCTION

Roughages are usually the main source of energy in range beef cattle wintering rations. The roughages most commonly used to winter beef cattle in Oklahoma are prairie hay and dry range grass. It is important that these roughages be properly supplemented with protein in order that they may be properly digested and in order for the animal, especially if it is a growing animal, to grow and store nitrogen during the winter. *In vitro* work has shown that small amounts of readily-available carbohydrate may improve cellulose digestion by rumen microorganisms. Also, in simple-stomach animals it has been shown that, under certain experimental conditions, energy intake affects nitrogen utilization.

It has been a common practice among cattlemen to feed a protein supplement containing approximately 40 percent protein to beef cattle being fed prairie hay or allowed to graze dry range grass during the winter. During the last several years, however, large amounts of supplements containing less than 40 percent protein have been fed range beef cattle during the winter. An experiment was conducted, therefore, to study the relative merits of supplements containing different amounts of protein for wintering beef heifer calves fed prairie hay or allowed to graze dry native grass.

Only a limited amount of research has been conducted in which the effect of energy intake on nitrogen utilization in ruminants has been studied. However, there is evidence that under certain experimental conditions energy intake influences nitrogen utilization. It was deemed desirable to study the effect of adding different amounts of a readily-available carbohydrate (cerelose) on nitrogen metabolism and on the digestibility of ration constituents by steers fed basal wintering-type rations. The effect of cerelose additions to rations of different protein content was studied. In this study the protein content of the basal rations was held within the realm of practical beef-cattle wintering rations.

REVIEW OF LITERATURE

The literature review is divided into four major parts. In reviewing digestibility and wintering studies only the experiments with ruminants were considered. However, since only a limited amount of research has been conducted with ruminants to study the effect of energy intake on protein utilization, several studies with simple-stomach animals are included in the review.

The Effect of Protein on Digestibility

Armsby (1917) stated that rations having a wide nutritive ratio are likely to show an impaired digestibility, especially by ruminants. He gave no figures indicating the width of the ratio. Watson _et al._ (1947) showed that the nutritive ratio of mixed rations did not affect their digestibility if the ratio ranged from 1:2.63 to 1:8.41. The nutritive ratio was varied by feeding timothy hay, barley, and soybean oil meal in various combinations. The digestion coefficients were determined with eight steers during eight 28-day periods.

Briggs, Gallup, and Darlow (1946) found that supplementing 10 lb. of prairie hay with 454 gm. of cottonseed meal, soybean meal, or a mixture of equal parts of soybean meal, cottonseed meal, and peanut meal caused a significant increase in the apparent digestibility of all ration nutrients by steers. They also reported that peanut meal supplementation resulted in a significant increase in the apparent digestibility of all ration nutrients except crude fiber. Feces were collected from four yearling steers during 10-day periods preceded by preliminary periods of 10 days duration or longer.

Swift et al. (1947) found that the addition of casein to a sheep ration containing 13.2 percent protein increased the apparent digestibility of crude protein, ether extract, and energy and decreased the digestibility of crude fiber and nitrogen-free extract. The basal ration, containing mixed alfalfa and timothy hay, corn meal, and linseed meal was supplemented with 58 and 116 gm. of casein. Five sheep were fed each of the three test rations.

Gallup and Briggs (1948) studied the relationship between the protein content of prairie hay and its digestibility by steers. Four or more steers were used to determine the digestibility of each ration. They found that the apparent dry matter digestibility increased from approximately 56 percent to 60 percent and the crude fiber digestibility increased from about 56 to 69 percent as the protein content of the hay increased from about 3 to 6 percent.

Burroughs and Gerlaugh (1949 a) studied the effect of soybean oil meal on roughage digestion in cattle. Four rations were used, two containing 8 percent protein and two containing 15 percent protein. The protein content of the rations was altered by substituting soybean oil meal for corn. At each of the two protein levels one ration contained corn cobs and timothy hay and one contained timothy hay as the only source of roughage. The total daily feed intake on all rations was approximately equal. The schedule of feeding the four rations was staggered over four collection periods in such a way that each ration was fed to one steer during each period. Feces were collected during 14-day periods preceded by preliminary periods of 14 days or longer on the test ration. They found that when the protein content of the ration was increased from 8 to 15 percent the average apparent digestibility of the corncob dry matter was increased from 58.9 to 66.7 percent. The average apparent digestibility of the timothy hay dry matter was increased from 50.7 to 59.1 percent when the protein content was raised from 8 to 15 percent.

In another study Burroughs et al. (1949 b) found that dried skimmilk increased the average apparent digestibility of the dry matter of certain roughages if corn starch made up a part of the ration. If corn starch was not included in the ration, the addition of dried skimmilk had no measurable effect on dry matter digestibility.

In a subsequent study Burroughs and associates (1950 a) studied the effect of casein on roughage digestion by steers. One and 2 lb. of casein were added to a basal ration containing 4 lb. ground corncobs, 4 lb. mineralized starch, 1 lb. chopped alfalfa hay, 0.1 lb. salt and 10 ml. vitamin A and D feeding oil. The protein content of the basal ration was 3.4 percent. The addition of 1 and 2 lb. of casein to the basal ration increased the protein content to 11.1 and 17.4 percent, respectively. The average apparent digestion coefficients for dry matter were 13.2, 46.4, and 53.5 percent, for the rations containing 3.4, 11.1, and 17.4 percent protein, respectively.

Fontenot (1953) studied the relative effects of supplements of different protein content on the digestibility of ration nutrients by steers. Three rations were fed which contained prairie hay and minerals plus 1 lb. of 20-, 30-, and 40-percent protein supplements. There were no measurable differences in the digestibility of crude fiber and dry matter among the three rations but the average apparent crude protein digestibility increased as the protein content of the supplement increased.

Williams *et al.* (1953) found that under their experimental conditions protein intake influenced dry matter digestibility by sheep. They found that the apparent dry-matter digestibility of medium- and high-protein diets was significantly higher than that of low-protein diets whether the ration contained 0, 99, or 149 gm. of wheaten starch. The high-, medium-, and low-protein diets contained 14.0-14.6, 60.0-63.4, and 81.8-83.7 gm. of protein, respectively. The trial was designed as a balanced lattice containing four blocks of replicates of each of nine treatments. The treatments were triplicated at random within each block and each triplicate was allotted to one of 12 sheep at random.

Certain protein-rich feeds have been shown to increase cellulose digestion *in vitro* (Burroughs *et al.* 1950 b).

It appears that if the protein content of the basal ration is relatively low the addition of protein usually increases the digestibility of certain of the ration constituents. The ones most noticeably affected seem to be crude protein, crude fiber, and dry matter. This effect of protein on digestibility seems to be especially pronounced if a starchy feed is included in the ration.

The Effect of Readily-Available Carbohydrates on Digestibility

Patterson and Outwater (1907) reported that molasses, when added to rations containing hay or hay and grain, caused an increase in the average dry matter digestibility by steers. Lindsey and Smith (1910) showed that molasses caused a decrease in organic matter digestibility whether the basal ration was composed of only hay or hay and concentrate. They used sheep as experimental animals. In the hay basal ration, molasses had to be present in relatively high concentrations to cause any marked depression. Williams (1925), working with dairy cows, reported that molasses did not uniformly affect the digestibility of crude fiber, nitrogen-free extract, and ether extract but tended to depress the digestibility of crude protein and dry matter.

Briggs (1937) reported on the effect of molasses on the digestibility of a lamb-fattening ration. Four wether lambs were used for that study. The basal ration contained 454 gm. alfalfa hay plus 454 gm. of either corn or oats. He found that the substitution of 230 gm. of molasses for 224 gm. of grain caused a decreased apparent digestibility of protein and fat and had no apparent effect on the digestibility of crude fiber and nitrogen-free extract.

Briggs and Heller (1940) conducted a digestion experiment with lambs in which 230 gm. of blackstrap molasses were substituted either for the same amount of corn in a corn-alfalfa hay ration or for the same amount of oats in an oats-alfalfa hay ration. The digestion coefficients were determined with 12 wether lambs, four being used in each of three trials. Ten-day collection periods were preceded by 10-day preliminary periods on the test ration. The substitution of molasses for either corn or oats had no appreciable effect on the apparent digestibility of crude fiber and nitrogen-free extract. The substitution of molasses for corn had no significant influence on the apparent digestibility of crude protein but the replacement of oats with molasses lowered crude protein digestibility by a highly significant amount.

Colovos _et al._ (1943), working with dairy heifers, found that the addition of either wood or cane molasses to a grass-legume hay ration caused a decrease in the average apparent digestibility of crude protein.

In order to study the specific effects of available carbohydrates on digestibility, it is desirable to use a purified carbohydrate instead of molasses. A few such studies have been reported.

Mitchell and associates (1940) found that the digestibility of crude fiber was decreased 25 percent by the addition of glucose to beef-calf rations of different protein content. The unsupplemented rations contained timothy hay, corn, and cottonseed meal in various combinations.

Hamilton (1942) studied the effect of added glucose on the digestibility of ration constituents by sheep. The experimental animals consisted of six cross-bred ewe lambs. The basal ration contained cut timothy hay, ground yellow corn, and cottonseed meal in approximate ratios of 2:2:1 and analyzed 14.6 percent protein. The animals were fed 1.64 lb. of basal ration per 100 lb. live-weight. When sugar was fed, the animals received in addition to the basal ration 150 to 200 gm. of corn sugar daily. In addition, in each period each sheep received 6 gm. bonemeal, 3 gm. salt, 3 gm. yeast, and 0.5 cc. cod liver oil. The plan of feeding was a double reversal procedure. The average apparent digestion coefficients for the basal ration and the basal ration plus sugar, respectively, were: dry matter, 65.4 and 67.7 percent; total nitrogen, 61.9 and 54.1 percent; crude fiber, 43.8 and 31.9 percent; nitrogen-free extract, 76.4 and 79.7 percent. The addition of the sugar caused a significant decrease in apparent crude protein and crude fiber digestibility and a significant increase in the apparent digestibility of nitrogen-free extract.

Swift *et al.* (1947) reported on the influence of starch and cerelose on the digestibility of rations by sheep. A ration composed of 420 gm. of mixed alfalfa and timothy hay, 420 gm. corn meal and 48 gm. linseed oil meal and analyzing 13.2 percent protein was supplemented with 58 and 116 gm. of cerelose and with the same amounts of starch. In the case of starch the sheep refused to eat the larger amount so results were obtained with only the lower level. A group of five sheep was fed each of the rations. A different group of sheep was used to study starch supplementation than was used to study the cerelose supplementation. The addition of 58 gm. of cerelose resulted in a significant increase in the digestibility of the dry matter and energy of the ration but had no significant effect on the apparent digestibility of crude protein. The addition of 116 gm. of cerelose caused a significant decrease in the apparent digestibility of crude protein and crude fiber. No appreciable change in the digestion coefficients for dry matter and energy was observed. The feeding of 58 gm. of starch per day caused a depression in the apparent digestibility of crude protein and crude fiber.

Burroughs et al. (1949 c) conducted five series of digestion trials to study the effect of mineralized corn starch on the digestibility of roughage dry matter by steers. They found that if corn cobs or corn cobs and a limited amount of alfalfa hay made up the roughage part of the ration the addition of corn starch caused a marked reduction in the apparent digestibility of the roughage dry matter. However, if alfalfa hay was the only source of roughage the corn starch had no consistent effect on the apparent digestibility of the roughage dry matter.

Chappel (1952) found that the addition of 60 or 180 gm. of cerelose had no measurable effect on the crude fiber digestibility of a high-roughage sheep ration.

Williams and associates (1953) showed that the addition of 99 or

149 gm. of wheaten starch to sheep rations containing 5.2, 10.0 or 13.1 percent protein caused no significant effect on dry matter digestibility.

Arias *et al*. (1951) found that small amounts of a readily-available carbohydrate improved cellulose digestion *in vitro*.

The addition of a readily-available carbohydrate did not measureably increase the digestibility of ration nutrients by ruminants. Under certain experimental conditions the addition of a readily-available carbohydrate depressed the digestibility of crude fiber and crude protein. At least one worker has shown that the addition of an available carbohydrate to rations containing corn cobs as a part or all of the roughage caused a depression in the average apparent digestibility of roughage dry matter.

The Effect of Energy Intake on Protein Utilization

Lusk (1928) cited an experiment conducted on himself to study the effect of carbohydrate on nitrogen metabolism. A reduction in the carbohydrate intake was accompanied by a marked increase in nitrogen excretion and consequently a depression in nitrogen retention. Munro (1951) cited experiments conducted by European workers prior to 1900 in which the effect of energy intake on nitrogen retention by ruminants was investigated. In these early experiments the addition of carbohydrate and fat to ruminant rations generally induced nitrogen retention.

Forbes *et al*. (1939) studied the effect of fat and carbohydrate additions on nitrogen utilization by young male albino rats fed quantities of basal diets adequate for maintenance. Observations were made on rats weighing approximately 100 and 250 gm. It was found that supplementing the basal ration with either 1.24 gm. of lard or 3 gm. of dextrin resulted in a marked decrease in the average urinary nitrogen excretion and a marked increase in the percentage nitrogen retention. These workers did not observe consistent differences between the effects of fat and carbohydrate on nitrogen retention.

Bosshardt et al. (1946) studied the influence of caloric intake on dietary protein utilization. In the first experiment weanling albino mice were used as experimental animals. The mice were divided into groups and fed 10-percent casein diets in which the fat percentage varied from 2 to 32 percent. The corresponding range in energy values was 3.9 to 5.5 Calories per gm. of feed, respectively. The protein efficiency ratio increased from 1.72 to 2.29 as the caloric intake increased from 3.9 to 5.5 Calories per gm. As the fat level increased the amount of food and consequently of protein intake decreased, which made it difficult for them to evaluate their results.

The second experiment consisted of two series of studies. During the first series diets containing well-heated soyflour as a protein source were fed ad libitum to growing rats. Three series of diets were used. In two of the series the fat, sugar and fiber were varied to give diets covering a wide range of caloric value, while in the other series isocaloric diets were fed. These workers observed a marked reduction in protein utilization when the caloric intake was reduced below 80 percent of maximal intake.

