THE EFFECT OF HIGH LEVELS OF ENERGY ON NITROGEN UTILIZATION AND DIGESTIBILITY OF WINTERING RATIONS BY STEERS

by

DIXON DALE HUBBARD

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Thesis Approved:

A. B. Nelson
Thesis Adviser

Robert J. Sirny

Robert MacVicar
Dean of the Graduate School

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INTRODUCTION

There has been extensive work done on the effect of high levels of energy on protein utilization in simple-stomached animals. However, only a limited amount of research has been conducted in which the effect of energy intake on nitrogen utilization in ruminants has been studied. This experimental work has given indications that protein utilization can be improved by increasing the energy level of a ration. However, the addition of high levels of energy, in some cases, has been shown to reduce digestibility of some ration constituents.

In most cases the source of energy in a ration is much cheaper than the source of protein. Thus, it is of economic importance to know whether or not the more expensive protein feeds could be replaced in part by the less expensive energy feeds.

Fat has been a surplus product since 1947 and it has been postulated that by 1958 there will be an annual surplus of 777 million lbs; however, very little attention has been given to the value of fat in ruminant nutrition. Most of the work concerned with nitrogen retention in ruminants has been done with carbohydrate, primarily with sugar.

For the subject of this thesis, it was decided to extend the studies on this problem to the effects of adding high levels of energy to basal wintering rations for steers. Two different sources of energy, fat and starch, were investigated as to their effects on nitrogen metabolism and on the digestibility of ration constituents.

REVIEW OF LITERATURE

The Effect of Energy Intake on Protein Utilization by Simple-Stomached Animals

The thesis has been generally accepted that the chief function of carbohydrate and fat in the animal organism is calorigenic and that dietary carbohydrate is better than dietary fat as a protein-sparing nutrient (Chalammetta and Mitchell, 1956).

Lusk (1928) experimented on himself to study the effect of carbohydrate on nitrogen metabolism. He found that a reduction in carbohydrate intake caused a marked increase in total nitrogen excretion and a depression in nitrogen retention.

Forbes et al. (1939) studied the effect of fat and carbohydrate addition on nitrogen retention by young rats. When a basal ration adequate for maintenance was supplemented with 1.24 gm of lard or 3 gm of dextrin, a marked decrease in the average urinary nitrogen excretion and a marked increase in the percentage nitrogen retention was noted. These workers did not observe consistent differences between the effects of fat and carbohydrate on nitrogen retention.

Thomson and Munro (1955) found that when olive oil was exchanged isocalorically for glucose in the diet of the rat, urinary nitrogen output increased for a few days and then returned to its former level. The transitory nature of the response may account for the failure of some investigators to observe any difference in nitrogen balance between groups of rats receiving isocaloric diets of fat and carbohydrate.

They also found that the exchange of fat for carbohydrate in protein-containing meals lead to a much greater increase in urinary nitrogen output than occurred after a similar exchange in meals devoid of protein. Thus the main consequence of replacing the carbohydrate of a mixed diet by fat was a deterioration in the utilization of dietary protein. The change in nitrogen balance resulting from substitution of fat for carbohydrate was of similar magnitude whether the fat was fed with protein of the diet or apart from it. This indicated that the phenomenon was essentially due to removal of carbohydrates from the protein-containing meal and not to an adverse effect of feeding fat with protein. There was a linear relationship between the carbohydrate content of the diet and the nitrogen balance of the rat.

Rosenthal and Allison (1951) studied caloric restriction with adult dogs consuming 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.

Munro and Naismith (1953) conducted a series of experiments to determine the effect of energy intake on protein metabolism in growing rats fed protein-containing and protein-free diets. The daily energy intake of the animals fed the basal diet was 800 to 900 Calories per square meter of body surface. The energy additions increased the daily energy intake to a maximum of 1700 Calories per square meter of body surface. There were many different diets with varying caloric intakes. They noticed no improvement in nitrogen balance after the caloric intake exceeded 1200 Calories. However, up to 1200 Calories there was a linear relationship between nitrogen balance and carbohydrate intake when protein-containing diets were fed. A curvilinear relationship was apparent between energy intake and nitrogen balance when carbohydrate was added to the protein-free diet. The addition of increasing amounts of fat to the protein-containing diet also resulted in a linear increase in nitrogen retention. However, when it was added to a protein-free diet no improvement in retention was observed. They 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 by addition of carbohydrate or fat. No significant change resulted from increasing the energy intake of the animals fed protein-free diets. These workers concluded that 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.

Chalammetta and Mitchell (1956) found that when fed in isocaloric amounts, dietary fat and carbohydrate had essentially the same effect on protein utilization in both the protein-depleted rat and the growing rat. They also found that neither the apparent digestibility nor the true digestibility of casein was improved by the higher (33 percent as compared to 5 percent) dietary fat level, and that fat did not seem to spare endogenous nitrogen under conditions of satisfactory and equal caloric intake. Also, higher dietary fat was not found to improve the biological value of casein in the protein-depleted rat. The metabolic fecal nitrogen per gram of food intake increased significantly when the dietary fat was increased because of a concomitant reduction in the food intake due to isocaloric feeding. This value, however, remained constant irrespective of the fat content of the diet when the rats were fed equal amounts of the low and high-fat diets.

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

Bosshardt et al. (1946) studied the influence of caloric intake on dietary protein utilization in weanling albino mice. They fed 10 percent casein diets in which the fat percentage varied from 2 to 32 percent. The protein efficiency ratio increased from 1.72 to 2.29 as the caloric intake increased. These results were hard to evaluate because as the fat level increased, the amount of food and consequently of protein intake decreased. They conducted a second experiment consisting of two separate studies. Three series of diets containing well-heated soyflour as a protein source were fed ad libitum to growing rats. 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 10 percent of maximal intake. Similar results were obtained with mice when casein was used as the protein source.

Womack and Marshall (1955) studied factors affecting liver fat and nitrogen balance in adult rats fed low levels of amino acids. They found that liver fat was reduced and negative nitrogen balances were decreased in adult protein-depleted rats fed extra threonine, corn, rice or wheat starch, or corn dextrin when compared to animals fed diets containing sucrose and low levels of amino acids. The results were not influenced by the type of carbohydrate fed during the protein depletion period. Substitution of potato starch or glucose for sucrose reduced liver fat but did not improve nitrogen balances. The addition of niacin, methionine, cullu-flour or sulfasuxidine, or substitution of fructose for sucrose did not change liver fat values or nitrogen balances for those obtained with sucrose.

