Protein and Energy Levels for Wintering Beef Calves and Effects on Subsequent Production

Marcus Hoelscher

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PROTEIN AND ENERGY LEVELS FOR WINTERING BEEF CALVES
AND EFFECTS ON SUBSEQUENT PRODUCTION

BY

MARCUS A. HOELSCHER

A thesis submitted
in partial fulfillment of the requirements for the
degree Doctor of Philosophy, Department of
Animal Husbandry, South Dakota State
College of Agriculture
and Mechanic Arts

June, 1960
This thesis is approved as a creditable, independent investigation by a candidate for the degree, Doctor of Philosophy, and acceptable as meeting the thesis requirements for this degree; but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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Four wintering trials involving 240 steer calves were conducted during 2 consecutive years to determine the effects of different levels of protein and energy on wintering and on performance in subsequent phases of production. The digestible nutrient and energy contents of the wintering rations were obtained by digestion trials and bomb calorimetric determinations.

During the winter of 1957-1958, 80 steer calves were divided into eight lots and received alfalfa and prairie hay rations. Four lots received different ratios of alfalfa and prairie hay which resulted in a protein content which ranged from 7.6 to 10.8 percent. The remaining four lots received a ration with 10.8 percent protein but were fed at the rate of a full feed and 88, 76 and 64 percent of a full feed. Daily gains for the first four lots increased from 0.38 to 0.68 pound as the daily digestible protein intake increased from 0.37 to 0.78 pound. The energy content of the rations remained constant. Daily gains of calves restricted in feed intake decreased from 0.83 to 0.28 pound as daily digestible protein intake decreased from 0.85 to 0.41 pound and as TDN decreased from 5.86 to 2.64 pounds daily. In subsequent phases of production, the lower gaining winter lots produced larger summer grazing and feed-lot gains which resulted in overall gains comparable to or
larger than the lots wintered at the highest rate of gain. Calves which were wintered at 0.50 pound daily, either by restriction of protein or energy, generally made the most efficient over-all gains.

In a second wintering trial, similar to the one described above, average daily gains increased from 0.39 to 0.83 pound as the daily digestible protein intake increased from 0.30 to 0.83 pound per steer. Gains were again directly related to the increased protein intake since energy intake remained nearly constant. As calves were restricted in feed, gains decreased from 1.06 to 0.48 pounds as the digestible protein and TDN intake decreased from 1.07 to 0.54 and 6.01 to 2.31 pounds respectively. When placed on a high roughage summer feeding program, gains were considerably higher than the previous summer grazing phase and ranged from an average of 2.14 to 2.46 pounds daily. This system of feeding did not result in an inverse relationship between winter and summer gains since some calves making the most winter gain also made the most summer gain. This shows that calves may be wintered for over a 1.0 pound gain without reduced summer gains when the wintering period is followed by a liberal feeding program.

Two other wintering trials were conducted with various protein levels on a limited grain ration. In the first trial conducted in 1957-1958, 40 steer calves were divided into four lots and received a ration which consisted of 25 percent oats and various ratios of alfalfa and prairie hay which resulted in a protein content which ranged from 8.6 to 12.8 percent. With the exception of one lot, daily gains increased from 1.24 to 1.49 pounds as the digestible protein intake increased from 0.37 to 0.78 pound daily while TDN intake remained fairly constant with an
average of 6.81 pounds. When steers of the first trial were placed in
the feed lot on a full feed of an alfalfa hay, corn and soybean oil meal
ration, gains ranged from 2.21 to 2.58 pounds. The two lots which were
wintered on the lower protein levels made larger gains and reached the
desired market weight of 1100 pounds 2 weeks earlier with lower feed
requirements than the steers wintered at the higher protein levels. Car-
cass differences in all trials were small with only a very slight advan-
tage for steers wintered at the highest rate of gain. In the second
wintering trial, the protein content of the ration ranged from 7.4 to
11.7 percent. Gains ranged from 1.16 to 1.48 pounds as the daily diges-
tible protein intake increased from 0.46 to 1.04 pounds and as energy
remained constant. With the exception of one lot, digestible protein and
TDN requirements were similar to the corresponding lots of the previous
trial. Average daily gain in all wintering trials generally increased
as the protein content of the ration increased. When rations with com-
parable protein intakes were fed, gains were increased with additional
energy intakes.