They conducted a similar study in which mice were used as experimental animals and casein as the protein source. As in the previous study with rats, a limit was approached above which protein utilization could not be increased by increasing caloric intake. In this study a sharp reduction in protein utilization occurred when the caloric intake was below 95 percent of maximal intake.

Barnes and Bosshardt (1946) studied the effect of caloric intake on protein utilization in growing rats and mice. In one study rats were fed isocaloric rations of varying protein content *ad libitum*. The caloric intake varied from 11.1 to 15.3 calories per 100 square centimeters of body surface. The protein content of the diets, expressed as percent of protein calories in the diet, varied from 3.7 to 35.4. It was found that the highest protein efficiency ratio was obtained when the caloric intake was 15.3 calories per 100 square centimeters. This did not coincid with the highest protein level.

In the mice experiment isocaloric diets of variable protein content were again fed *ad libitum*. The percent of protein calories in the diet varied from 2.79 to 29.40. The caloric intake varied from 2.34 to 2.87 calories per gram average weight$^{2/3}$. As in the rat study mentioned above, the highest caloric intake coincided with the highest protein utilization.

In an experiment with growing mice Bosshardt *et al.* (1948) showed that when dietary calories were restricted by decreasing the consumption of fat and carbohydrate, while holding the protein intake constant, there was decreased protein utilization and decreased growth rate. Protein utilization was measured as the percentage of the absorbed nitrogen utilized for body gain. Under the condition of this experiment in which all diets contained some fat, carbohydrate, and protein, these workers observed that fat and carbohydrate were equal in their protein-sparing effect.

Munro and Naismith (1953) conducted a series of experiments with growing rats to determine the effect of energy intake on protein metabolism. In experiments 1 and 2 the rats were fed protein-containing diets and in experiments 3 and 4 they were fed protein-free diets. The daily energy intake of the animals fed the basal diet was about 800 to 900 Calories per square meter body surface. During experiments 1 and 3 carbohydrate was used to furnish additional energy and during experiments 2 and 4 fat was used. Additional energy was added to the basal diet in increasing amounts so that the daily energy intake increased from about 800 to 900 to about 1700 Calories per square meter body surface. Observations were made on body weight, nitrogen balance, and live nitrogen.

They found a linear relationship between energy intake and change in body weight. However, the influence of energy intake on body weight change was greater in the experiments in which protein-containing diets were fed. The influence of energy intake on nitrogen balance was found to be dependent on protein intake. If carbohydrate was added to the protein-containing diet, nitrogen balance increased in a strictly linear fashion with increments in energy intake. A curvilinear relation was apparent between energy intake and nitrogen balance when carbohydrate was added to the protein-free diet. No improvement in nitrogen balance was noted after the caloric intake exceeded about 1200 Calories per square meter. The addition of increasing amounts of fat to the protein-containing diet resulted in a linear increase in nitrogen retention. However, when it was added to a protein-free diet no improvement in retention was observed. It was also found that when the rats were receiving adequate-protein diets the amount of liver nitrogen was positively influenced by increments in energy intake, whether produced by addition of carbohydrate or fat. No significant change resulted from increasing the energy intakes of the animals fed protein-free diets.

These workers proposed an explanation of their results in terms of factors influencing protein synthesis. According to this view protein synthesis depends on the supply of both amino acids and energy, either of which can be a limiting factor in rate of protein synthesis. In the case of protein-free diets, energy intake may influence nitrogen balance up to a certain point (1200 Calories per square meter body surface in experiment 3) by promoting reutilization of amino acids circulating in the blood but eventually the limited nature of this source of amino acid will prevent further improvement in nitrogen balance as energy rises. When protein is included in the diet this limitation no longer exists and protein synthesis proceeds at a rate dependent on the level of energy yielding metabolites in the tissues.

Forbes and Swift (1944) showed that the percentage nitrogen excreted in the urine was reduced considerably by feeding cerelose and lard, alone or in combination, to mature rats fed a basal diet. It was also found that the average percentage nitrogen excreted in the urine was considerably lower when 1.5 gm. of lard were added than when either 4 gm. of cerelose or 2 gm. of cerelose and 0.737 gm. of lard were added to the basal diet.

Allison and Anderson (1945) conducted a study with six adult dogs. Nitrogen balance and biological value were measured at different levels of absorbed nitrogen and at two caloric intake levels, 80 and 100 calories per kilogram body weight. They demonstrated that increasing the caloric intake from 80 to 100 calories per kilogram body weight resulted in an increased nitrogen balance but was without effect on biological value.

Allison et al. (1946) showed that caloric restriction had to be severe before nitrogen utilization was affected in adult dogs. They used the nitrogen balance index as the criterion of nitrogen utilization . Dried uncooked egg albumin was the source of dietary protein nitrogen. Three caloric intakes were used, adequate, 50 percent adequate, and 25 percent adequate.

The nitrogen balance index was 0.96 for the dogs receiving an adequate or one half-adequate caloric intake. However, when the intake was reduced to 25 percent of normal the utilization of egg white was reduced. At this low caloric intake the dogs were not put in positive nitrogen balance even with nitrogen intakes as high as 4 gm. per day per square meter body surface. Increases in nitrogen intake were accompanied by large increases in urinary nitrogen. When the caloric intake was increased to 50 percent adequate by adding sucrose or lard, nitrogen balance was increased and urinary nitrogen lowered, thus demonstrating the protein-sparing action of carbohydrate and fat.

Rosenthal and Allison (1951) reported on studies conducted to study the effect of caloric intake on nitrogen utilization in adult dogs fed a constant amount of protein. They found that caloric restriction resulted in a decreased nitrogen balance but was without effect on the nitrogen balance index unless the restricted feeding was continued for several days.

Rosenthal (1952) studied the effect of caloric restriction and dietary fat on protein utilization. He tested the effect of varying the fat level at different caloric intakes. He showed that the nitrogen balance index of casein was not altered from normal by varying the fat content of the diet from 5 to 85 percent of total calories when the caloric intake was 100 or 50 percent of that required to maintain body weight. However, if the caloric intake was reduced to 25 percent normal an increase in dietary fat from 5 to 85 percent resulted in a decrease in nitrogen balance index from 0.70 to 0.41.

Larson and Chaikoff (1937) studied the effect of time of feeding a carbohydrate supplement on nitrogen excretion by adult dogs. They found that 50 gm. of glucose fed to adult dogs with the meal, 1, 2, 3, and 4 hours after the last meal or 4, 2, and 1 hour before the next meal caused a reduction in nitrogen excretion. Feeding the glucose 10 and 18 hours after the last meal had no effect.

Munro and Wikramanyake (1954) have recently shown that the addition of carbohydrate to the diet caused a reduction in nitrogen output even when it was taken separately from the protein of the diet. In experiments with human beings the maximum period of separation which was practicable was 5½ hours. In the case of the rat and dog the sparing effect was demonstrated even if the carbohydrate was given 12 hours apart from the rest of the diet.

Stevenson _et al._ (1946) observed that the incorporation of eggs in a basal ration at a level equivalent to 3.5 percent protein resulted in a marked depression in the quantity of nitrogen present in the urine of adult rats reduced to a constant plane of metabolism by feeding a low-nitrogen, 20-percent fat ration. They showed that upon the systematic reduction of the energy value of the diet, the sparing action of the egg protein was lost when the caloric intake was cut to less than 50 percent of normal intake.

Benditt _et al._ (1948) studied the effect of level of caloric intake on protein utilization in protein-depleted young adult albino rats. The test animals were protein depleted by feeding a low-protein, but otherwise adequate diet for 2½ months. Protein utilization was measured as the increase in body protein at the end of a 121-day feeding period on the test diet. Groups of five or six animals were used. During this experiment the protein intake of all the rats was approximately equal, averaging 8.5 gm. per kilogram body weight. The daily caloric intake varied from 560 to 1840 Calories per square meter body surface. The daily protein gain increased from 0.3 to 3.5 gm. per kilogram body weight as the caloric intake increased up to the 1240 Calorie level. Increasing caloric intake beyond this level had no effect on protein utilization.

In studies with six-month-old male rats, Swanson (1951) showed that reducing the caloric intake to 50 or 25 percent of normal had a greater influence on nitrogen metabolism when low-fat diets were fed than when high-fat diets were fed. In these tests the rats were brought to an approximately steady state of nitrogen metabolism by being maintained on a protein-free otherwise-adequate diet for 18 days. All observations were made during the following 14-16 days. Two groups of animals were prepared for study, one group receiving a high-fat and another group receiving a low-fat ration during the depletion period. The nitrogen retention of all animals was determined in a balance test beginning on the nineteenth day and lasting 5 or 7 days. Part of the animals were then fed nitrogen-poor diets of reduced calories and their nitrogen balance determined following a 4-day adjustment period. The remaining animals were continued on the full-calorie diet and their balances were redetermined. Nitrogen balance was measured at 25, 50, 75, and 100 percent normal intake.

It was found that nitrogen metabolism was not markedly altered by reducing the caloric intake to 75 percent normal. Reducing the caloric intake to 50 percent did not markedly affect the nitrogen metabolism of the animals on the high-fat diet but nitrogen balance was drastically reduced if the low-fat diet was fed. Reducing the caloric intake to 25 percent normal increased catabolism in the rats fed either the high-fat or the low-fat diet. However, the nitrogen balance of the animals fed the low-fat diet was still much less that of the rats fed the high-fat diet.

In another series of experiments in which the fat level was varied from 0 to 20 percent and the caloric intake was varied from 25 to 100 percent of normal, this worker obtained data indicating that the nitrogen metabolism of the animals fed a 25 percent normal caloric intake was not altered by a reduction in the fat content from 20 to 15 percent, but was markedly affected if the fat content was reduced to 10 percent or less.

In an earlier study with rats fed protein-free diets, Willman and associates (1947) reported that if rats were receiving only one-fourth normal caloric intake the animals fed a low-fat diet had a much greater urinary nitrogen excretion than those fed a high-fat diet.

Werner (1948) reported that a reduction of calories at a constant protein intake results in negative nitrogen balance in man.

The effect of energy intake on nitrogen utilization has been much less extensively studied in ruminants than in simple-stomach animals. Mitchell, Hamilton, and Haines (1940) conducted an experiment with beef calves in which the protein-sparing action of glucose was studied. Four steers were fed rations containing 7.53, 9.94, 15.57, and 22.41 percent protein alone and supplemented with glucose. When the sugar was fed with the three rations of higher protein content, all the steers consumed 1200 grams glucose except one that consumed only 1000 gm. When the glucose was fed with the 7.53 percent protein ration, three steers consumed 400 gm. and one consumed 1000 gm. glucose. The feces and urine were collected and nitrogen balances determined. The average daily nitrogen balances, expressed in gm., for the rations of different protein content with and without glucose, respectively, were: 7.53 percent protein, 5.39 and 5.65; 9.94 percent protein, 8.81 and 10.38; 15.57 percent protein, 21.81 and 15.52; 22.41 percent protein, 23.22 and 19.86. The protein-sparing effect of the sugar supplement was evident only when glucose was added to basal rations containing above 10 percent protein.

In an experiment with dairy calves (Colovos, 1949) the addition of wood molasses to grass-legume mixed hay was accompanied by a decrease in urinary nitrogen, an increase in fecal nitrogen, and a small increase in average nitrogen balance. Cane molasses appeared less effective in reducing the urinary nitrogen.

Lofgreen, Loosli, and Maynard (1951) studied the influence of energy intake on nitrogen retention in growing dairy calves. Eighteen Holstein heifer calves weighing about 150 lb. were divided into four lots and placed on four dietary treatments. The treatments were low energy-low protein, high energy-low protein, low energy-high protein, and high energy-high protein intakes. The low-protein level was the crude protein allowance as recommended by the Morrison standard and the high protein was 160 percent of this allowance. The low-energy level was the total digestible nutrient allowance recommended by the Morrison standard and the high-energy level was 115 percent of the allowance. The hay used was good quality alfalfa, timothy, or clover hay. The concentrate mixture was a 16-percent protein commercial calf starter at the start of the experiment and was changed to a growing mixture when the animals reached about 250 lb. The proper proportions of protein were maintained by supplementing the starter or growing mixture with a mixture of protein supplements. To furnish the high energy level, the total feed allowance was increased while maintaining the protein intake constant by the proper reduction in the percentage of protein in the concentrate mixture. Nitrogen balances were determined when the calves weighed 150, 200, 250, and 300 lb. Feces and urine were collected during 5-day collection periods preceded by 7-day preliminary periods.

The average nitrogen retention, expressed as the percent of consumed nitrogen, was 25.8 and 31.6, respectively, for the animals fed low energy-low protein and high energy-low protein rations and 24.4 and 21.5, respectively, for those fed the low energy-high protein and high energy-high protein rations. Increasing the non-nitrogenous total digestible nutrient consumption resulted in a marked increase in nitrogen retention of dairy calves fed a moderate-protein level but was without effect if the calves were fed a high-protein level.

Fontenot (1953) obtained data indicating that increased energy intake may exert a protein-sparing effect. Supplementing prairie hay with 2 lb. of a supplement containing approximately 20 percent protein resulted in a higher average nitrogen retention by beef steers than the supplementation of the hay with 1 lb. of a supplement containing approximately 40 percent protein. However, the observations were made on a small number of animals, 4 receiving the 20-percent protein supplement and 3 receiving the 40-percent protein supplement.

Williams et al. (1953) studied the effect of adding two levels of starch to rations of different protein content on nitrogen utilization by sheep. They found that the addition of 49 or 99 gm. of starch to a basal ration containing 5.2 percent protein resulted in a significant increase in biological value of the protein. However, the addition of either level of starch to rations containing 10.0 or 13.1 percent protein produced no significant effect on biological value. In the case of the last two basal rations when 49 or 99 gm. of starch were added, 58 gm. of wheat bran were removed and 74 gm. of wheat and 18 gm. of molasses were added. Observations were made with four animals per treatment. Further details of the experimental design have been previously presented.