Bosshardt et al. (1948) found that the restriction of calories by decreasing the consumption of fat and carbohydrate while holding the protein intake constant, decreased protein utilization and growth rate in growing mice. These workers observed that fat and carbohydrate were equal in their protein-sparing effect.

Forbes and Swift (1944) in an experiment with mature rats, found that the percentage nitrogen excreted in the urine was reduced considerably by feeding cerelose and lard, alone or in combination. They also found that the average percentage nitrogen excreted in the urine was considerably lower when 1.5 gm of lard was 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.

Rosenthal (1952), in a study with dogs, tested the effect of varying the fat level at different caloric intakes. He found 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, when he reduced the caloric intake to 25 percent of 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.

Benditt *et al*. (1948) conducted a study on the level of caloric intake as to its effect on protein utilization in protein-depleted adult albino rats. In this experiment the protein intake of all the rats was approximately equal, averaging 8.5 gm per kilogram of body weight. The daily caloric intake varied from 560 to 1840 Calories per square meter of body surface. The daily protein gain increased from 0.3 to 3.5 gm per kg of body weight as the caloric intake increased up to the 1240 Caloric level. They found that increasing caloric intake beyond this level had no effect on protein utilization.

Willman *et al*. (1947) found that if rats were receiving only one-fourth of the normal caloric intake the animals fed a low-fat diet had a much greater urinary nitrogen excretion than those fed a high-fat diet.

Swanson (1951) found a greater influence on nitrogen metabolism in six-month-old male rats when low-fat diets were fed than when high-fat diets were fed. The rats were brought to a steady state of nitrogen metabolism by being maintained on a protein-free diet for 18 days. During the depletion period she fed a high-fat ration to one group of animals and a low-fat ration to another group. She found that nitrogen metabolism was not markedly altered by reducing the caloric intake to 75 percent of normal. Reducing the caloric intake to 50 percent did not markedly affect the nitrogen metabolism of the high-fat diet but nitrogen balance was drastically reduced when the low-fat diet was fed. Reducing the caloric intake to 25 percent of normal increased catabolism in the rats fed either the high-fat or the low-fat diet. However, the nitrogen retention of the animals fed the low-fat diet was still much less than the rats fed the high-fat diet.

To obtain information on the protein-sparing action of fat Barnett (1955) conducted a study with albino rats. Different animals received rations containing 25 percent protein provided by soybean flour low in fat (0.6 percent) and high in protein (52 percent). Rations A, B, and C contained 7, 20, and 30 percent, respectively, of hydrogenated vegetable shortening as a source of fat. In addition, all rations included a complete salt mixture and were abundantly supplied with essential vitamins. There were 30 animals on each treatment and the sexes were evenly divided. The rations were evaluated by an efficiency ratio, as expressed by the gain in body weight per gram of protein intake. He found that as the percent of fat in the ration increased, there was a marked reduction in total food consumed, with an accompanying increase in protein efficiency. Increasing the amount of fat from 7 to 20 percent of the ration resulted in a 17.1 percent increase in protein efficiency. Further increasing the fat to 30 percent gave a 31.6 percent increase in protein utilization as compared to ration A.

From the literature reviewed it is apparent that energy intake influences nitrogen utilization in simple-stomached animals. Carbohydrate seems to have a greater sparing action on protein than fat. However, many workers found that under certain experimental conditions fat and carbohydrate seem to be equal in their protein-sparing action.

The Effect of Energy Intake on Digestibility of Ration Nutrients and Protein Utilization in the Ruminant

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 increased nitrogen retention.

Lofgreen et al. (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 in the Morrison (1948) standard and the high protein was 160 percent of this allowance. The low-energy level was the total digestible nutrient allowance recommended in 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.

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 low-protein level but was without effect if the calves were fed a high-protein level.

Swift _et al._ (1947) studied the effect of different supplements on apparent digestibility of a ration by sheep. Corn oil, starch, and cerelose were the supplements used. The basal ration contained 420 gm mixed hay (alfalfa and timothy of excellent quality), 420 gm corn meal, and 48 gm linseed meal. Additions to the basal ration were: 34 gm corn oil, 68 gm corn oil, 58 gm starch, 116 gm starch, 58 gm cerelose, and 116 gm cerelose. It was found that the addition of 34 gm of corn oil increased the apparent and true digestibility of every feed constituent with the greatest increase in protein digestibility. When the amount of corn oil was doubled, however, all of the digestion coefficients except that for ether extract, were reduced to values below those obtained with the basal ration. In the case of starch the sheep refused to eat the larger amount so results were obtained with only the lower level, and the feeding of 58 gm of starch per day caused a depression in the apparent digestibility of crude fiber and protein. 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 protein.

The addition of 116 gm of cerelose caused a significant decrease in the apparent digestibility of protein and crude fiber. No appreciable change in the digestion coefficients for dry matter and energy was observed.

Swift et al. (1948) conducted an experiment with sheep on the effect of dietary fat on utilization of energy and protein. The basal ration was the same as the one used by Swift et al. (1947). The primary objective of this experiment was to determine the optimum amount of fat in rations for sheep. They fed 6 rations containing 3, 4, 5, 6, 7, and 8 percent ether extract. They found that as the fat content of the ration increased, the percentage digestibility of the ether extract increased in a regular manner. Similarly, the digestibility of the nitrogen-free extract decreased regularly with each addition of fat. There was a definite trend toward a decrease in the digestibility of dry matter with increased fat in the ration. They found that when rations differed by 3 percent of fat the differences in digestibility were statistically significant. No consistent effect on digestibility of protein or crude fiber was noticed by these workers.

Brooks et al. (1954) reported the effect of corn oil and lard on the digestion of cellulose and crude fiber. Three digestion trials were conducted using the chromimum oxide indicator method with 20 crossbred yearling wether lambs in each trial. The basal ration contained 908 gm cottonseed hulls, 94 gm casein, 6 gm Cr_2O_3 and 2500 I. U. vitamin A per day. All sheep lost weight during the trial, but the weight loss was greater in sheep fed the corn oil than in sheep fed the basal ration. The coefficients of digestibility of cellulose and protein were reduced 52 and 17 percent, respectively, by the addition of

32 gm of corn oil. The sheep developed anorexia and consumed only 87 percent as much feed as the sheep in the basal lot during the last part of the feeding period. When 64 gm of corn oil was fed daily, the sheep consumed only 70 percent as much feed as the basal lot and they scoured and appeared listless. The coefficients of digestibility of cellulose and protein were reduced 70 and 36 percent, respectively. Sheep receiving 32 gm of lard per day digested 33 percent less cellulose than those on the basal ration. There was no apparent loss of appetite and there was little change in the digestibility of protein, but a marked decrease in cellulose digestion. Sheep receiving 64 gm of lard did not scour or appear listless, but their feed intake was reduced 6 percent. The coefficient of digestibility of cellulose was 52 percent lower than in sheep fed the basal ration, and the coefficient of digestibility of protein was decreased 33 percent.