From the literature reviewed it is apparent that energy intake influences nitrogen utilization in simple-stomach animals. Under certain experimental conditions fat and carbohydrate seem to be equal in their protein-sparing action while under other conditions they are not. At certain levels of protein intake, energy intake has been shown to cause an improvement in nitrogen balance in cattle. In sheep, increasing the energy intake seems to increase the biological value of the protein of rations of low protein content.

The Importance of Protein for Wintering Ruminants

Lantow (1930) conducted an experiment over a three-year period in which heifer calves were allowed to graze range forage during the entire yearly period. A different group of heifers was used each year. During the wintering period some of the heifer calves were allowed to graze the forage alone while others were fed different amounts of cottonseed cake in addition. During the wintering period the average gains increased as the amount of supplement fed increased. The average yearly gains of the heifers that were fed supplemental feed during the winter were higher than those of the heifers fed no supplement. There were no great differences among the various supplemented groups but the heifers fed the two higher levels of cottonseed cake during the winter made higher average yearly gains than did those fed the lower levels.

Brouse (1944) studied the value of cottonseed cake as a supplement to prairie hay for wintering calves. He found that the feeding of 0.5, 0.75, or 1.0 lb. of cottonseed cake during the wintering period resulted in increased winter and yearly gains. He also compared the relative value of 1.0 and 1.5 lb. of cottonseed cake for wintering calves fed prairie hay _ad libitum._ It was shown that supplementing prairie hay with 1.5 lb. of cottonseed cake per head daily resulted in a greater average winter gain than supplementation with 1.0 lb. However, the average yearly gains of the calves fed 1.0 and 1.5 lb. cottonseed cake during the winter were about equal.

Connell _et al._ (1948) conducted a three-year study to test the effect of adding a protein supplement to a wintering ration for steer calves on the subsequent gains of the animals on grass and in the feed lot. During the wintering period all the steers were fed chopped forage sorghum fodder and silage _ad libitum._ One group was fed 1 lb. per head daily of cottonseed meal or soybean oil meal in addition to their roughage while the other group received no protein supplementation. All the animals received salt and a mineral mixture of 2 parts ground limestone, 2 parts steamed bonemeal, and 1 part salt, free-choice. The average length of the wintering period was 113 days. During the summer the steers were grazed together on native short grass pasture for an average of 184 days and then fed in dry lot for an average of 183 days. These investigators showed that the feeding of one lb. of protein supplement caused an increase in average daily gain during the wintering period from 0.49 to 1.24 lb. The average summer gains were in favor of the steers fed no protein supplement. The average daily gain from the start of the experiment until the end of the grazing period was 1.04 and 0.91 lb. for the steers wintered with and without a protein supplement, respectively. During the fattening period the steers that had been fed a protein supplement during the winter gained an average of 1.95 lb. per head daily while those that had been fed no supplement gained 2.00 lb.

Kessler, Aicher, and Weber (1950) have summarized the results of a three-year study of the effect of supplementing silage with 0.5 or 1.0 lb. cottonseed cake on the winter gains of stock calves. The average of the wintering periods showed that supplementing silage with 1.0 lb. cottonseed cake resulted in a greater average daily gain than supplementation with only 0.5 lb. The average daily gain was 0.74 and 0.56 lb., respectively. The average feed cost per 100 lb. gain was less for the animals fed the cottonseed cake at the 1.0 lb. level than for those fed at the 0.5 lb. level. Data for the first two individual wintering periods can be found elsewhere (Weber and Aicher, 1946; Weber et al., 1951).

Brouse (1944) studied the relative value of cottonseed cake and 12-percent protein cubes as supplements to prairie hay (winter period of 180 days) and grass (grazing period of 150 days). Beef calves were used as experimental animals. One group of calves was fed cottonseed cake and another group was fed a 12-percent protein supplement. Both groups were fed their respective supplements at the rate of 0.75 lb. per head daily during the wintering period and 1.0 lb. per head daily during the subsequent grazing period. The average winter gains of the calves fed the cottonseed cake and the 12-percent protein supplement were 140 and 111 lb., respectively. Both groups made equal summer gains of 256 lb. per head.

This same worker conducted a subsequent study with beef calves fed prairie hay ad libitum supplemented with 1 lb. of either cottonseed cake, 22-percent protein cubes, or 12-percent protein cubes during the wintering period and allowed to graze during the summer period. The average winter gains of the calves fed cottonseed cake, 22-percent protein cubes, and 12-percent protein cubes were 186, 142, and 115 lb. per head, respectively. The average yearly gains in the same order as above were 373, 338, and 333 lb. per head, respectively. He reported the results of a study in which beef calves were fed 1 lb. cottonseed cake or 22-percent protein cubes in addition to prairie hay ad libitum. Results similar to those reviewed above were obtained.

Lantow and Snell, (1924) reported that there was little difference between the feeding value of ground corn and cottonseed cake when these supplements were fed during a 160-day period to cows being wintered on the range. The 5 cows fed 2.84 lb. of corn lost an average of 6 lb. and the 4 cows fed 2.84 lb. of cottonseed cake gained an average of 8 lb. during the period.

Black, Quesenberry, and Baker (1938) showed that cows wintered on the range and fed cottonseed cake produced calves that averaged 1.9 lb. heavier at birth and 13.6 lb. heavier at weaning than calves produced by cows fed no supplement. However, the average feed and range cost per 100 lb. of calf at weaning time was higher for the cows fed the supplement.

Stanley (1938) reported that the feeding of an average of 1.14 lb. of cottonseed cake to beef cows wintered on the range caused an increase of 35 lb. in the average winter gain of the cows. Calves from cows that were fed the cake during the winter were significantly heavier at birth than calves produced by the cows fed no supplementary protein. The average weaning weight of the calves from the cake-fed cows was slightly greater than that of calves from the cows receiving no cake but the difference was not great enough to pay for the supplementary cottonseed cake.

Nelson et al. (1953, 1954 a) conducted a 3-year study on the value of supplements containing approximately 20 and 40 percent protein for wintering bred yearling heifers on dry range grass. The average level of feeding the supplements during the first wintering period was 2.24 lb. per head daily. During the two last wintering periods the heifers were fed an average of 2.5 lb. of supplement per head daily. Data are reported only for the heifers that successfully raised a calf. The average weight change from the start of the wintering period until approximately March 1, which was the last weight obtained before the first cows calved in early spring, shows that the feeding of the 40-percent protein supplement always resulted in greater weight gains of the heifers than the feeding of the 20-percent protein supplement. The average birth weights of the calves produced by the cows fed the 40-percent protein supplement were a little greater than those of the calves from the cows fed the 20-percent protein supplement, the difference being significant only during the first two years. The weaning weights of the calves were not consistently influenced by the level of protein in the supplement fed the dams during the winter.

In an experiment with ewes wintered on range grass Chittenden et al. (1935) reported that 1/3 lb. of cottonseed cake per head daily produced greater average weight gains than an equal amount of corn. The supplements were fed during a 60-day period. Ewes fed either of the supplements maintained their weight better than those fed no supplement; however the unsupplemented ewes were fed a total of 1 lb. of cottonseed cake during 4 days of severe weather. The average birth and weaning weights of the lambs were not appreciably influenced by the addition of either of the supplements to the ewes' rations.

Van Horn and associates (1950, 1951, 1952, 1953) have conducted studies during a 4-year period with ewes wintered on the range and fed equal amounts of supplements of different protein content. Four different supplements were fed at the rate of 1/3 lb. per head per day. The protein content of the four supplements ranged from 10.8 to 11.8, 18.2 to 20.1, 27.1 to 30.6, and 32.2 to 39.2 percent during the four years. Approximately 200 ewes were fed each supplement each year. During each wintering period the average weight gains of the ewes increased as the protein content of the supplement fed increased. There were no large differences in the birth weights of the lambs among the various groups. However, each year the average birth of all lambs from ewes fed the supplement containing the highest amount of protein was slightly greater than that of the lambs from ewes fed the supplement containing the lowest amount of protein.

Supplementing a low-protein roughage with protein produces an increase in winter gains of cattle. Increasing the protein intake up to a certain level by increasing the total amount of a high-protein supplement or by increasing the concentration of protein in a supplement produces an increased winter gain in calves and breeding sheep and cattle. Protein supplementation of the dam's ration apparently affects the birth weight of the offspring under certain experimental conditions and does not seem to have a marked effect on the weaning weight of the offspring under the conditions of the experiments reviewed.

PART I. THE EFFECT OF ADDED CARBOHYDRATE ON NITROGEN METABOLISM OF STEERS

EXPERIMENT 1

The purpose of this experiment was to determine the effect of increasing amounts of cerelose on nitrogen utilization and the digestibility of ration constituents by steers fed a wintering-type basal ration composed of prairie hay, minerals and sufficient cottonseed meal to maintain nitrogen equilibrium.

Experimental Procedure

In Experiment 1 a group of twelve grade Hereford steers weighing approximately 515 lb. at the start of the experiment were used. The steers were fed four different rations during a series of four digestion trial periods extending from February 20, 1953 to June 9, 1953. The experiment was of a 4 x 4 latin square design in which three different latin squares were used. The steers were kept in false-bottom metabolism stalls as described by Nelson *et al.* (1954 b). A 10-day preliminary period preceded each 10-day collection period. At the end of the second 20-day period the steers were removed from the metabolism stalls and placed in hay-bedded box stalls for a 5-day rest period. The steers were fed twice daily.

The rations fed and the chemical composition of the feeds used in this experiment are given in Table 1. The average chemical composition of the rations is given in Table 2.

Table 1

Daily Amounts and Average Chemical Composition of Feeds Used in Experiment 1

Feed	Daily allowance in ration				Dry matter	Percentage composition of dry matter					
	8 A	8 B	8 C	8 D		Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	Ash
	gm.	gm.	gm.	gm.	%						
Prairie hay	2724	2724	2724	2724	94.47	92.20	4.93	2.48	32.77	52.02	7.80
Cottonseed meal	270	270	270	270	94.44	93.71	44.23	5.62	11.30	32.56	6.29
Cerelose	0	350	700	1050	90.94	100.00				100.00	
Salt	25	25	25	25	100.00						100.00
Dicalcium phosphate	26	26	26	26	97.09	12.02	6.86			5.16	87.98
Monosodium phosphate	10	10	10	10	100.00						100.00

Table 2

Average Chemical Composition of Rations Offered in Experiment 1

Ration	Percent dry matter	Percentage composition of dry matter					
		Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	Ash
8 A	94.86	90.52	8.36	2.74	30.19	49.23	9.48
8 B	94.46	91.47	7.53	2.44	27.20	54.29	8.54
8 C	94.13	92.24	6.85	2.22	24.74	58.32	7.77
8 D	93.86	92.88	6.28	2.03	22.69	61.87	7.13

The basal ration (Ration 8 A) contained 2724 gm. prairie hay, 270 gm. cottonseed meal, 10 gm. monosodium phosphate, 26 gm. dicalcium phosphate, and 25 gm. salt. It contained 8.36 percent protein. Rations 8 B, 8 C, 8 D consisted of the basal ration plus 350, 700, and 1050 gm. cerelose, respectively. These cerelose additions lowered the percentage of protein in the rations to 7.35, 6.85, and 6.28 percent, respectively.

The prairie hay was of average quality essentially free of weeds. The cottonseed meal was expeller pressed. The monosodium phosphate and dicalcium phosphate were of high purity and the ground rock salt was of feeding grade.

Feces were collected in metal boxes and transferred at frequent intervals to covered metal containers. The feces were weighed daily, and 5 percent aliquots were preserved in tightly covered glass jars under refrigeration. Thymol crystals were used to aid in preservation. Proximate analyses, as described by the Association of Official Agricultural Chemists (1950), were made on composite 10-day samples. During the first two digestion trials urine was collected by means of a rubber funnel held in place by two straps over the back of each steer. A rubber hose connected to the funnel directed the urine into 8-liter collection bottles beneath the floor of the stalls. During the last two trials urine was collected by means of a metal grid and metal funnel. The urine was diluted with water to a constant weight daily, and an aliquot was acidified and stored under refrigeration. Nitrogen was determined by the Kjeldahl method on combined daily aliquots from each steer.

The Thomas-Mitchell formula was used in the calculation of biological values of the nitrogen:

Biological value =

$$\frac{\text{N intake} - (\text{fecal N} - \text{metabolic N}) - (\text{urinary N} - \text{endogenous N})}{\text{N intake} - (\text{fecal N} - \text{metabolic N})} \times 100$$

The metabolic nitrogen and endogenous nitrogen were calculated by the method proposed by Swanson and Herman (1943). Fecal metabolic nitrogen was considered to be 5.3 grams per kilogram of dry matter intake. In calculating the endogenous urinary nitrogen the following equation was used: $N = 0.712\ X^{0.42}$ where N represents the grams of endogenous nitrogen and X the body weight in kilograms. Swanson and Herman calculated these values from results obtained by feeding low-nitrogen rations to dairy heifers.

The results for nitrogen balances, biological values, and apparent digestibility of organic matter, crude protein, crude fiber, and nitrogen-free extract were statistically analyzed according to methods described by Snedecor (1946).

Results and Discussion

The average daily nitrogen balance and biological value data are given in Table 3. The individual data for nitrogen balance and biological value are presented in Table 15, appendix.

The addition of 350 gm. of cerelose to the basal ration had no marked effect on nitrogen balance. The average daily nitrogen balance was 6.06 and 5.94 gm., respectively, for the rations containing 0 and 350 grams of cerelose. When the amount of cerelose added to the basal ration was increased from 350 to 700 and 1050 gm., the daily nitrogen balance dropped significantly (P .01) to 4.75 and 4.19 gm., respectively. The results, expressed as percentage nitrogen retention, were

Table 3

Average Daily Nitrogen Balance and Biological Value Data for Experiment 1

Ration	Intake		Excretion		Nitrogen retention		Meta-bolic N	Endo-genous N	True digested N	Absorbed N utilized	Biolog-ical value
	Dry matter	Nitro-gen	Fecal N	Urinary N							
	gm.	gm.	gm.	gm.	gm.	%	gm.	gm.	gm.	gm.	%
8 A	2884.1	38.50	18.40	14.04	6.06	15.76	15.28	6.99	35.39	28.34	80.04
8 B	3204.9	38.59	19.52	13.13	5.94	15.42	16.99	7.00	36.06	29.92	82.98
8 C	3482.2	38.27	21.44	12.09	4.74	12.46	18.46	6.99	35.29	30.20	85.54
8 D	3757.0	37.88	21.84	11.84	4.20	11.10	19.91	7.00	35.94	31.10	86.52

similar to these. The difference in nitrogen balance between rations 8 C (700 gm. cerelose) and 8 D (1050 gm. cerelose) was not statistically significant. Average urinary nitrogen excretion decreased as the amount of cerelose in the ration increased, indicating an improvement in utilization of absorbed nitrogen. However, average fecal nitrogen, due probably to increased metabolic nitrogen, increased to a greater extent than the decrease in urinary nitrogen, the net effect being a depression in nitrogen retention when high levels of cerelose were fed. The results are in general agreement with those obtained by Mitchell _et al._ (1940). Mitchell _et al._ found that the feeding of glucose to beef calves failed to increase nitrogen retention if the basal ration contained approximately 10 percent or less of protein. The results obtained in the present experiment are not in full agreement with those obtained in an earlier study conducted at the Oklahoma station (Fontenot, 1953). In the early study when two rations differing in caloric value but of approximately equal protein content were fed, the higher caloric ration induced the higher average nitrogen retention. A much smaller number of animals were used in that study than in the one reported here. Several studies with simple-stomach animals have also shown that decreased nitrogen retention accompanies caloric restriction. However, in some of these studies the caloric restriction was severe and the rations fed were low in fiber. Mitchell (1924) has shown that the fiber content of the ration influences fecal metabolic nitrogen.

The average biological value of protein increased in approximately a linear fashion as the amount of cerelose in the ration increased up to the 700 gm. level. The average biological values of protein in the rations containing 0, 350, 700, and 1050 gm. of cerelose were 80.04, 82.98, 85.54, and 86.52, respectively. The cerelose additions resulted in a highly significant ($P < .01$) increase in biological value. Furthermore, the biological value of the protein of the high cerelose rations (Ration 8 C and 8 D) was greater ($P < .01$) than that of the low cerelose ration (Ration 8 B) but the difference between Rations 8 C and 8 D was not statistically significant. The improvement in biological value observed when cerelose was added to the low-protein basal ration is in agreement with the recent work of Williams et al. (1953) in Australia. They observed an increase in biological value when starch was added to a low-protein sheep ration. Several workers have observed that a decrease in the protein percentage of a ration is usually accompanied by an increase in biological value. Some work with dogs (Allison et al. 1946), and rats and mice (Bosshardt et al., 1946, 1948; Barnes and Bosshardt, 1946; Benditt et al., 1948) show that nitrogen utilization is impaired when caloric intake is restricted.

Average values for the apparent digestibility of nutrients in each ration are shown in Table 4. The individual values are shown in Table 13, appendix. The addition of 350 gm. of cerelose to the basal ration had no apparent effect on organic matter digestibility. The apparent digestibility of organic matter in the rations containing 0 and 350 gm. cerelose was 63.34 and 63.36 percent, respectively. Increasing the amount of cerelose from 350 to 700 and 1050 gm. caused the organic matter digestibility to decrease significantly ($P < .01$) to 61.07 and 59.20 percent, respectively. The difference between the 700 and 1050 gm. levels was significant ($P < .05$). The effect of cerelose additions on dry matter digestibility appeared similar to that on organic matter digestibility.

Table 4

Average Apparent Digestion Coefficients for Experiment 1

Ration	Cerelose intake	Apparent percentage digestibility					
		Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract
	gm.						
8 A	0	60.04	63.34	52.26	70.72	71.58	59.76
8 B	350	60.31	63.36	49.45	69.94	66.98	63.14
8 C	700	58.38	61.07	44.01	70.12	58.66	63.71
8 D	1050	56.79	59.20	42.36	69.52	49.21	64.19

The average apparent crude protein digestibility decreased as the amount of cerelose in the ration increased. The difference in digestibility of crude protein between the basal and the cerelose-containing rations was highly significant. Increasing the cerelose intake from 350 to 700 and 1050 gm. per day resulted in a significant ($P < .01$) decrease in the crude protein digestion. The decrease in crude protein digestibility when the sugar addition was increased from 700 to 1050 gm. was significant at the 5 percent level. Thus, the addition of increasing amounts of readily-available carbohydrate to a wintering ration of the type used in this study appears to cause a progressive decrease in the crude protein digestibility. The depression in apparent crude protein digestibility caused by cerelose additions was probably due to increased fecal metabolic nitrogen excretion. The data in Table 3, which shows that there was no appreciable difference in true digested nitrogen among the four rations support this idea. These results are in general agreement with those obtained by Hamilton (1942) and Swift *et al.* (1947).

The apparent digestibility of crude fiber was decreased by a highly significant amount by cerelose addition. Increasing the cerelose intake from 350 to 700 and 1050 gm. or from 700 to 1050 gm. also caused a highly significant depression in digestibility. The depression in crude fiber digestibility seemed progressive but was especially severe when more than 350 gm. cerelose were included in the ration. Therefore, in wintering rations the value of large amounts of readily-available carbohydrate is nullified, in part, by decreased digestibility of crude fiber. The results obtained in this study are in general agreement with those reported by Mitchell *et al.* (1940), Hamilton (1942), and Swift *et al.* (1947). These workers, in separate experiments, observed that addition of relatively high levels of available carbohydrate to ruminant rations caused a marked depression in crude fiber digestibility.

The apparent digestibility of the nitrogen-free extract of the cerelose-containing rations was significantly ($P < .01$) greater than that in the basal ration. However, there were no significant differences in nitrogen-free extract digestibility among the cerelose-containing rations. Hamilton (1942) also observed an increase in nitrogen-free extract digestibility when glucose was added to a sheep ration.

There were no great differences in apparent ether extract digestibility among the various rations.

EXPERIMENT 2

The purpose of this experiment was to determine the influence of adding 700 and 1050 gm. of cerelose to a basal ration similar to that used in Experiment 1 but containing 10 percent protein.

Experimental Procedure

A group of six grade Hereford steers weighing an average of 540 pounds at the start of the experiment on November 9-11, 1953 were used. They were fed three rations which differed with respect to cerelose additions during a series of three digestion trials extending from November 25, 1953 to February 8, 1954. The experiment was of a 3 x 3 latin square design in which two randomly selected latin squares were used.

The rations offered and the chemical composition of the feeds used are given in Table 5. The average chemical composition of rations offered are shown in Table 6.

Table 5

Daily Amounts and Average Chemical Composition of Feeds Used in Experiment 2

Feed	Daily allowance in ration			Dry matter	Percentage composition of dry matter					
	10 A	10 B	10 C		Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	Ash
	gm.	gm.	gm.	%						
Prairie hay										
Trial 1	2724	2724	2724	95.47	93.62	5.07	2.35	34.16	52.04	6.38
Trials 2 and 3	2544	2544	2544	95.25	94.35	5.08	2.27	33.44	53.56	5.65
Cottonseed meal	404	404	404	94.55	93.50	41.95	6.01	10.81	34.73	6.50
Cerelose	0	700	1050	93.65	100.00				100.00	
Salt	25	25	25	100.00						100.00
Steamed bonemeal	16	16	16	97.00	13.97	7.31			6.66	86.03
Monosodium phosphate	16	16	16	100.00						100.00

Table 6

Average Chemical Composition of Rations Offered in Experiment 2

Items	Percent dry matter	Percentage composition of dry matter					
		Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	Ash
Trial 1							
Ration 10 A	95.43	91.92	9.72	2.68	30.66	48.96	8.08
Ration 10 B	95.11	93.35	7.99	2.21	25.25	57.90	6.65
Ration 10 C	94.99	93.90	7.34	2.03	23.17	61.36	6.10
Trials 2 and 3							
Ration 10 A	95.22	92.46	9.91	2.77	29.72	50.06	7.54
Ration 10 B	94.93	93.86	8.06	2.25	24.18	59.37	6.14
Ration 10 C	94.82	94.39	7.37	2.06	22.12	62.84	5.61

In Trial 1 the basal ration (Ration 10 A) contained 2724 gm. prairie hay, 404 gm. cottonseed meal, 25 gm. salt, 16 gm. steamed bonemeal, and 16 gm. monosodium phosphate. During this trial some of the steers refused a considerable amount of feed, so, during the two subsequent trials, the prairie hay intake was reduced to 2544 gm. per steer daily while the other ration components were fed at the same level as in Trial 1. The protein content of the basal ration offered during Trial 1 was 9.72 percent. The average protein content of the basal ration offered during Trials 2 and 3 was 9.91 percent. Rations 10 B and 10 C contained the basal ration plus 700 and 1050 gm. of cerelose, respectively. The cerelose additions resulted in a lowering of the average protein content of the rations to 7.99 and 7.34 percent, respectively, during Trial 1 and 8.06 and 7.37 percent, respectively, during the two subsequent trials. The averaged protein content of the three rations fed during the three trials is shown in Table 8.

The steamed bonemeal used was of a feeding grade. The other feeds used in this experiment were similar to those described for Experiment 1.

The steers were handled in a similar manner as in Experiment 1, except that they were removed from the metabolism stalls and placed in hay-bedded box stalls for a rest period of 3 to 5 days after each digestion trial. The methods used in collecting, sampling, and analyzing the excreta, and in the treatment of data, were similar to those described for Experiment 1.

Results and Discussion

Data for one animal on each ration were discarded because of feed refusals. For the statistical analyses the missing items were replaced using the method described by Cochran and Cox (1950).

The average daily nitrogen balance and biological value data are presented in Table 7. The individual data are given in Table 17, appendix.

The average daily nitrogen retentions obtained when rations containing 0, 700, and 1050 gm. cerelose were fed were 6.66, 8.73, and 7.79 gm., respectively. Nitrogen retention, expressed as gm. per day or percent of intake was significantly increased ($P < .05$) by the cerelose additions. As shown in Table 14, appendix, one of the steers, when fed the basal ration (Ration 10 A), had a very low nitrogen retention. However, since there were no other indications that the steer was abnormal this erratic value was included in the statistical analysis. As observed in Experiment 1 the feeding of the high levels of cerelose resulted in a marked decrease in average urinary nitrogen. However, the increase in average fecal nitrogen was not quite as large as the decrease in urinary nitrogen so the net result was a small improvement in average nitrogen retention. The fact that nitrogen retention was increased by cerelose in this experiment but was decreased in the first one may be related to the difference in protein content of the two basal rations. Mitchell _et al._ (1940) reported data indicating that there was a relation between protein content of the basal ration and the nitrogen-sparing action of added glucose.

The cerelose additions resulted in a significant ($P < .01$) increase in the biological value of nitrogen. The average biological values for the rations containing 0, 700, and 1050 gm. cerelose were 72.39, 83.53 and 83.83, respectively. These results agree with those obtained in Experiment 1 in which the basal ration contained approximately 8 percent

Table 7

Average Daily Nitrogen Balance and Biological Value Data for Experiment 2

Ration	Intake		Excretion		Nitrogen retention		Meta-bolic N	Endo-genous N	True digested N	Absorbed N utilized	Biolog-ical value
	Dry matter	Nitro-gen	Fecal N	Urinary N							
	gm.	gm.	gm.	gm.	gm.	%	gm.	gm.	gm.	gm.	%
10 A	2869.3	44.71	20.06	18.00	6.66	14.76	15.21	7.00	39.86	28.86	72.39
10 B	3531.2	45.60	23.10	13.78	8.73	19.12	18.72	6.99	41.22	34.43	83.53
10 C	3830.3	45.43	23.82	13.82	7.79	17.14	20.30	7.00	41.91	35.09	83.83

protein. In the present experiment, the addition of high levels of cerelose resulted not only in an improvement in utilization of absorbed nitrogen but also in an improvement in the utilization of ingested nitrogen. As in Experiment 1, the difference in biological value of nitrogen between the two high cerelose rations was not statistically significant.

The average apparent digestion coefficients are given in Table 8. The individual coefficients are presented in Table 18, appendix. The average apparent digestibility of the organic matter of the rations containing 0, 700, and 1050 gm. cerelose was 61.55, 61.55, and 62.71 percent respectively. Differences between these values were not significant. Other workers (Hamilton, 1942; Swift et al. 1947; Williams et al., 1953) have usually found that a readily-available carbohydrate either decreased or had no effect on dry matter digestibility.

The addition of 700 and 1050 gm. cerelose to the basal ration resulted in a highly significant decrease in apparent crude protein digestibility from 55.07 to 49.34 and 47.53 percent, respectively. These results agree with those obtained in Experiment 1. The crude protein digestibility was not significantly affected by increasing the cerelose intake from 700 to 1050 gm. per day.

The average crude fiber digestibility decreased from 64.58 to 51.18 and 47.44 percent, respectively, when cerelose was added to the basal ration at the 700 and 1050 gm. levels. Differences between the basal and cerelose-containing rations and between the two cerelose-containing rations were significant at the 1 percent level. These results, which agree with those obtained in the first experiment and with those reported by Mitchell et al., (1940), Hamilton (1942) and Swift et al (1947), reflect the effect of sugar additions and/or decreased

Table 8

Average Apparent Digestion Coefficients for Experiment 2

Ration	Cerelose intake	Average protein content	Average percentage digestibility					
			Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract
	gm.	%						
10 A	0	9.84	59.38	61.55	55.07	50.01	64.58	61.61
10 B	700	8.04	59.79	61.55	49.34	49.83	51.18	67.87
10 C	1050	7.36	61.08	62.71	47.53	50.14	47.44	70.36

protein percentage of the ration on crude fiber digestion.

The addition of cerelose caused a highly significant increase in apparent digestibility of nitrogen-free extract. The difference betwee the two cerelose-containing rations was also significant ($P < .01$). The digestion coefficients for the rations containing 0, 700, and 1050 gm. cerelose were 61.61, 67.87, and 70.36 percent, respectively.

There were no large differences among the different rations in ether extract digestibility.