Rhodes et al. (1956) found that when corn syrup was replaced with 1.8, 3.0, and 4.2 percent corn oil in rations containing 65 to 80 percent cottonseed hulls, the digestibility of protein and cellulose was significantly decreased. Nitrogen retention paralleled protein digestibility.

Erwin et al. (1956a) studied the effect of different feed additives on digestibilities of dry matter, crude fiber, ether extract and protein. They found that the addition of 7 percent fat (bleachable fancy tallow) significantly ($P < 0.01$) reduced the digestibility of dry matter and crude fiber by steers when fed either a high alfalfa hay or high straw ration. The digestibility of the added fat was significantly higher than the ether extract present in the ration. The only difference in the two rations fed was that one contained 82 percent alfalfa hay and the other contained 82 percent wheat straw.

In a previous experiment Erwin et al. (1956b) studied the effect of 7 percent fat on high-and low-quality roughage diets. It was found that the addition of 7 percent fat significantly increased ($P < 0.01$) rates of gain of steers fed alfalfa hay, and that this same level of fat significantly reduced ($P < 0.01$) the rates of gain of steers consuming wheat straw rations during a 183-day feeding period. The reduction was such that the over-all effect of fat in the two rations was to significantly depress the rate of gain.

Hale and King (1955) studied the effect of added fat on the digestibility of rations by lambs. Corn oil, prime tallow, and hydrogenated animal fat were added at 0, 4, 8, and 12 percent levels to the ration. The 4 percent addition had little, if any, effect upon digestibility of dry matter. The two higher levels markedly reduced dry matter digestibility. When feed and feces were corrected for fat content the corn oil had the most detrimental effect upon digestibility of dry matter.

Johnson et al. (1956) conducted a study on the effect of addition of inedible tallow to a calf starter containing 0, 2.5, 5.0, and 10.0 percent inedible stabilized tallow. The pounds of dry matter required per pound of live weight increase were less in the calves fed the starter containing tallow. The utilization of total digestible nutrients was not appreciably affected by the addition of tallow. These workers conducted digestibility and mineral balance studies with eight of the above calves and four lambs. The results from these studies indicated that when tallow was fed, there was a decrease in the apparent digestibility of dry matter, organic matter, protein, and nitrogen-free extract in calves and lambs, whereas ether extract digestibility was increased for both species.

Robinson et al. (1956) studied the sparing action of added carbohydrate and fat in ruminant rations. They used 8 grade Hereford steers fed a basal wintering-type ration (9.5 percent protein on the dry matter basis) of 3000 gm prairie hay, 454 gm cottonseed meal, and complex minerals. Finely ground corn was used as a source of carbohydrate and refined corn oil as a source of fat. In the trials with carbohydrate 118 gm of cottonseed meal was replaced with an iso-nitrogenous amount of corn. In the trials with fat 200 gm of corn oil was added directly to the cottonseed meal or the basal ration. The addition of corn decreased nitrogen excretion in the urine but increased it in the feces. The increased fecal nitrogen excretion was associated with the increased intake and excretion of dry matter and a lower digestibility of crude fiber. Total nitrogen retention was decreased from 24.2 percent of the intake to 22.5 percent. The addition of fat decreased urinary nitrogen excretion without affecting fecal nitrogen excretion. Total nitrogen retention was increased from 21.1 percent of the intake to 24.7 percent.

Lucas and Loosli (1944) studied the effect of added dietary fat upon the digestibility of other ration components fed to dairy cattle. They found that the digestibility of dry matter, nitrogen-free extract, and crude fiber were reduced when the ether extract content of the diet was increased to 7 percent by the addition of corn oil or soybean oil.

Ward (1956) found that corn oil depressed growth of lambs when added to a semi-purified diet containing cottonseed hulls. Later, in a digestion study he found that corn oil, when added to rations containing low-quality roughage, lowered the apparent digestibility of nitrogen-free extract, crude fiber and dry matter. The corn oil content of the ration was 10 percent.

Hentges _et al_. (1954) conducted an experiment which indicated that waste beef fat could satisfactorily replace up to 5 percent of the concentrate in steer fattening rations. These workers conducted a 154-day feeding trial in which they fed rations containing 0, 5, and 10 percent additional fat. These rations produced daily gains of 1.8, 1.9, and 1.5 lb, respectively.

Willey _et al_. (1952), in a fattening experiment, found no difference in rate of gain of steers fed a ration in which the fat content had been raised from 3 to 7.5 percent by the addition of cottonseed oil. It was noted, however, that the amount of feed required per 100 lb of gain decreased from 820 to 710 lb when fat was added to the ration.

Kammlade and Butler (1954) conducted a fattening experiment with lambs in which they added fat at the 0, 5, 10, and 15 percent levels. They obtained greater feed efficiency and lowered cost of gain for lambs fed rations containing 5 and 10 percent fat. There were no significant differences between gain and carcass weight of any of the groups.

Summers _et al_. (1956) found that a decrease in the corncob content of a ration from 80 to 65 percent by corn starch replacement significantly reduced the digestion of cellulose from 74.2 to 68.4 percent.

Burroughs _et al_. (1949) conducted five 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.

Head (1953) conducted a series of digestion trials with sheep, in which he studied the effect of quantity and quality of carbohydrate and protein on cellulose digestion. He found that the addition of relatively small amounts of maize or potato starch to a ration of hay was associated with a depression in the digestibility of cellulose. He also found that the greater the amount of supplementary starch given to the sheep, the greater the depression in cellulose digestibility. The depression was greater when potato starch was added to the ration. The retention of nitrogen was not influenced by the addition of starch to the hay ration; however, retention was increased when starch was added to a hay and casein ration. The addition of other supplements (starch and protein) had no marked effect on the digestibility of the ration.

Williams _et al_. (1953) studied the effect of adding two levels of starch to rations containing different protein levels 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.