EXPERIMENT 3

The purpose of this experiment was to determine the effect of ad- ng 700 and 1050 gm. of cerelose to a basal ration similar to those ed in Experiments 1 and 2 but containing 12 percent protein.

Experimental Procedure

This experiment was conducted simultaneously with Experiment 2 with six grade Hereford steers. The steers averaged 530 pounds at the start of the experiment on November 9-11, 1953. They were fed the basal and cerelose supplemented rations during a series of three digestion trials lasting from November 25, 1953 to February 9, 1954. The experimental design was identical with that described for the second experiment.

The rations offered and the chemical composition of the feeds used are given in Table 9. The average chemical composition of the rations are shown in Table 10.

The basal ration (Ration 12 A) fed during Trial 1 was composed of 2724 gm. prairie hay, 600 gm. cottonseed meal, 25 gm. salt, 14 gm. steamed bonemeal, and 8 gm. monosodium phosphate. During this trial, the

Table 9

Daily Amounts and Average Chemical Composition of Feeds Used in Experiment 3

Feeds	Daily allowance in ration			Dry matter	Percentage composition of dry matter					
	12 A	12 B	12 C		Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	Ash
	gm.	gm.	gm.	%						
Prairie hay										
Trial 1	2724	2724	2724	95.47	93.62	5.07	2.35	34.16	52.04	6.38
Trials 2 and 3	2544	2544	2544	95.25	94.35	5.08	2.27	33.44	53.56	5.65
Cottonseed meal	600	600	600	94.55	93.50	41.95	6.01	10.81	34.73	6.50
Cerelose	0	700	1050	93.65	100.00				100.00	
Salt	25	25	25	100.00						100.00
Steamed bonemeal	14	14	14	97.00	13.97	7.31			6.66	86.03
Monosodium phosphate	8	8	8	100.00						100.00

Table 10

Average Chemical Composition of Rations Offered in Experiment 3

Items	Percent dry matter	Percentage composition of dry matter					
		Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	Ash
Trial 1							
Ration 12 A	95.37	92.28	11.63	2.85	29.65	48.15	7.72
Ration 12 B	95.08	93.59	9.66	2.37	24.63	56.93	6.41
Ration 12 C	94.96	94.09	8.91	2.18	22.70	60.30	5.91
Trials 2 and 3							
Ration 12 A	95.17	92.82	11.88	2.99	28.64	49.31	7.18
Ration 12 B	94.89	94.09	9.77	2.46	23.56	58.30	5.91
Ration 12 C	94.79	94.58	8.97	2.26	21.64	61.71	5.42

steers being fed the ration containing the larger amount of cerelose refused a considerable amount of feed; so, in the two subsequent trials, the prairie hay intake was reduced to 2544 gm. per head per day. The other ration components were fed at the same level as in Trial 1. The basal ration contained 11.63 percent protein during Trial 1 and averaged 11.88 percent during Trials 2 and 3. Rations 12 B and 12 C were composed of the basal ration plus 700 and 1050 gm. cerelose, respectively. During Trial 1 the cerelose additions lowered the protein content of the ration to 9.66 (Ration 12 B) and 8.91 (Ration 12 C) percent, respectively. During Trials 2 and 3 the average protein content of Rations 12 B and 12 C was 9.77 and 8.97 percent, respectively. The average protein content of the three rations fed in this experiment is shown in Table 12.

Other experimental techniques were similar to those used during Experiment 2.

Results and Discussion

During the experiment there were no large feed refusals by the animals fed Rations 12 A and 12 B. However three animals fed the ration containing the larger amount of cerelose (Ration 12 C) refused a considerable amount of feed, so the data for these animals were discarded. Data are reported for six steers per treatment in the case of Rations 12 A and 12 B and for three steers in the case of Ration 12 C. In order to conduct the statistical analyses the missing items were replaced using the method described by Cochran and Cox (1950).

The average nitrogen balance and biological value data are shown in Table 11. The individual figures are given in Table 19, appendix.

Table 11

Average Daily Nitrogen Balance and Biological Value Data for Experiment 3

Ration	Intake: Dry matter	Intake: Nitrogen	Excretion: Fecal N	Excretion: Urinary N	Nitrogen retention		Metabolic N	Endogenous N	True digested N	Absorbed N utilized	Biological value
	gm.	gm.	gm.	gm.	gm.	%	gm.	gm.	gm.	gm.	%
12 A	3096.2	58.43	22.98	22.74	12.70	21.74	16.41	7.06	51.86	36.17	69.74
12 B	3719.8	58.18	27.96	17.23	13.00	22.32	19.71	7.09	49.93	39.80	79.72
12 C	4020.4	57.82	28.34	15.69	13.79	23.84	21.31	7.23	50.79	42.32	83.33

The addition of 700 and 1050 gm. cerelose to the 12-percent prote sal ration had no significant effect on the amounts of nitrogen retai by the steers, whether the results were expressed as gm. per day or as percent of intake. However, the trend of results favored the cerelose containing rations as in Experiment 2 where significant differences we obtained. The increase in average daily nitrogen retention from 13.00 to 13.77 gm. when cerelose intake was increased from 700 to 1050 gm. p day was not significant. In the present experiment the average urinar nitrogen excretion decreased with increases in cerelose intake but the average fecal nitrogen increased to such a great extent as to overcome this advantage.

The addition of 700 and 1050 gm. cerelose to the basal ration res ed in a highly significant increase in biological value of the nitroge from 69.74 to 79.72 and 83.33, respectively. These results agree with those observed in Experiments 1 and 2 with basal rations containing ap proximately 8 and 10 percent protein, respectively. The increase in average biological value when the cerelose intake was increased from 700 to 1050 gm. was statistically significant ($P < .05$).

The average apparent digestion coefficients are presented in Tabl 12. The individual coefficients are given in Table 20, appendix. The addition of 700 and 1050 gm. cerelose to the basal ration did not result in a significant change in organic matter digestibility. Increas ing the amount of cerelose in the ration from 700 to 1050 gm. had no s nificant effect on the digestibility of this ration constituent. The average coefficients for the rations containing 0, 700, and 1050 gm. cerelose were 62.35, 62.61, and 62.79 percent, respectively. These results agree well with those obtained in Experiment 2.

Table 12

Average Apparent Digestion Coefficients for Experiment 3

Ration	Cerelose intake	Average protein content	Average percentage digestibility					
			Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract
	gm.	%						
12 A	0	11.79	60.31	62.35	60.63	56.36	64.33	61.93
12 B	700	9.73	60.77	62.61	51.88	54.08	53.20	68.62
12 C	1050	8.95	61.05	62.79	50.93	53.47	48.14	70.05

The apparent crude protein digestibility was decreased significantly ($P < .01$) by the cerelose additions; differences between the two cerelose-containing rations were not significant. The results obtained in the three different experiments cannot be compared directly but it seems that increasing the cerelose intake from 700 to 1050 gm. has a more drastic effect on the apparent crude protein digestibility if the basal ration contains a small amount of protein than if it contains a larger amount.

The addition of 700 and 1050 gm. of cerelose to the basal ration resulted in a significant decrease in crude fiber digestibility; the average coefficients were 64.33 53.20, and 48.14 percent, respectively, for Rations 12 A, 12 B, and 12 C. Unlike the results obtained in Experiments 1 and 2, increasing the amount of cerelose from 700 to 1050 gm. per head daily had no significant effect. Although the results of the three experiments cannot be compared directly, it appears that the level of protein in the basal ration may determine, in part, the effect of cerelose on crude fiber digestion.

The average digestion coefficients for nitrogen-free extract were 61.93, 68.62, and 70.05 percent, for rations 12 A, 12 B, and 12 C, respectively. Differences between the basal and supplemented rations were statistically significant ($P < .05$) but the difference between the two supplemented rations was not.

There were no great differences among the different rations in average apparent ether extract digestibility.

PART II. SUPPLEMENTS OF DIFFERENT PROTEIN CONTENT FOR WINTERING BEEF HEIFER CALVES

During the last several years the practice of feeding supplements containing less than 40 percent crude protein to range beef cattle has increased in the Southwest. The present study was initiated to determine the relative value of supplements containing approximately 20, 30, and 40 percent protein when fed in equal amounts to weanling heifer calves being fed prairie hay or allowed to graze dry native grass during the winter. A 4-year summary of data collected from November, 1949 until October, 1953 is reported.

Experimental Procedure

The experimental animals consisted of a total of 253 grade Hereford weanling heifer calves, a different group of heifers being used each year. Five lots of weanling heifer calves were used during the first year. There were eight heifers in each of Lots 1, 2, and 3 and 11 heifers in each of Lots 6 and 7. In each of the 3 subsequent years, there were two additional lots of heifers, Lots 4 and 5. During those 3 years there were 10 heifers in each of the seven lots. Each year the heifer calves were allotted according to weight. The heifers of Lots 1, 2, and 3 were fed prairie hay *ad libitum*, in traps, supplemented with approximately 1 lb. per head per day of 20-, 30-, and 40-percent protein supplements, respectively, during each wintering period. The heifers of Lots 4, 5, 6, and 7 were allowed to graze the dry native grass at the Lake Carl Blackwell range area during the wintering period. The heifers of Lot 4 were fed approximately 1 lb. per head per day of 20-percent protein supplement and those of Lot 5 were fed approximately 1 lb. of the 40-percent protein supplement. The heifers of Lots 6 and 7 were fed approximately 2 lb. per head per day of 20- and 40-percent protein supplements, respectively. All the cattle had access to a mineral mixture composed of two parts salt and one part steamed bonemeal.

The supplements containing different amounts of protein were fed in a pelleted form. The 20-percent protein supplement fed during the first wintering period (1949-1950) was composed of 67 percent ground yellow corn and 33 percent cottonseed meal. In the three subsequent wintering periods the proportions were 66 and 34 percent, respectively. The 30-percent protein supplement fed each winter was composed of 62 percent cottonseed meal and 38 percent ground yellow corn. The 40-percent protein supplement was pelleted cottonseed meal. The calcium and phosphorus content of the three supplements fed during the last two winter feeding periods (1951-1952, 1952-1953) was approximately equalized by the inclusion of steamed bonemeal and/or ground limestone. The average chemical composition of the prairie hay and the three different supplements is shown in Table 13. The average chemical composition of the supplements containing no added minerals (fed in 1949-1950, 1950-1951) and the supplements containing added minerals (fed in 1951-1952, 1952-1953) are presented separately in the table.

The average date at the start of the winter feeding period was October 31. The cattle were weighed at approximately monthly intervals throughout the experiment. During the wintering period the heifers of Lots 4, 5, 6, and 7 had access to pastures which provided comparable grazing. The average date at the end of the wintering period was April 3

Table 13

Average Chemical Compositions of Feeds Used

Feed	Percent dry matter	Percentage composition of dry matter						
		Crude fiber	Crude protein	Nitrogen-free extract	Ether extract	Ash	Calcium	Phos-phorus
20-percent protein pellet (fed in 1949-50, 1950-51)	91.18	5.73	21.30	63.48	5.87	3.62	0.15	0.44
20-percent protein pellet (fed in 1951-52, 1952-53)	91.04	4.84	21.40	63.73	3.77	6.26	1.23	0.92
30-percent protein pellet (fed in 1949-50, 1950-51)	91.60	8.26	31.06	49.28	6.62	4.78	0.22	0.77
30-percent protein pellet (fed in 1951-52, 1952-53)	91.72	7.22	30.37	50.92	3.97	7.52	1.20	0.94
40-percent protein pellet (fed in 1949-50, 1950-51)	92.84	11.32	41.76	32.92	7.70	6.30	0.24	0.89
40-percent protein pellet (fed in 1951-52, 1952-53)	92.70	10.15	42.76	31.89	6.22	9.08	1.12	1.09
Prairie hay (av. of 4 years)	93.25	33.50	4.66	50.76	3.28	7.80	0.41	0.06

and the average length of the period was 153 days. When supplementary feeding was discontinued all the heifers were placed on native grass pastures.

On approximately May 15 of each year of the test the heifers were divided into breeding groups on the basis of winter treatment and a bull was placed with each group. The different groups of heifers had access to pastures of approximately the same size and of comparable grazing. The summer grazing phase was completed on the average date of October 31. At the end of the summer period the cattle were weighed and removed from the experiment. The average length of the summer period was 212 days and the average length of the yearly period was 365 days.

Results and Discussion

A summary of the average weight changes, feed consumption, and financial results is given in Table 14. The figures for all lots except Lots 4 and 5 represent a 4-year avarage. The figures for those two lots represent a 3-year average. The data for each year are given in Tables 21 through 24, appendix. Results for some of the individual years have been reported by Daniel (1951) and Fontenot (1953).

Trap-Fed Heifers. Lots 1, 2, and 3.