Hamilton (1942) studied the effect of corn sugar upon the digestibility of the nutrients of a ration. He used six sheep as experimental animals and the double reversal method of feeding. The basal ration contained cut timothy hay, ground yellow corn, and cottonseed meal in approximate ratios of 2:2:1. This ration contained 14.6 percent protein. The animals were fed 1.64 lb daily of basal ration per 100 lb live-weight. Corn sugar was added at the rate of 150 to 200 gm. In addition, each sheep received 6 gm bonemeal, 3 gm yeast, and 0.5 cc cod liver oil. The average apparent digestion coefficients, in percent, for the basal ration and the basal ration plus sugar, respectively, were: dry matter, 65.4 and 67.7; total nitrogen, 61.9 and 54.1; crude fiber, 43.8 and 31.9; nitrogen-free extract, 76.4 and 79.7. The addition of the sugar caused a significant decrease in apparent protein and crude fiber digestibility and a significant increase in digestibility of nitrogen-free extract.

Fontenot _et al_. (1955) conducted digestion and nitrogen balance trials with steers to determine the effect of adding different amounts of cerelose in wintering rations containing approximately 8, 10, and 12 percent protein. The basal wintering ration was composed of prairie hay, cottonseed meal and minerals in the proportions frequently fed to wintering beef cattle. Additions of cerelose to the extent of 350, 700, and 1050 gm to the 8 percent protein ration resulted in a significant depression in nitrogen retention. A significant increase in nitrogen retention was obtained when 700 and 1050 gm of cerelose were added to the basal ration containing 10 percent protein, and a small but not statistically significant increase when the basal ration contained 12 percent protein. The added cerelose increased the estimated biological value of the protein of all three rations. It decreased the apparent, but not the true, digestibility of protein, depressed the digestibility of crude fiber, and increased the digestibility of nitrogen-free extract at each level of protein. The trend of results was toward an increase in the effects mentioned above with each increasing level of cerelose intake.

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 ration by sheep.

Woods et al. (1956) studied the effect of varying levels of protein and cerelose on the utilization of mature timothy hay by sheep. They found that as the percentage protein increased from 6.9 to 10.9 to 13.6 the apparent digestibility of dry matter, organic matter, protein, energy, and nitrogen-free extract increased. The addition of either 3.3 or 6.2 percent cerelose at all levels of protein had no significant effect on the digestibility of dry matter, organic matter, and energy. However, with each cerelose addition the digestibility of nitrogen-free extract was increased significantly ($P < 0.01$). The addition of 3.3 percent cerelose at all levels of protein had no significant effect on the digestibility of protein, but the additional 6.2 percent of cerelose significantly decreased protein digestibility ($P < 0.01$) below that of rations containing 0 and 3.3 percent of cerelose.

Mitchell et al. (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 gm glucose except one that consumed 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 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.

Patterson and Outwater (1907) found that when molasses was added to steer rations containing hay or hay and grain, the average digestibility of dry matter was increased.

Briggs (1937) studied the effect of molasses on digestibility of a ration by lambs. 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 crude fiber and nitrogen-free extract.

Lindsey and Smith (1910), in a study with sheep, found that molasses caused a decrease in organic matter digestibility whether the basal ration was composed of only hay or hay and concentrate. However, the concentration of molasses had to be relatively high in the hay ration before there was a marked depression in digestibility.

In an experiment with dairy cattle Williams (1925) found that molasses did not uniformly affect the digestibility of crude fiber, nitrogen-free extract, and ether extract but tended to depress the digestibility of protein and dry matter.

Briggs and Heller (1949) conducted a digestion experiment with lambs in which they substituted blackstrap molasses for corn or oats in a corn-alfalfa ration and an oat-alfalfa ration. They found that the substitution of molasses for 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 protein but the replacement of oats with molasses significantly lowered protein digestibility.

From the literature reviewed it was concluded that at certain levels of protein intake, increased energy intake has been shown to cause an improvement in nitrogen balance in ruminants, and under certain conditions it has been shown to increase the biological value of protein. The addition of fat in moderate amounts has been found to increase digestibility of ration constituents. However, the addition of relatively large quantities of fat decreases digestibility of ration constituents except ether extract which is increased. The addition of carbohydrate did not measurably increase the digestibility of ration nutrients by ruminants, and under certain experimental conditions the addition of carbohydrate depressed the digestibility of crude fiber and protein. Carbohydrates seem to have a greater protein-sparing action than fat in ruminants.

THE EFFECT OF ADDED FAT ON DIGESTIBILITY OF RATION COMPONENTS AND NITROGEN METABOLISM

EXPERIMENT 1

The purpose of this test was to determine the effect of 10 percent added fat on nitrogen utilization and the digestibility of ration constituents by steers fed a wintering-type basal ration composed of prairie hay, minerals, and cottonseed meal.

Experimental Procedure

Ten grade Hereford steers with an average weight of 625 lb at the start of the experiment were used. They were fed two different rations during two digestion trial periods extending from December 3, 1956 to February 11, 1957. A completely randomized design was used. The steers were kept in false-bottom metabolism stalls as described by Nelson _et al._ (1954).

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.

The basal ration (Ration A) consisted of 3000 gm prairie hay, 585 gm cottonseed meal, 323 gm corn, 25 gm dicalcium phosphate, and 25 gm salt, and contained 10.9 percent protein. Ration B consisted of the basal ration plus 440 gm of corn oil. The corn oil addition lowered the percentage of protein in the ration to 9.7 percent.

TABLE 1

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

Feed	Daily Allowance in Ration A	Daily Allowance in Ration B	Dry matter	Percentage Composition of Dry Matter: Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	Ash	Nitrogen
	gm.	gm.	percent							
Prairie hay	3000	3000	95.0	92.6	4.7	2.3	34.4	51.1	7.4	0.7
Cottonseed meal	585	585	94.1	93.5	44.2	5.1	12.7	31.5	6.5	7.1
Corn	323	323	90.4	98.4	9.8	4.5	2.2	81.8	1.6	1.6
Corn oil	0	440	100.0	100.0	--	100.0	--	--	--	--
Minerals	50	50	100.0	--	--	--	--	--	100.0	--

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	Nitrogen
A	95.6	91.9	10.9	2.8	28.3	50.0	8.0	1.7
B	95.1	92.8	9.7	13.1	25.3	44.7	7.2	1.5

he prairie hay was of average quality. The cottonseed meal was an expeller process product, and the mineral mix was of high purity.

The steers fed corn oil were allowed 10 days in which the oil content of the ration was gradually increased to 10 percent. A 10-day preliminary period preceded each 10-day collection period making a total of 30 days in each trial. The steers were fed one-half the daily allowance twice daily.

Feces were collected in metal boxes and transferred at frequent intervals to covered metal containers. The feces were collected daily and 5 percent samples 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. The urine was collected by means of a metal grid and metal funnel. In the first trial the urine was weighed daily and a 2 percent sample was taken. In the second trial, the urine was diluted to a constant weight daily with a 2 percent sample taken for analysis. In both trials the samples were acidified and stored under refrigeration. Nitrogen was determined by the Kjeldahl method on combined daily samples from each steer.