The average winter gain of the heifers wintered in traps and fed prairie hay supplemented with 1 lb. per head per day of 20-, 30-, and 40-percent protein supplements was -11, 34, and 81 lb., respectively. The gains of the heifer calves were directly related to the protein content of the supplement fed. It appears that the level of protein was the factor limiting gains and that the 20- and 30-percent protein

Table 14

Data of Weanling Heifer Calves Fed Supplements Containing 20, 30, and 40 Percent Protein

During the Wintering Period (Four-Year Average)

Items	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7
Heifers per lot (total)	38	35	38	30	30	41	41
Average daily ration (lb.)							
20-percent protein pellet	1.00			1.01		2.01	
30-percent protein pellet		1.01					
40-percent protein pellet			1.00		1.01		2.01
Prairie hay	9.34	10.20	10.37				
Range				ad lib	ad lib	ad lib	ad lib
Mineral	0.08	0.08	0.07	0.10	0.09	0.10	0.10
Winter feeding period (average, 153 days)							
Average weight data (lb.)							
Initial, 10-31	433	425	429	430	431	430	430
Final, 4-2	422	459	510	404	446	445	468
Total gain	-11	34	81	-26	15	15	38
Average daily gain	-0.07	0.22	0.53	-0.17	0.10	0.10	0.25
Average financial results (dollars)							
Initial value per head	123.40	121.29	122.40	131.13	131.45	122.56	122.56
Feed cost per head	15.90	17.53	18.14	9.68	12.85	14.96	17.15
Total cost per heifer (feed plus heifer)	139.30	138.82	140.54	140.8.	144.30	137.52	139.71
Value per head at end of winter[1]	120.65	128.58	140.64	118.89	130.12	125.04	128.55
Net return per head	-18.65	-10.24	0.10	-21.92	-14.18	-12.48	-11.16

Table 14 (continued)

Items	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7
			Summer grazing period (average, 212 days)				
Average weight data (lb.)							
Initial, 4-2	422	459	510	404	446	445	468
Final, 10-31	683	698	719	680	687	706	698
Total gain	261	239	209	276	241	261	230
Average daily gain	1.24	1.13	0.99	1.31	1.44	1.24	1.09
			Yearly (average, 365 days)				
Average weight data (lb.)							
Initial, 10-31	433	425	429	430	431	430	430
Final, 10-31	683	698	719	680	687	706	698
Total gain	250	273	290	250	256	276	268
Average daily gain	0.68	0.75	0.79	0.68	0.70	0.76	0.73
Total feed cost (dollars)							
Winter	15.90	17.53	18.14	9.68	10.80	14.96	17.15
Summer	14.10	14.10	14.10	14.14	14.14	14.10	14.10
Yearly	30.00	31.63	32.24	23.82	24.94	29.06	31.25

Average feed prices

20 percent protein pellet	$72.62 per ton
30 percent protein pellet	78.78 per ton
40 percent protein pellet	86.99 per ton
Prairie hay	13.75 per ton
Range	
Winter	3.31 per head
Summer	14.06 per head

[1] The weights were shrunk 3 percent.

supplements did not furnish enough protein to promote good growth. These results are in agreement with those obtained by Brouse (1944), who showed that when beef calves were fed prairie hay supplemented with 1 lb. of either 12-, 22-, or 40-percent protein supplement the winter gains were directly related to the protein content of the supplement.

The average hay consumption of the heifers fed the 30- and 40-percent protein supplements was about equal and exceeded that of the heifers fed the 20-percent protein supplement. The high net energy content and/or the low protein content of the low-protein supplement may have contributed to the differences.

The average feed cost per head during the wintering period increased with each increase in the protein content of the supplement. However, the average winter gain increased sufficiently so that the net return per heifer was positively related to the concentration of protein in the supplement. The 4-year average shows that the lot of heifers fed the 40-percent protein supplement was the only one in which the value per heifer at the end of the winter exceeded the total cost per heifer (feed plus heifer). In this lot the net return per heifer was only $0.10. The low average net return was mainly due to increased feed prices and decreased cattle prices during the last 2 years of this study.

In the spring there was usually a strong demand for thinner heifers such as those of Lot 1, so the appraised value per hundred-weight at the end of the wintering period favored cattle which had been fed the 20-percent protein supplement in 3 of the 4 years.

During the summer grazing period the average gains of the cattle were inversely related to their winter gains and the protein content of the supplement fed in the winter. The heifers of Lots 1, 2, and 3 made average summer gains of 261, 239, and 209 lb. respectively. As has been previously observed by ranchers and experimenters, the heifers that gained the least during the winter gained the most during the subsequent grazing period.

The average yearly gain of the heifers of Lots 1, 2, and 3 was 250, 273, and 290 lb., respectively. Thus, the average yearly gain, like the winter gain, was directly related to the protein content of the supplement fed during the winter.

Range-Fed Heifers. Lots 4, 5, 6, and 7.

The heifers that were allowed to graze the dry cured native grass and were fed 1 lb. per head per day of 20-percent protein supplement during the winter (Lot 4) lost an average of 26 lb. per head while those fed 1 lb. of the 40-percent protein supplement (Lot 5) gained 15 lb. during the wintering period. The heifers fed 2 lb. per head per day of 20- and 40-percent protein supplements (Lots 6 and 7) gained an average of 15 and 38 lb. per head, respectively. Thus on an equal intake basis the supplement containing the higher amount of protein (40 percent) promoted the greater winter gain. During the 3 years in which both lots were included in the study it is of interest that the heifers of Lot 5 gained an average of 15 lb. per head and those of Lot 6 gained an average of 12 lb. per head. These results indicated that protein and not energy was the first limiting factor under this system of feeding and management. Possibly, when pastures provide only limited amounts of dry cured native grass additional energy supplied by 2 lb. of the 20-percent protein supplement would be beneficial. For example, in a nitrogen balance study (Fontenot, 1953) steers fed 7 lb. of prairie hay supplemented with 2 lb. per head daily of a 20-percent protein supplement retained more nitrogen than those fed the same amount of hay supplemented with 1 lb. of a 40-percent protein supplement.

The average feed cost per head during the winter was higher for the heifers fed the 40-percent protein supplement than for those fed an equal amount of the 20-percent protein supplement. At the end of the wintering period the total cost per heifer exceeded the value per head in all lots. When the supplements were fed at the same level, however, the financial loss was greater in feeding the 20-percent protein supplement than the 40-percent protein supplement.

The only consistent difference in appraised value per hundredweight among these lots of heifers was between Lots 4 and 7. The thinner heifers of Lot 4 were always appraised higher than the fleshier ones of Lot 7.

During the summer grazing period the heifers of Lots 4, 5, 6, and 7 gained an average of 276, 241, 261, and 230 lb., respectively. As was observed with heifers wintered in traps, when the supplements were fed in equal amounts, the summer gain was inversely related to the winter gain and the protein content of the supplement.

The average yearly gain of the heifers fed the 20- and 40-percent protein supplements at the one-pound level was 250 and 256 lb., respectively. The average yearly gain of the heifers fed the above supplements at the two-pound level was 276 and 268 lb., respectively. From these results (small difference in gain) it appears that if the supplements are fed at the same level and good grazing is available in the summer, heifers fed 20- and 40-percent protein supplements will make about equal yearly gains. However, additional studies should be conducted to determine the effect of winter treatment of heifer calves on their subsequent performance in later years.

SUMMARY

Three metabolism experiments were conducted to study the effect of cerelose on nitrogen utilization and digestion of ration constituents by steers fed wintering-type basal rations containing different amounts of protein.

A feeding experiment was conducted over a 4-year period to test the relative value of supplements of different protein content for weanling beef heifer calves fed prairie hay _ad libitum_ or allowed to graze dry native grass during the winter.

The addition of 350 gm. of cerelose to a basal ration containing approximately 8 percent protein had no marked effect on nitrogen retention. Increasing the amount of cerelose in the ration from 350 to 700 and 1050 gm. resulted in a significant depression in nitrogen retention.

The addition of 700 and 1050 gm. of cerelose to a ration containing approximately 10 percent protein, however, resulted in a significant increase in nitrogen retention and resulted in a small but non-significant increase when added to a ration containing approximately 12 percent protein. Increasing the cerelose intake from 700 to 1050 gm. did not significantly affect nitrogen retention regardless of the protein content of the basal ration. A general effect of cerelose additions was to increase fecal nitrogen excretion and decrease urinary nitrogen excretion roughly in proportion to the amount of cerelose added.

Added cerelose resulted in a significant increase in biological value of the ration nitrogen, whether the basal ration contained 8, 10,

or 12 percent protein. When cerelose was added to the low-protein basal ration at levels of 350, 700, and 1050 gm., the response, as measured by average biological value was approximately linear up to but not beyond the 700 gm. level. Increasing the level of cerelose in the ration from 700 to 1050 gm. had a significant effect on biological value when the 12-percent protein basal ration was used but had no significant effect when the 8-and 10-percent protein basal rations were used.

The addition of cerelose to each basal ration resulted in a significant decrease in the apparent digestibility of crude protein and crude fiber and in a significant increase in the apparent digestibility of nitrogen-free extract; it had little effect on ether extract digestibility. Crude protein digestibility was further depressed by increasing the cerelose intake beyond the 700 gm. level only when the 8-percent protein basal ration was used. Increasing the amount of cerelose from 700 to 1050 gm. resulted in a highly significant decrease in crude fiber digestibility when the 8-and 10-percent protein rations were used. Only when the 10-percent protein basal ration was used did the increase in cerelose intake from 700 to 1050 gm. cause a significant increase ($P < .01$) in apparent nitrogen-free extract digestibility.

The digestibility of organic matter was significantly depressed by the addition of cerelose to the basal ration containing 8 percent protein. It was not appreciably affected by cerelose additions to the basal rations containing 10 and 12 percent protein.

When supplements containing 20, 30, and 40 percent protein were fed in the same amounts under the same experimental conditions, the average winter gains of the heifer calves were positively related, and average summer gains were negatively related, to the protein concentration in the supplement. The average yearly gains of the heifers wintered in traps and fed prairie hay _ad libitum_ increased with increases in the protein content of the supplement fed during the winter. The average yearly gains of heifers allowed to graze dry native grass during the winter were slightly greater for those fed 1 lb. per head per day of the 20-percent protein supplement than for those fed an equal amount of the 40-percent protein supplement. When the two supplements were fed at the rate of 2 lb. per head per day to heifers wintered on dry range grass, the yearly gains were slightly in favor of the cattle fed the 40-percent protein supplement.

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APPENDIX

TABLE 15

Daily Nitrogen Balance and Biological Value Data for Experiment 1

Ration	Trial no.	Steer no.	Intake: Dry matter	Intake: Nitrogen	Excretion: Fecal N	Excretion: Urinary N	Nitrogen retention		Metabolic N	Endogenous N	True digested N	Absorbed N utilized	Biological value
			gm.	gm.	gm.	gm.	gm.	%	gm.	gm.	gm.	gm.	%
8A	1	53	2876.5	37.60	18.34	13.20	6.06	16.12	15.24	6.89	34.50	28.19	81.71
	1	61	2876.5	37.60	17.63	13.84	6.13	16.30	15.24	7.10	35.21	28.47	80.86
	1	63	2876.5	37.60	17.95	15.20	4.45	11.84	15.24	7.07	34.89	26.76	76.70
	2	2	2892.2	38.57	17.87	13.60	7.10	18.41	15.33	7.16	36.03	29.59	82.13
	2	65	2892.2	38.57	19.64	12.56	6.37	16.52	15.33	6.84	34.26	28.54	83.30
	2	67	2892.2	38.57	16.20	12.40	9.97	25.85	15.33	7.07	37.70	32.37	85.86
	3	55	2890.2	38.47	18.02	13.20	7.25	18.85	15.32	6.98	35.77	29.55	82.61
	3	57	2890.2	38.47	18.29	13.10	7.08	18.40	15.32	7.13	35.50	29.53	83.18
	3	60	2890.2	38.47	18.74	14.00	5.73	14.89	15.32	6.95	35.05	28.00	79.89
	4	1	2895.1	39.80	17.84	17.00	4.96	12.46	15.34	7.16	37.30	27.46	73.62
	4	54	2895.1	39.80	20.39	15.20	4.21	10.58	15.34	6.84	34.75	26.39	75.94
	4	66	2842.2	38.46	19.83	15.20	3.43	8.92	15.06	6.68	33.69	25.17	74.71
	Av.		2884.1	38.50	18.40	14.04	6.06	15.76	15.28	6.99	35.39	28.34	80.04
8B	1	2	3194.8	37.60	19.12	13.84	4.64	12.34	16.93	7.18	35.41	28.75	81.19
	1	60	3172.2	37.41	19.08	12.96	5.37	14.35	16.81	6.95	35.14	29.13	82.90
	1	54	3194.8	37.60	17.89	12.00	7.71	20.51	16.93	6.86	36.64	31.50	85.97
	2	53	3210.5	38.57	19.01	12.84	6.72	17.42	17.02	6.92	36.58	30.66	83.82
	2	61	3210.5	38.57	18.95	13.04	6.58	17.06	17.02	7.10	36.64	30.70	83.79
	2	63	3210.5	38.57	19.58	14.00	4.99	12.94	17.02	7.07	36.01	29.08	80.76
	3	1	3208.5	38.47	19.91	13.20	5.36	13.93	17.01	7.16	35.57	29.53	83.02
	3	65	3208.5	38.47	19.74	11.60	7.13	18.53	17.01	6.84	35.74	30.98	86.68
	3	66	3208.5	38.47	18.80	11.50	8.17	21.24	17.01	6.72	36.68	31.90	86.97
	4	55	3213.4	39.80	21.75	13.40	4.65	11.68	17.03	7.01	35.08	28.69	81.78
	4	57	3213.4	39.80	21.28	14.70	3.82	9.60	17.03	7.13	35.55	27.98	78.71
	4	67	3213.4	39.80	19.17	14.50	6.14	15.43	17.03	7.01	37.66	30.17	80.11
	Av.		3204.9	38.59	19.52	13.13	5.94	15.42	16.99	7.00	36.06	29.92	82.98

Table 15 (continued)