The Thomas-Mitchell formula was used to calculate biological values of the protein: 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: $N = 0.712\ W^{0.42}$ where N represents the grams of endogenous nitrogen and W the body weight in kilograms. Swanson and Herman calculated these values from results obtained by feeding low-nitrogen rations to dairy heifers. To calculate fecal metabolic nitrogen they used an average figure obtained from 20 heifers on a low-nitrogen diet. They derived the formula $N = 0.712\ W^{0.42}$ from the average relationships between body weight and endogenous urinary nitrogen during periods of low-nitrogen feeding.

The results of this experiment were analyzed statistically according to methods described by Snedecor (1956).

Results and Discussion

During the second trial one animal was removed from the experiment because of extreme stiffness. In the statistical analyses the missing item was replaced by the missing data technique as proposed by Snedecor (1956).

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 9, appendix.

The addition of 10 percent corn oil to the basal ration had no marked effect on nitrogen balance. The average daily nitrogen balance was 13.9 and 14.1 gm, respectively, for the rations containing 0 and 440 gm of corn oil. There was a significant difference in nitrogen balance between trials. The animals in the second trial failed to retain as much nitrogen as the animals in the first trial. The factors contributing to such short-time changes in nitrogen metabolism are not fully understood. One factor may have been the confinement and relatively great restriction of movement of the steers for a long period of time.

TABLE 3

Average Daily Nitrogen Balance and Biological Value Data Experiment 1

Ration	Intake		Excretion		Nitrogen retention		Metabolic N	Endogenous N	True digested N	Absorbed N utilized	Biological value
	Dry matter	Nitrogen	Fecal N	Urinary N							
	gm	gm	gm	gm	gm	percent	gm	gm	gm	gm	percent
A	3742.7	65.1	27.9	23.2	13.9	21.4	19.8	7.6	57.0	41.4	72.6
B	4182.7	65.1	28.6	22.3	14.1	21.6	22.2	7.6	58.7	44.0	75.0

The average urinary nitrogen decreased when 10 percent corn oil was added to the basal ration. However, the average fecal nitrogen increased, due probably to an increase in metabolic nitrogen. The increase in metabolic nitrogen excretion was associated with the increased intake and excretion of dry matter by the steers receiving corn oil. The increase in fecal nitrogen was not quite as great as the decrease in urinary nitrogen. The net effect of the two rations was a difference of only .2 gm of nitrogen retained. The percentage of the nitrogen intake retained was 21.6 and 21.4 for the rations with and without corn oil, respectively. Robinson et al. (1956) found that when 200 gm of corn oil was added to a wintering-type ration similar to the one used in this experiment, total nitrogen retention was increased from 21.1 to 24.7 percent. Mitchell et al. (1940) 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. These results indicate that increasing energy in the diet does not affect nitrogen retention if the level added is relatively high. With simple-stomached animals Forbes and Swift (1944) and Forbes (1939) found that added energy in the diet decreased average urinary nitrogen.

The addition of 10 percent fat resulted in an increase in biological value which approached significance at the 5 percent level of probability. The average biological values for 0 and 10 percent fat were 72.6 and 75.0, respectively. The increase in biological value obtained in this experiment is in agreement with the work of Fontenot et al. (1955) and Williams et al. (1953). Fontenot et al. (1955) found that biological value increased in almost a linear fashion when he fed cerelose at increasing levels. Williams et al. (1953) reported 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 protein. Early workers, such as Mitchell (1924), observed that a decrease in the protein percentage of a ration is usually accompanied by an increase in biological value. Other workers (Allison et al., 1946; Bosshardt et al., 1946, 1948; Barnes and Bosshardt, 1946; and Benditt et al., 1948) in experiments with simple-stomached animals, have shown that nitrogen utilization is impaired when caloric intake is restricted.

The difference in biological value in this experiment was not as great as the difference obtained by Fontenot et al. (1955) and Williams et al. (1953), however, they used a carbohydrate energy source and it was not in isocaloric relationship with the quantity of fat used in this trial. This may indicate that there is a point above which additional energy depresses biological value. Also, Rhodes et al. (1956) found that replacing carbohydrate with fat in ruminant rations decreased nitrogen utilization. This is in agreement with findings in experiments with simple-stomached animals.

Apparently the addition of 10 percent corn oil to a basal wintering ration containing 10.9 percent protein had little if any affect on the sparing of protein.

Average values for apparent digestibility of nutrients in each ration are shown in Table 4. The individual values are shown in Table 10 in the appendix. The addition of 10 percent fat to the basal ration decreased all the digestion coefficients except that for ether extract which increased significantly ($P < 0.01$) from 52.9 to 84.9. This is in agreement with Swift et al. (1947) who observed that when corn oil

TABLE 4

Average Apparent Digestion Coefficients for Experiment 1

Ration	Corn Oil intake gm	Apparent Percentage Digestibility					
		Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract
A	0	58.8	62.0	57.1	52.9	63.9	62.5
B	440	52.7	55.3	56.0	84.9	48.0	50.5

was fed at high levels it decreased all digestion coefficients except for ether extract. Johnson et al. (1956) and Erwin et al. (1956) both observed an increase in the digestion coefficient of ether extract when high levels of fat were fed to ruminants.

The average apparent crude fiber digestibility decreased when 10 percent fat was added. The average coefficients for crude fiber when 0 and 440 gm of fat were added were 63.9 and 48.0, respectively. This difference was highly significant ($P < 0.01$). These results are in agreement with several of the previously cited workers who had observed that the addition of high levels of energy to ruminant rations caused a marked depression in crude fiber digestibility.

The difference in protein digestibility between the basal and the fat-containing ration paralleled that of nitrogen retention, and there was no significant difference within trials but a highly significant difference between trials. The average coefficients were 57.1 and 56.0 for the addition of 0 and 440 gm of corn oil, respectively. This finding is not in accord with those of Johnson et al. (1956), Rhodes et al. (1956), Swift et al. (1947), or Hamilton (1942). These workers found that the addition of high levels of energy to the diet of ruminants decreased the digestibility of protein.

The average apparent digestibility of nitrogen-free extract was markedly reduced from 62.5 to 50.5 by the addition 10 percent corn oil. This difference was highly significant ($P < 0.01$). This observation is in agreement with the results reported by Johnson et al. (1956), Swift et al. (1947, 1948), Lucas and Loosli (1944), and Ward (1956).

The digestion coefficients for dry matter and organic matter followed a similar pattern. Both were significantly decreased ($P < 0.01$) by the addition of 10 percent corn oil to the basal ration. The average digestion coefficients for organic matter and dry matter when 0 and 440 gm of corn oil were added were 62.0 and 55.3 for organic matter and 58.8 and 52.7 for dry matter. This has been a general observation by most of the workers already cited.

THE EFFECT OF ADDED STARCH ON DIGESTIBILITY OF RATION COMPONENTS AND NITROGEN METABOLISM

EXPERIMENT 2

The purpose of this experiment was to determine the influence of adding 440 gm of starch to a basal ration similar to that used in Experiment 1. Nitrogen utilization and digestibility of ration constituents were the measures studied.

Experimental Procedure

A group of nine grade Hereford steers weighing an average of 642 pounds at the start of the experiment was used. They were fed two rations, a basal and the basal plus 440 gm of starch, during two digestion trials extending from February 26, 1957 to April 5, 1957. This experiment differed from Experiment 1 in that there was no adjustment period in which the amount of starch in the ration was increased slowly as was done when fat was used as the source of energy. The steers were those used in Experiment 1. They were given a two week resting period prior to starting the experiment.

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

In this experiment the basal ration (Ration C) contained 3000 gm prairie hay, 600 gm cottonseed meal, 25 gm salt and 25 gm dicalcium

TABLE 5

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

Feed	Daily Allowance in Ration			Percentage Composition of Dry Matter						
	C	D	Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	Ash	Nitrogen
	gm	gm	percent							
Prairie hay	3000	3000	92.8	93.2	4.8	3.0	34.3	51.0	6.8	.8
Cottonseed meal	600	600	93.4	93.9	43.5	4.8	12.7	32.9	6.1	6.9
Starch	0	440	100.0	100.0	--	--	--	100.0	--	--
Mineral	50	50	100.0	--	--	--	--	--	100.0	--

TABLE 6

Average Chemical Composition of Rations Offered in Experiment 2

Ration	Percent dry matter	Percentage Composition of Dry Matter						
		Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	Ash	Nitrogen
C	93.0	91.9	11.1	3.3	30.2	47.3	8.1	1.8
D	93.7	92.8	9.9	2.9	26.7	53.3	7.1	1.6

phosphate. The average protein content of the basal ration was 11.1 percent. The experimental ration (Ration D) contained all the feeds of the basal ration plus 440 gm of starch. The starch addition resulted in lowering the average protein content of the ration to 9.9 percent.

The feeds used in this experiment were similar to those described for Experiment 1.

The steers were handled in the same manner as in Experiment 1, except for the elimination of the 10-day period for adjusting to the ration and environment. The method used in collecting, sampling, and analyzing the excreta, and in the statistical treatment of data, were similar to those described for Experiment 1.

Results and Discussion

Data for one steer fed starch in the second trial was discarded because this steer had diarrhea during most of the trial. For the statistical analyses the missing item was replaced by the method described by Snedecor (1956).

The average daily nitrogen balance and biological value data are given in Table 7. The individual data are given in Table 11, appendix.

The average nitrogen retention resulting when rations contained 0 and 440 gm of starch were 5.6 and 9.8 gm, and 9.2 and 16.1 percent, respectively. Nitrogen retention, expressed as gm per day or percent of intake, was significantly increased ($P < 0.01$) by the starch addition.

As was observed in Experiment 1, the feeding of high levels of energy resulted in a decrease in urinary nitrogen. However, in Experiment 1 the increase in fecal nitrogen compensated for nearly all of the

TABLE 7

Average Daily Nitrogen Balance and Biological Value Data for Experiment 2

Ration	Intake		Excretion		Nitrogen retention		Metabolic N	Endogenous N	True digested N	Absorbed N utilized	Biological value
	Dry matter	Nitrogen	Fecal N	Urinary N							
	gm	gm	gm	gm	gm	percent	gm	gm	gm	gm	percent
C	3389.1	60.6	25.2	29.7	5.6	9.2	18.0	7.7	53.2	31.2	58.6
D	3837.4	60.6	27.4	23.5	9.8	16.1	20.3	7.7	53.6	37.9	70.5

decrease in urinary nitrogen with a net result of a slight improvement in average nitrogen retention. In Experiment 2, however, the increase in fecal nitrogen was not as great as the decrease in urinary nitrogen and a increase of 6.9 percent retention of the total nitrogen intake was obtained when starch was added to the basal ration. Rhodes et al. (1956) found that nitrogen retention was decreased when a carbohydrate was replaced by fat in the diet of ruminants. Fontenot et al. (1955) reported a significant increase in nitrogen retention when 700 and 1050 gm of cerelose were added to a basal ration containing 10 percent protein. This ration was very similar to that used in this experiment except that cerelose replaced starch as a carbohydrate source. Head (1953) found that the addition of starch to a hay and casein ration increased nitrogen retention by sheep.

Although Experiment 2 differed from Experiment 1 in that a significant difference in nitrogen retention was obtained due to treatment, it was very much the same in that a significant difference in nitrogen retention between trials ($P < 0.01$) resulted. The crude protein digestibility and biological value were significantly different ($P < 0.05$) between Trial 1 and 2. The differences between trials in digestibility of ether extract and nitrogen-free extract were also significant ($P < 0.01$).

The starch addition resulted in a significant ($P < 0.01$) increase in the biological value of protein. The average biological values for rations containing 0 and 440 gm of starch were 58.6 and 70.5, respectively. Thus the addition of starch not only resulted in an improvement in nitrogen retention but also in an improvement in the utilization of absorbed nitrogen. This observation is in agreement with work by

Fontenot et al. (1955) in which similar results were obtained when high levels of carbohydrate were fed in the form of cerelose. However, as was stated in Experiment 1, early workers have found that a decrease in protein percentage of a ration is usually accompanied by an increase in biological value.

Apparently the addition of 10 percent starch to a basal wintering ration containing 11 percent protein has a sparing action on protein.

The average apparent digestion coefficients are given in Table 8. The individual coefficients are presented in Table 12, appendix. The average apparent digestibility of the organic matter and dry matter followed a similar pattern and neither were affected to any marked extent by the treatment. The average digestion coefficients for organic matter for rations containing 0 and 440 gm of starch were 62.5 and 63.6, respectively, and for dry matter they were 58.8 and 60.2, respectively. Other workers (Fontenot et al., 1955; Woods et al., 1956; Hamilton, 1942; Swift et al., 1947; Williams et al., 1953) have found that readily-available carbohydrate either decreased or had no effect on dry matter or organic matter digestibility.