Ration	Trial no.	Steer no.	Intake: Dry matter	Intake: Nitrogen	Excretion: Fecal N	Excretion: Urinary N	Nitrogen retention		Metabolic N	Endogenous N	True digested N	Absorbed N utilized	Biological value
			gm.	gm.	gm.	gm.	gm.	%	gm.	gm.	gm.	gm.	%
8C	1	1	3513.1	37.60	20.63	12.00	4.97	13.22	18.62	7.21	35.59	30.80	86.54
	1	67	3513.1	37.60	21.61	11.84	4.15	11.04	18.62	7.10	34.61	29.87	86.30
	1	55	3359.0	36.68	20.58	10.96	5.14	14.01	17.80	6.95	33.90	29.89	88.17
	2	57	3528.8	38.57	21.05	11.12	6.40	16.59	18.70	7.16	36.22	32.26	89.07
	2	66	3528.8	38.57	19.65	11.36	7.56	19.60	18.70	6.77	37.62	33.03	87.80
	2	54	3167.6	35.46	19.77	11.36	4.33	12.21	16.79	6.84	32.48	27.96	86.08
	3	61	3526.8	38.47	21.63	11.60	5.24	13.62	18.69	7.07	35.53	31.00	87.25
	3	53	3526.8	38.47	20.63	11.60	6.24	16.22	18.69	6.92	36.53	31.84	87.19
	3	63	3526.8	38.47	21.56	12.30	4.61	11.98	18.69	7.01	35.60	30.31	85.14
	4	2	3531.7	39.80	22.61	13.50	3.69	9.27	18.72	7.10	35.91	29.51	82.18
	4	60	3531.7	39.80	23.68	13.50	2.62	6.58	18.72	6.95	34.84	28.29	81.20
	4	65	3531.7	39.80	32.85	13.90	2.05	5.15	18.72	6.81	34.67	27.58	79.55
	Av.		3482.2	38.27	21.44	12.09	4.75	12.46	18.46	6.99	35.29	30.20	85.54
8D	1	57	3831.4	37.60	21.71	11.28	4.61	12.26	20.31	7.16	36.20	32.08	88.62
	1	65	3543.7	34.95	20.88	10.88	3.19	9.13	18.78	6.86	32.85	28.83	87.76
	1	66	3570.4	35.51	20.30	11.84	3.37	9.49	18.92	6.84	34.13	29.13	85.35
	2	1	3847.1	38.57	22.55	11.60	4.42	11.46	20.39	7.18	36.41	31.99	87.86
	2	60	3796.5	38.16	21.73	11.68	4.75	12.45	20.12	6.95	36.55	31.82	87.06
	2	55	3651.6	37.14	21.03	11.12	4.99	13.44	19.35	6.98	35.46	31.32	88.32
	3	2	3845.1	38.47	21.63	11.70	5.14	13.36	20.38	7.13	37.22	32.65	87.72
	3	67	3845.1	38.47	21.06	10.00	7.41	19.26	20.38	7.04	37.79	34.83	92.17
	3	54	3602.6	36.24	20.37	10.80	5.07	13.99	19.09	6.84	34.96	31.00	88.67
	4	53	3850.0	39.80	23.50	13.70	2.60	6.53	20.40	6.95	36.70	29.95	81.61
	4	61	3850.0	39.80	23.68	13.70	2.42	6.08	20.40	7.04	36.52	29.86	81.76
	4	63	3850.0	39.80	23.69	13.80	2.31	5.80	20.40	6.98	36.51	29.69	81.32
	Av.		3757.0	37.88	21.84	11.84	4.19	11.10	19.91	7.00	35.94	31.10	86.52

TABLE 16

Apparent Digestion Coefficients for Experiment 1

Ration	Trial no.	Steer no.	Dry matter intake	Apparent percentage digestibility: Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract
			gm.						
8 A	1	61	2876.5	58.58	62.00	52.88	67.15	71.35	57.60
	1	53	2876.5	60.66	64.12	51.00	77.67	73.04	60.26
	1	63	2876.5	58.68	61.53	52.24	69.20	67.77	58.91
	2	2	2892.2	61.37	65.33	53.86	80.05	77.18	59.07
	2	65	2892.2	57.80	61.40	49.05	73.97	73.48	55.27
	2	67	2892.2	61.09	64.30	58.29	70.60	72.81	59.68
	3	57	2890.2	56.94	60.08	52.49	66.55	69.48	54.85
	3	60	2890.2	57.61	60.91	51.13	69.79	62.89	60.81
	3	55	2890.2	56.39	59.58	53.20	64.99	68.49	54.52
	4	1	2895.1	65.81	68.63	55.29	68.29	74.77	67.42
	4	54	2895.1	62.72	66.14	48.99	67.29	73.13	65.01
	4	66	2842.2	62.88	66.08	48.68	73.03	74.54	63.70
	Av.		2884.1	60.04	63.34	52.26	70.72	71.58	59.76
8 B	1	2	3194.8	63.06	66.71	49.14	80.08	72.29	65.79
	1	60	3172.2	61.19	64.21	48.74	68.01	68.05	64.24
	1	54	3194.8	63.40	66.61	52.36	72.51	72.41	65.42
	2	63	3210.5	59.06	62.24	49.22	71.49	68.17	60.60
	2	53	3210.5	63.90	67.68	50.75	80.42	75.85	65.30
	2	61	3210.5	59.86	63.04	51.00	75.29	67.52	61.86
	3	1	3208.5	60.72	63.78	48.27	58.74	69.45	63.17
	3	65	3208.5	52.30	55.09	48.77	65.46	54.35	55.91
	3	66	3208.5	59.01	62.07	51.11	66.54	67.54	60.49
	4	55	3213.4	55.46	57.46	45.55	64.08	53.50	60.66
	4	57	3213.4	61.71	64.62	46.64	63.29	65.67	66.71
	4	67	3213.4	64.05	66.76	51.84	73.41	68.97	67.50
	Av.		3204.9	60.31	63.36	49.45	69.94	66.98	63.14

Table 16 (continued)

Ration	Trial no.	Steer no.	Dry matter intake	Apparent percentage digestibility					
				Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract
			gm.						
8 C	1	1	3513.1	64.63	67.33	44.92	80.15	67.27	69.48
	1	67	3513.1	59.52	62.53	42.49	62.49	60.94	65.46
	1	55	3359.0	55.28	57.71	43.77	70.64	56.11	59.55
	2	57	3528.8	55.15	57.75	45.47	69.46	57.44	58.86
	2	66	3528.8	61.61	64.49	49.06	75.80	66.91	64.82
	2	54	3167.6	60.50	63.91	44.29	79.89	65.96	64.79
	3	61	3526.8	54.24	56.94	43.69	69.06	52.36	60.18
	3	53	3526.8	59.67	62.48	46.46	61.22	61.54	64.86
	3	63	3526.8	55.71	58.30	43.88	69.44	56.49	60.40
	4	2	3531.7	59.21	61.73	43.29	67.01	54.37	66.59
	4	60	3531.7	58.85	61.15	40.58	68.56	56.55	65.11
	4	65	3531.7	56.13	58.49	40.24	67.74	47.95	64.46
	Av.		3482.2	58.38	61.07	44.01	70.12	58.66	63.71
8 D	1	57	3831.4	58.35	60.88	42.01	73.79	52.89	65.28
	1	65	3543.7	50.91	53.30	39.97	66.66	38.63	59.50
	1	66	3570.4	58.49	61.07	42.72	63.24	52.18	65.96
	2	1	3847.1	62.90	65.59	41.71	82.21	63.41	68.25
	2	60	3796.5	55.28	57.81	43.00	74.97	50.89	61.27
	2	55	3651.6	57.97	60.22	43.64	83.53	54.27	63.25
	3	2	3845.1	51.09	53.35	43.86	56.33	41.67	58.78
	3	67	3845.1	55.10	57.54	45.01	69.15	44.71	63.44
	3	54	3602.6	57.81	60.65	43.56	57.66	53.15	65.37
	4	53	3850.0	60.09	62.48	41.05	62.50	49.48	69.18
	4	61	3850.0	54.79	56.94	40.96	68.99	40.22	63.93
	4	63	3850.0	58.71	60.59	40.80	75.18	49.00	66.07
	Av.		3757.0	56.79	59.20	42.36	69.52	49.21	64.19

TABLE 17

Daily Nitrogen Balance and Biological Value Data for Experiment 2

Ration	Trial no.	Steer no.	Intake: Dry matter	Intake: Nitrogen	Excretion: Fecal N	Excretion: Urinary N	Nitrogen retention	Nitrogen retention	Metabolic N	Endogenous N	True digested N	Absorbed N utilized	Biological value
			gm.	gm.	gm.	gm.	gm.	%	gm.	gm.	gm.	gm.	%
10A	1	59	2900.6	42.01	20.15	18.90	2.96	7.05	15.37	7.04	37.23	25.37	68.14
	2	82	2860.4	45.08	19.72	19.00	6.36	14.11	15.16	6.84	40.52	28.36	69.99
	2	94	2860.4	45.08	19.74	17.50	7.84	17.39	15.16	7.16	40.50	30.16	74.47
	3	86	2862.6	45.70	21.18	14.00	10.52	23.02	15.17	7.04	39.68	32.72	82.46
	3	89	2862.6	45.70	19.50	20.60	5.60	12.25	15.17	6.90	41.37	27.67	66.88
	Av.		2869.3	44.71	20.06	18.00	6.66	14.76	15.21	7.00	39.86	28.86	72.39
10B	1	89	3652.0	46.90	23.03	14.30	9.57	20.41	19.36	6.98	43.23	35.91	83.07
	2	59	3451.8	44.64	22.50	14.49	7.65	17.14	18.29	6.95	40.43	32.89	81.35
	2	90	3516.0	45.08	22.08	13.90	9.10	20.19	18.63	7.04	41.63	34.77	83.52
	3	94	3518.1	45.70	23.66	13.40	8.64	18.91	18.65	7.13	40.69	34.42	84.59
	3	82	3518.1	45.70	24.23	12.80	8.67	18.97	18.65	6.84	40.12	34.16	85.14
	Av.		3531.2	45.60	23.10	13.78	8.73	19.12	18.72	6.99	41.22	34.43	83.53
10C	1	82	3853.7	46.09	22.94	15.60	7.55	16.38	20.42	6.98	43.57	34.95	80.22
	1	94	3923.9	45.77	25.77	11.10	8.90	19.44	20.80	7.21	40.80	36.91	90.46
	2	89	3776.2	44.51	23.51	13.70	7.30	16.40	20.01	7.01	41.01	34.32	83.69
	3	59	3774.1	45.23	24.47	13.00	7.76	17.16	20.00	6.84	40.76	34.60	84.89
	3	90	3823.8	45.53	22.41	15.70	7.42	16.30	20.27	6.98	43.39	34.67	79.90
	Av.		3830.3	45.43	23.82	13.82	7.79	17.14	20.30	7.00	41.91	35.09	83.83

TABLE 18

Apparent Digestion Coefficients for Experiment 2

Ration	Trial no.	Steer no.	Dry matter intake	Apparent percentage digestibility					
				Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract
			gm.						
10 A	1	59	2900.6	57.11	59.07	52.01	46.79	63.76	58.03
	2	82	2860.4	61.06	63.23	56.20	55.81	67.70	62.48
	2	94	2860.4	59.16	61.36	56.23	58.06	63.07	61.56
	3	86	2862.6	56.99	58.88	53.64	44.11	59.54	60.33
	3	89	2862.6	62.56	65.19	57.25	45.30	68.84	65.63
	Av.		2869.3	59.38	61.55	55.07	50.01	64.58	61.61
10 B	1	89	3652.0	59.58	61.30	50.92	49.15	52.96	66.80
	2	59	3451.8	57.95	59.60	49.50	54.18	45.77	66.53
	2	90	3516.0	60.25	62.11	51.10	60.02	50.91	68.12
	3	94	3518.1	59.24	60.87	48.33	46.20	50.10	67.62
	3	82	3518.1	61.95	63.85	46.83	39.58	56.14	70.29
	Av.		3531.2	59.79	61.55	49.34	49.83	51.18	67.87
10 C	1	82	3853.7	61.59	62.91	50.02	50.43	49.36	69.82
	1	94	3923.9	58.18	59.70	43.80	42.56	46.85	66.90
	2	89	3776.2	61.33	63.16	47.22	60.12	46.01	70.94
	3	59	3774.1	60.70	62.32	45.72	53.61	45.47	70.54
	3	90	3823.8	63.60	65.47	50.88	43.96	49.52	73.60
	Av.		3830.3	61.08	62.71	47.53	50.14	47.44	70.36

TABLE 19

Daily Nitrogen Balance and Biological Value Data for Experiment 3

Ration	Trial no.	Steer no.	Intake: Dry matter	Intake: Nitrogen	Excretion: Fecal N	Excretion: Urinary N	Nitrogen retention		Metabolic N	Endogenous N	True digested N	Absorbed N utilized	Biological value
			gm.	gm.	gm.	gm.	gm.	%	gm	gm.	gm.	gm.	%
12A	1	67	3215.0	59.83	22.57	22.68	14.58	24.37	17.04	7.04	54.30	38.66	71.20
	1	107	3215.0	59.83	23.70	24.54	11.59	19.37	17.04	7.13	53.17	35.76	67.26
	2	87	3035.9	57.45	21.85	21.94	13.66	23.78	16.09	6.91	51.69	36.66	70.92
	2	99	3035.9	57.45	23.19	23.60	10.66	18.56	16.09	7.18	50.35	33.93	67.39
	3	93	3037.7	58.00	23.18	20.70	14.12	24.34	16.10	6.84	50.92	37.06	72.78
	3	98	3037.7	58.00	23.40	23.00	11.60	20.00	16.10	7.24	50.70	34.94	68.92
	Av.		3096.2	58.43	22.98	22.74	12.70	21.74	16.41	7.06	51.86	36.17	69.74
12B	1	98	3784.4	59.20	28.13	17.70	13.37	22.58	20.06	7.29	51.13	40.72	79.64
	1	99	3870.5	59.83	26.59	18.45	14.79	24.72	20.51	7.13	53.75	42.43	78.94
	2	107	3691.5	57.45	26.75	17.01	13.69	23.83	19.56	7.16	50.26	40.41	80.41
	2	93	3691.5	57.45	29.75	15.30	12.40	21.58	19.56	6.87	47.26	38.83	82.16
	3	87	3587.5	57.18	28.02	16.40	12.76	22.32	19.01	7.04	48.17	38.81	80.57
	3	67	3693.2	58.00	28.54	18.50	10.96	18.90	19.57	7.04	49.03	37.57	76.63
	Av.		3719.8	58.18	27.96	17.23	13.00	22.32	19.71	7.09	49.93	39.80	79.72
12C	2	98	4019.2	57.45	28.52	16.10	12.83	22.33	21.30	7.29	50.23	41.42	82.46
	3	99	4021.0	58.00	27.78	16.18	14.04	24.21	21.31	7.21	51.53	42.56	82.59
	3	107	4021.0	58.00	28.71	14.80	14.49	24.98	21.31	7.18	50.60	42.98	84.94
	Av.		4020.4	57.82	28.34	15.69	13.79	23.84	21.31	7.23	50.79	42.32	83.33