The addition of 440 gm of starch to the basal ration resulted in a significant decrease ($P < 0.01$) in protein digestibility from 58.3 to 54.8 percent. This finding is not in agreement with the results in Experiment 1 when the energy was added in the form of fat, however, it is in agreement with other workers referred to in the preceding paragraph.

The crude fiber digestibility decreased from 65.7 to 60.8 percent when 440 gm of starch was added to the basal ration. This difference was significant at the 1 percent level of probability. These results

TABLE 8

Average Apparent Digestion Coefficients for Experiment 2

Ration	Starch intake	Apparent Percentage Digestibility					
		Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract
	gm						
C	0	58.8	62.5	58.3	59.3	65.6	61.6
D	440	60.2	63.6	54.8	59.3	60.8	66.9

agree with those observed when fat was added as an energy source. This decrease reflects the effect of starch addition and/or decreased protein percentage of the ration on crude fiber digestion.

The addition of starch caused a highly significant ($P < 0.01$) increase in apparent digestibility of nitrogen-free extract. The digestion coefficients for nitrogen-free extract for the rations containing 0 and 440 gm of starch were 61.6 and 66.9 percent, respectively.

There was no difference between the two rations in ether extract digestibility, with the two digestion coefficients being 59.3 in both cases.

SUMMARY

Two digestion and metabolism experiments were conducted to study the effect of 10 percent corn oil and 10 percent starch on nitrogen utilization and digestion of ration constituents by steers fed wintering-type basal rations containing approximately 10 percent protein. Trial differences existed in both experiments. The differences were of greater number and magnitude in Trial 2 than in Trial 1, and were always due to a reduction in digestibility, nitrogen retention, or biological value in the second trial. Although trial differences existed statistically significant treatment effects were obtained in most instances.

The addition of 10 percent corn oil to the ration caused a significant ($P < 0.01$) reduction in digestibility of dry matter, organic matter, crude fiber and nitrogen-free extract, and a significant ($P < 0.01$) increase in ether extract digestibility. The addition also increased the biological value of the protein to a point which approached significance at the 5 percent level. However, it had no significant effect on the protein digestibility or nitrogen retention.

The addition of 10 percent starch to the ration caused a significant ($P < 0.01$) decrease in digestibility of crude protein and crude fiber. The digestibility of ether extract was the same for both rations and the differences in digestibility of organic matter and dry matter were not significantly different. Nitrogen retention and biological value were significantly increased ($P < 0.01$) by the addition of the 10 percent starch to the basal ration.

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A P P E N D I X

TABLE 9

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	percent	gm	gm	gm	gm	percent
	1	1	3759.1	65.6	25.6	23.2	16.9	25.7	19.9	7.8	60.0	44.6	74.3
	1	2	3759.1	65.6	27.4	24.8	13.4	20.5	19.9	7.8	58.1	41.2	70.8
	1	3	3759.1	65.6	26.8	26.1	12.7	19.4	19.9	7.3	58.8	40.0	68.1
	1	4	3759.1	65.6	25.7	23.3	16.6	25.2	19.9	7.7	59.8	44.2	73.9
A	1	5	3759.1	65.6	27.4	24.4	13.8	21.0	19.9	7.7	58.2	41.4	71.2
	2	6	3726.2	64.6	29.1	22.0	13.5	20.9	19.7	7.7	55.2	40.9	74.0
	2	7	3726.2	64.6	28.6	21.2	14.8	22.9	19.7	7.2	55.7	41.7	74.9
	2	8	3726.2	64.6	28.9	22.0	13.7	21.2	19.7	7.8	55.5	41.2	74.3
	2	9	3726.2	64.6	29.1	23.1	12.3	19.1	19.7	7.6	55.2	39.7	71.9
	2	10	3726.2	64.6	30.5	22.4	11.7	18.1	19.7	7.7	53.8	39.1	72.7
	Av.		3742.6	65.1	27.9	23.2	13.9	21.4	19.8	7.6	57.0	41.4	72.6
	2	1	4166.2	64.6	28.7	22.2	13.7	21.2	22.1	7.8	58.0	43.5	75.1
	2	2	4166.2	64.6	29.4	22.7	12.5	19.4	22.1	7.8	57.3	42.4	74.0
	2	*3	4166.2	64.6	28.9	22.7	12.9	20.0	22.1	7.3	57.7	42.8	74.0
	2	4	4166.2	64.6	30.1	23.4	11.0	17.1	22.1	7.7	56.5	40.8	72.3
B	2	5	4166.2	64.6	27.5	22.6	14.5	22.4	22.1	7.7	59.2	44.3	74.8
	1	6	4199.1	65.6	28.3	21.2	16.1	24.5	22.3	7.7	59.6	46.0	77.2
	1	7	4199.1	65.6	28.0	19.5	17.6	26.8	22.3	7.2	59.9	47.5	79.4
	1	8	4199.1	65.6	27.4	23.7	14.6	22.2	22.3	7.8	60.5	44.6	73.7
	1	9	4199.1	65.6	30.0	24.5	11.1	16.9	22.3	7.6	57.9	41.0	70.9
	1	10	4199.1	65.6	27.7	20.8	17.1	26.0	22.3	7.7	60.2	47.1	78.2
	Av.		4182.6	65.1	28.6	22.3	14.1	21.6	22.2	7.6	58.7	44.0	75.0

* Removed due to stiffness.

TABLE 10

Apparent Digestion Coefficients for Experiment 1

Ration	Trial no.	Steer no.	Dry matter intake	Apparent Percent Digestibility					
				Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract
			gm						
	1	1	3759.1	61.4	64.6	61.0	56.0	66.6	64.7
	1	2	3759.1	57.8	60.7	58.1	56.3	61.8	61.0
	1	3	3759.1	57.8	61.1	59.1	56.0	62.0	61.2
	1	4	3759.1	59.0	62.4	60.8	52.7	63.3	62.8
A	1	5	3759.1	58.9	62.1	58.2	52.6	64.2	62.4
	2	6	3726.2	58.9	62.0	54.9	53.7	64.4	62.6
	2	7	3726.2	58.3	61.6	55.7	49.5	64.2	62.1
	2	8	3726.2	59.8	63.0	55.3	51.9	66.2	63.6
	2	9	3726.2	57.3	60.6	54.9	49.6	62.6	61.3
	2	10	3726.2	58.9	62.2	52.8	50.3	64.1	63.8
	Av.		3742.6	58.8	62.0	57.1	52.9	63.9	62.5
	2	1	4166.2	55.6	58.1	55.6	87.4	49.5	55.0
	2	2	4166.2	51.2	54.4	54.5	86.6	48.2	48.4
	2	*3	4166.2	53.7	56.3	55.2	86.7	48.9	51.7
	2	4	4166.2	52.4	55.2	53.3	85.7	47.5	50.9
B	2	5	4166.2	55.1	57.4	57.4	87.1	50.5	52.6
	1	6	4199.1	51.1	53.5	56.7	83.4	45.6	48.5
	1	7	4199.1	51.7	54.5	56.9	81.8	50.0	48.3
	1	8	4199.1	53.8	56.1	58.2	84.4	47.4	52.2
	1	9	4199.1	48.5	50.8	54.1	82.1	42.8	45.5
	1	10	4199.1	53.8	56.3	57.7	83.7	49.5	51.8
	Av.		4182.6	52.7	55.3	56.0	84.9	48.0	50.5

* Removed due to stiffness.

TABLE 11

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		Metabolic N	Endogenous N	True digested N	Absorbed N Utilized	Biological value
			gm	gm	gm	gm	gm	percent	gm	gm	gm	gm	percent
	4	1	3355.9	59.7	24.2	28.3	7.2	12.1	17.8	7.7	53.3	32.7	61.4
	4	2	3355.9	59.7	24.8	31.9	3.0	5.1	17.8	7.8	52.7	28.6	54.2
	4	3	3355.9	59.7	25.4	31.5	2.8	4.7	17.8	7.3	52.1	27.9	53.6
	4	4	3355.9	59.7	24.9	25.4	9.4	15.7	17.8	7.7	52.6	34.9	66.3
C	4	5	3355.9	59.7	26.4	31.6	1.7	2.9	17.8	7.7	51.1	27.2	53.2
	3	6	3430.6	61.3	25.5	29.7	6.1	10.0	18.2	7.8	54.0	32.1	59.4
	3	7	3430.6	61.3	24.0	30.6	6.8	11.0	18.2	7.8	55.5	32.7	58.9
	3	8	3430.6	61.3	26.0	28.5	6.8	11.1	18.2	7.7	53.5	32.7	61.2
	3	9	3430.6	61.3	25.4	29.7	6.3	10.2	18.2	7.8	54.1	32.3	59.6
	Av.		3389.1	60.6	25.2	29.7	5.6	9.2	18.0	7.7	53.2	31.2	58.6
	3	1	3870.6	61.3	26.4	21.5	13.4	21.9	20.5	7.7	55.5	41.7	75.2
	3	2	3870.6	61.3	25.2	25.0	11.2	18.2	20.5	7.8	56.7	39.5	69.6
	3	3	3870.6	61.3	26.5	22.7	12.1	19.7	20.5	7.3	55.3	40.0	72.2
	3	4	3870.6	61.3	28.5	20.1	12.7	20.7	20.5	7.7	53.3	41.0	76.8
D	3	5	3870.6	61.3	25.5	25.1	10.8	17.5	20.5	7.7	56.4	39.0	69.2
	4	*6	3795.9	59.7	28.5	24.2	7.0	11.7	20.1	7.8	51.3	34.9	68.0
	4	7	3795.9	59.7	27.8	25.3	6.6	11.1	20.1	7.8	52.0	34.5	66.3
	4	8	3795.9	59.7	27.4	23.1	9.2	15.5	20.1	7.7	52.5	37.1	70.7
	4	9	3795.9	59.7	30.4	24.2	5.1	8.5	20.1	7.8	49.4	33.1	66.9
	Av.		3837.4	60.6	27.4	23.5	9.8	16.1	20.3	7.7	53.6	37.9	70.5

* Removed due to diarrhea.

TABLE 12

Apparent Digestion Coefficients for Experiment 2

Ration	Trial	Steer	Dry matter intake	Apparent Percent Digestibility					
				Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract
			gm						
C	4	1	3355.9	59.0	62.9	59.4	59.9	66.9	61.3
	4	2	3355.9	58.3	61.7	58.5	61.5	64.9	60.4
	4	3	3355.9	57.6	61.5	57.4	63.9	64.9	60.0
	4	4	3355.9	57.6	61.3	58.3	64.5	65.2	59.2
	4	5	3355.9	59.2	62.8	55.8	65.8	67.2	61.4
	3	6	3430.6	58.4	61.9	58.4	55.4	63.9	61.9
	3	7	3430.6	60.2	63.9	60.9	57.0	66.2	63.6
	3	8	3430.6	57.6	61.4	57.6	52.9	63.6	61.5
	3	9	3430.6	61.3	64.9	58.6	52.6	68.0	65.1
	Av.		3389.1	58.8	62.5	58.3	59.3	65.6	61.6
D	3	1	3870.6	60.8	64.4	57.0	51.2	62.2	67.5
	3	2	3870.6	61.7	64.9	59.0	55.8	61.6	68.1
	3	3	3870.6	61.9	65.4	56.8	55.9	62.2	69.0
	3	4	3870.6	56.9	60.1	53.5	54.6	54.4	64.4
	3	5	3870.6	63.0	66.6	58.5	56.5	64.9	69.5
	4	*6	3795.9	59.3	62.8	52.2	64.9	60.6	65.8
	4	7	3795.9	60.4	63.6	53.4	67.2	60.7	66.8
	4	8	3795.9	60.8	64.1	54.1	66.5	62.3	66.8
	4	9	3795.9	56.9	60.7	49.0	61.0	58.8	63.9
	Av.		3837.4	60.2	63.6	54.8	59.3	60.8	66.9

* Removed due to diarrhea.

VITA

DIXON DALE HUBBARD

Candidate for the Degree of

Master of Science

Thesis: THE EFFECT OF HIGH LEVELS OF ENERGY ON NITROGEN UTILIZATION AND DIGESTIBILITY OF WINTERING RATIONS BY STEERS

Major: Animal Husbandry

Biographical

Born: May 13, 1934, at Dill, Oklahoma.

Undergraduate Study: Oklahoma Agricultural and Mechanical College, Stillwater, Oklahoma, 1952-1956.

Graduate Study: Oklahoma State University of Agriculture and Applied Science, Stillwater, Oklahoma, 1956-1957.

Experience: Livestock Farming; Graduate Assistant in Animal Husbandry.

Date of Final Examination: August, 1957.

THESIS TITLE: THE EFFECT OF HIGH LEVELS OF ENERGY ON NITROGEN UTILIZATION AND DIGESTIBILITY OF WINTERING RATIONS BY STEERS

AUTHOR: Dixon Dale Hubbard

THESIS ADVISER: Dr. A. B. Nelson

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TYPIST: Mrs. Jerry Martin