TABLE 20

Apparent Digestion Coefficients for Experiment 3

Ration	Trial no.	Steer no.	Dry matter intake	Apparent percentage digestibility: Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract
			gm.						
12 A	1	67	3215.0	56.93	58.87	62.20	50.69	61.71	56.80
	1	107	3215.0	60.59	62.47	60.32	56.67	65.90	61.22
	2	87	3035.9	61.10	63.31	61.92	59.25	64.62	63.12
	2	99	3035.9	59.15	61.03	59.67	56.82	60.88	61.68
	3	93	3037.7	62.59	64.67	60.03	57.52	67.21	64.71
	3	98	3037.7	61.48	63.76	59.65	57.18	65.62	64.04
	Av.		3096.2	60.31	62.35	60.63	56.36	64.32	61.93
12 B	1	98	3784.4	62.08	63.64	52.38	55.42	57.41	68.57
	1	99	3870.5	59.58	61.09	55.62	53.00	51.13	66.65
	2	107	3691.5	62.46	64.66	53.43	51.75	56.17	70.40
	2	93	3691.5	56.90	58.57	48.17	62.27	44.78	65.55
	3	87	3587.5	59.74	61.71	51.05	46.48	49.91	68.95
	3	67	3693.2	63.88	65.99	50.65	55.53	59.82	71.58
	Av.		3719.8	60.77	62.61	51.88	54.08	53.20	68.62
12 C	2	98	4019.2	62.26	64.17	50.46	54.22	53.52	70.15
	3	99	4021.0	58.87	60.21	51.96	54.89	41.24	68.42
	3	107	4021.0	67.02	63.98	50.36	51.30	49.66	71.58
	Av.		4020.4	61.05	62.79	50.93	53.47	48.14	70.05

TABLE 21

Data of Weanling Heifer Calves Wintered on Supplements Containing

20, 30, and 40 Percent Protein (1949-50)[1]

Items	Lot 1	Lot 2	Lot 3	Lot 6	Lot 7
Heifers per lot	8	8	8	11	11
Average daily ration (lb.)					
20-percent protein pellet	0.99			1.99	
30-percent protein pellet		0.99			
40-percent protein pellet			0.99		1.98
Prairie hay	8.99	8.93	9.53		
Range				ad lib	ad lib
Mineral	0.09	0.09	0.07	0.08	0.08
	Winter feeding period	(138 days)			
Average weight data (lb.)					
Initial, 11-14-49	435	422	422	429	429
Final, 4-1-50	421	436	491	454	451
Total gain	-14	14	69	25	22
Average daily gain	-0.10	0.10	0.50	0.18	0.16
Financial results (dollars)					
Initial value per head($22.50 per cwt.)	97.88	94.95	94.95	96.52	96.52
Feed cost per head	11.44	11.75	12.77	12.33	14.44
Total cost per heifer(feed plus heifer)	109.32	106.70	107.72	108.85	110.96
Appraised value per cwt.	25.50	25.50	25.00	25.25	25.00
Value per head[2]	104.14	107.84	119.07	111.20	109.37
Net return per head	-5.18	1.14	11.35	2.35	-1.59

Table 21 (continued)

Items	Lot 1	Lot 2	Lot 3	Lot 6	Lot 7
			Summer grazing period (224 days)		
Average weight data (lb.)					
Initial, 4-1-50	421	436	491	454	451
Final, 11-10-50	708	710	736	726	695
Total gain	287	274	245	272	244
Average daily gain	1.28	1.22	1.09	1.21	1.08
			Yearly (362 days)		
Average weight data (lb.)					
Initial, 11-14-49	435	422	422	429	429
Final, 11-10-50	708	710	736	726	695
Total gain	273	288	314	297	266
Average daily gain	0.75	0.80	0.87	0.82	0.73
Total feed cost (dollars)					
Winter	11.44	11.75	12.77	12.33	14.44
Summer	14.00	14.00	14.00	14.00	14.00
Yearly	25.44	25.75	26.77	26.33	28.44

Feed prices

20-percent protein pellet	$62.80 per ton
30-percent protein pellet	67.80 per ton
40-percent protein pellet	78.20 per ton
Prairie hay	11.00 per ton
Range	
Winter	3.50 per head
Summer	14.00 per head

[1] These data are also reported by Daniel (1951).

[2] The weights were shrunk 3 percent.

TABLE 22

Data of Heifer Calves Wintered on Supplements Containing

20, 30, and 40 Percent Protein (1950-51)[1]

Items	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7
Heifers per lot	10	8[2]	10	10	10	10	10
Average daily ration (lb.)							
20-percent protein pellet	1.01			1.01		2.03	
30-percent protein pellet		1.01					
40-percent protein pellet			1.01		1.01		2.03
Prairie hay	9.04	9.26	9.52				
Range				ad lib	ad lib	ad lib	ad lib
Mineral	.06	.08	.06	.09	.09	.08	.09
	Winter feeding period (167 days)						
Average weight data (lb.)							
Initial, 10-20-50	423	408	423	419	422	420	420
Final, 4-6-51	439	490	538	391	433	444	465
Total gain	16	82	115	-28	11	24	45
Average daily gain	.10	.61	.69	-.17	.07	.14	.27
Financial results (dollars)							
Initial value per head (at $32.00/cwt.)	135.36	130.56	135.36	134.08	135.04	134.40	134.50
Feed cost per head	12.73	13.29	13.90	8.93	10.02	14.56	16.78
Total cost per heifer (feed plus heifer)	148.09	143.85	149.26	143.01	145.06	148.96	151.18
Appraised value per cwt.	39.00	38.00	37.00	39.00	39.00	39.00	38.00
Value per head[3]	166.07	180.61	193.09	147.92	163.80	167.97	171.40
Net return per head	17.98	36.76	43.83	4.91	18.74	19.01	20.22

Table 22 (continued)

Items	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7
			Summer grazing period (181 days)				
Average weight data (lb.)							
Initial, 4-6-52	439	490	538	391	433	444	465
Final, 10-4-51	673	713	724	702	684	708	706
Total gain	234	223	186	311	251	264	241
Average daily gain	1.29	1.54	1.03	1.72	1.39	1.46	1.33
			Yearly (348 days)				
Average weight data (lb.)							
Initial, 10-20-50	423	408	423	419	422	420	420
Final, 10-4-51	673	713	724	702	684	708	706
Total gain	250	305	301	283	262	288	286
Average daily gain	.72	.88	.86	.81	.75	.83	.82
Total feed cost (dollars)							
Winter	12.73	13.29	13.90	8.93	10.02	14.56	16.78
Summer	13.17	13.17	13.17	13.17	13.17	13.17	13.17
Yearly	25.90	26.46	27.07	22.10	23.19	27.73	29.95

Feed prices

20-percent protein pellet	$66.67 per ton
30-percent protein pellet	71.81 per ton
40-percent protein pellet	79.50 per ton
Prairie hay	9.00 per ton
Range	
Winter	3.00 per ton
Summer	13.00 per ton

[1]The data for the winter feeding period are also reported by Daniel (1951) and the data for all periods are reported by Fontenot (1953).
[2]Two heifers were removed from the experiment due to pregnancy.
[3]Weights were shrunk 3 percent.

TABLE 23

Data of Weanling Heifer Calves Wintered on Supplements Containing 20, 30, and 40 Percent Protein (1951-52)[1]

Item	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7
Heifers per lot	10	9[2]	10	10	10	10	10
Average daily ration (lb.)							
20-percent protein pellet	1.01			1.01		2.02	
30-percent protein pellet		1.03					
40-percent protein pellet			1.01		1.01		2.02
Prairie hay	10.07	11.81	11.63				
Range				ad lib	ad lib	ad lib	ad lib
Mineral	.05	.06	.08	.08	.09	.12	.09
Winter feeding period (162 days)							
Average weight data (lb.)							
Initial, 10-26-51	421	419	418	418	418	418	418
Final, 4-5-52	411	446	491	396	428	416	457
Total gain	-10	27	73	-22	10	-2	39
Average daily gain	-.06	.17	.45	-.14	.06	-.01	.24
Financial results (dollars)							
Initial value per head ($35.00/cwt)	147.35	146.65	146.30	146.30	146.30	146.30	146.30
Feed cost per head	18.46	21.07	21.12	9.33	10.04	15.55	16.76
Total cost per heifer (feed plus heifer)	165.81	167.72	167.52	155.63	156.34	161.85	163.06
Appraised value per cwt.	34.00	33.00	32.00	34.00	34.00	34.00	32.50
Value per head[3]	135.55	142.76	152.41	130.60	141.15	137.20	144.07
Net return per head	-30.26	-24.69	-15.01	-25.03	-15.19	-24.65	-18.99

Table 23 (continued)

Items	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7
	Summer grazing period (215 days)						
Average weight data (lb.)							
Initial, 4-5-52	411	446	491	396	428	416	457
Final, 11-6-52	673	670	694	666	658	661	671
Total gain	262	224	203	270	230	245	214
Average daily gain	1.22	1.04	0.94	1.26	1.07	1.14	1.00
	Yearly (377 days)						
Average weight data (lb.)							
Initial, 10-26-51	421	419	418	418	418	418	418
Final, 11-6-52	673	670	694	666	658	661	671
Total gain	252	251	276	248	240	243	253
Average daily gain	.67	.67	.73	.66	.64	.64	.67
Total feed cost (dollars)							
Winter	18.46	21.07	21.12	9.33	10.04	15.55	16.76
Summer	13.00	13.00	13.00	13.00	13.00	13.00	13.00
Yearly	31.46	34.07	34.12	22.33	23.04	28.55	29.76

Feed prices

20-percent protein pellet	$74.00 per ton
30-percent protein pellet	77.50 per ton
40-percent protein pellet	82.00 per ton
Prairie hay	15.00 per ton
Range	
Winter	3.00 per head
Summer	13.00 per head

[1] These data are also reported by Fontenot (1953).
[2] One heifer was removed from the experiment due to pregnancy.
[3] Weights were shrunk 3 percent.

TABLE 24

Data of Weanling Heifer Calves Wintered on Supplements Containing

20, 30, and 40 Percent Protein (1952-53)

Items	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7
Heifers per lot	10	10	10	10	10	10	10
Average daily ration (lb.)							
20-percent protein pellet	1.01			1.01		2.01	
30-percent protein pellet		1.01					
40-percent protein pellet			1.01		1.01		2.01
Prairie hay	9.26	10.81	10.81				
Range				ad lib	ad lib	ad lib	ad lib
Mineral	0.10	0.07	0.07	0.12	0.10	0.12	0.12
Winter feeding period (151 days)							
Average weight data (lb.)							
Initial, 11-2-52	452	452	452	452	452	452	452
Final, 4-2-53	417	463	518	424	476	467	498
Total gain	-35	11	66	-28	24	15	46
Average daily gain	-0.23	0.07	0.44	-0.19	0.16	0.10	0.30
Financial results (dollars)							
Initial value per head ($25.00 per cwt.)	113.00	113.00	113.00	113.00	113.00	113.00	113.00
Feed cost per head	20.95	24.01	24.79	10.78	12.34	17.39	20.62
Total cost per heifer (feed plus heifer)	133.95	137.01	137.79	123.78	125.34	130.39	133.62
Appraised value per cwt.	19.00	18.50	19.50	19.00	18.50	18.50	18.50
Value per head[1]	76.85	83.09	97.98	78.14	85.42	83.81	89.37
Net return per head	-57.10	-53.92	-39.81	-45.64	-39.92	-46.58	-44.25

Table 24 (continued)

Items	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7
	Summer grazing period (222 days)						
Average weight data (lb.)							
Initial, 4-2-53	417	463	518	426[2]	476	467	498
Final, 11-10-53	679	700	723	671	718	730	721
Total gain	262	233	205	245	242	263	223
Average daily gain	1.18	1.05	0.92	1.10	1.09	1.18	1.00
	Yearly (373 days)						
Average weight data (lb.)							
Initial, 11-2-52	452	452	452	454	452	452	452
Final, 11-10-53	679	700	723	671	718	730	721
Total gain	227	248	271	217	266	278	269
Average daily gain	0.61	0.66	0.73	0.59	0.71	0.75	0.72
Total feed cost (dollars)							
Winter	20.95	24.01	24.79	10.78	12.34	17.39	20.62
Summer	16.25	16.25	16.25	16.25	16.25	16.25	16.25
Yearly	37.20	40.26	41.04	27.03	28.59	33.64	36.87

Feed prices

20-percent protein pellet	$87.00 per ton
30-percent protein pellet	98.00 per ton
40-percent protein pellet	108.25 per ton
Prairie hay	20.00 per ton
Range	
Winter	3.75 per head
Summer	16.25 per head

[1] The weights were shrunk 3 percent.

[2] One heifer died in summer.

TABLE 25

Weights of Steers Used in Calculating Biological Value

Experiment no.	Steer no.	Trial no. 1	2	3	4
1[1]	1	545	540	535	535
	2	540	535	530	525
	53	490	495	495	500
	54	485	480	480	480
	55	500	505	505	510
	57	535	535	530	530
	60	500	500	500	500
	61	525	525	520	515
	63	520	520	510	505
	65	485	480	480	475
	66	480	470	460	455
	67	525	520	515	510
2	59	515	500	480	
	82	505	480	480	
	86	525	520	515	
	89	505	510	490	
	90	525	515	505	
	94	545	535	530	
3	67	515	520	515	
	87	520	520	515	
	93	480	485	480	
	98	560	560	550	
	99	530	540	545	
	107	530	535	540	

[1]The weights were estimated from weights obtained prior to the start of the experiment and at the end of the last trial.

TABLE 26

Examples of Methods Used in Statistical Analyses

Experiment	Analysis of Variance: Source		Degrees of freedom
1	Total		47
	Latin square		2
	Animals		9
	Period	(9)	
	Period		3
	Period X latin square		6
	Treatment	(9)	
	Treatment		3
	8A vs 8B, 8C, 8D	1	
	8B vs 8C, 8D	1	
	8C vs 8D	1	
	Treatment X latin square		6
	Error		18
2	Total		14
	Latin square		1
	Animals		4
	Period		2
	Treatment		2
	10A vs 10B, 10C	1	
	10B vs 10C	1	
	Error		5
3	Total		14
	Latin square		1
	Animals		4
	Period		2
	Treatment		2
	12A vs 12B, 12C	1	
	12B vs 12C	1	
	Error		5

VITA

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