There were considerable variations in the digestible protein and
TDN determined from digestion coefficients obtained with each ration as
fed and calculated from digestion coefficients obtained with each hay
fed alone. The differences may be explained by the magnitude of differ-
ences in digestion coefficients obtained when feeding each hay alone and
those obtained from the rations as fed. This illustrates the shortcom-
ings of calculating digestible nutrients from digestion coefficients of
nutrients in feeds determined at one level but included in rations at
other levels.

In comparisons of the caloric value of TDN, it was found to be quite variable but averaged 1992 kilocalories per pound of TDN for all rations. The variations encountered do not necessarily indicate inaccuracy of the digestible energy determinations but show that the values obtained may be influenced by the digestion coefficients obtained in the TDN method.

The average value obtained in these experiments (1992 kcal/lb. TDN) is about the same as the average value of 2000 kcal./lb. TDN suggested by other workers to use in converting TDN to digestible calories. The variability encountered shows some inaccuracy would be encountered in using a single value to convert existing TDN values to digestible calories. However, this is also true in calculating TDN from existing digestion coefficients.
CHAPTER I

INTRODUCTION

The need for minimum amounts of protein and energy by animals for maintenance, growth and production has been recognized for many years. It is also well known that the requirements will vary depending on species, age, weight and rate of growth or production.

In order to provide livestock feeders with useful guides in feeding, several feeding standards containing recommended nutrient requirements have been prepared. The most commonly used standards for beef cattle are the "Morrison Feeding Standards" (1956) and the National Research Council's "Nutrient Requirements of Beef Cattle" prepared by the Subcommittee on Beef Cattle Nutrition (1959).

Feeding standards give recommended requirements for protein and other nutrients for various weight and age groups of beef cattle for different types of production. The standards are based on results of research, and the recommended requirements appear reasonably accurate for the conditions specified.

There are some shortcomings to feeding standards. For the most part, they are based on the results of short-term trials. Only in a few experiments have nutritive requirements of beef cattle been studied during both growing and fattening phases of the same animals. Much of the data on protein and energy requirements have been compiled from experiments which were not designed to specifically study these requirements.
Beef cattle are the only farm animals that can be marketed profitably over a wide range of weights and ages. This fact has resulted in the use of many systems of feeding for growing and fattening beef cattle. Nutritive requirements will vary depending on the type of feeding system used and the level of production sought.

Several studies have been made to determine the effects of limited amounts of protein and energy on rate of gain, feed requirement and subsequent production. In general, it has been shown that restricted feeding for a limited period of time reduces gain and increases feed requirement per unit of gain during the period of restriction. When put on liberal rations or turned to pasture, the animals on the restricted feeding systems gain more rapidly and more efficiently than those on previous liberal rations. The important aspects of restricted feeding for certain periods are the effects on amount, kind and cost of feed during the period of restriction and the later effects on gain, feed efficiency, time required to produce slaughter cattle, total feed requirement and carcass grade, weight and composition.

While the inverse relationship of gain and feed efficiency between different phases of production has been demonstrated, more work is needed on the effects of the feeding system on the other factors listed. This information would be valuable in selecting the most economical feeding system to meet the producer's feed supply and desired type of operation. The work reported in this thesis was undertaken with these practical considerations in mind. The study dealt with the rate of feeding protein and energy on gains and feed requirements with wintering rations and
effects on subsequent production under two feeding systems.
CHAPTER II

REVIEW OF LITERATURE

Effect of Nutrition on Rate and Type of Growth

A series of early investigations dealing with cattle maintained at different levels of production were initiated by Waters (1908) and carried out by Trowbridge et al. (1915, 1918, 1919), Haigh et al. (1920), Moulton et al. (1921, 1922a, 1922b, 1923) and Ritchie et al. (1923). These experiments included extensive trials to determine the cost of the maintenance of cattle, the effects of fattening mature cattle, the effects of low planes of nutrition upon growth of young growing and fattening cattle and the effects of three different planes of nutrition upon growth and composition of cattle from birth to maturity.

In an experiment designed to determine the effects of different levels of nutrition on growth, Trowbridge et al. (1918) subjected three groups of calves to three different planes of nutrition. Group I was fed to gain 0.50 pound per head daily, group II was fed to make no gain while group III was fed to lose 0.5 pound per head daily. The rations fed to these groups consisted of alfalfa hay, corn and linseed meal and were adequate in protein. The results showed that when animals in good condition were changed to rations insufficient to provide for normal growth there was a tendency to grow in spite of fed restriction. Much of the surplus fat was apparently used for energy and growth of lean flesh and skeleton. Animals appeared to stop growing when their fat supply was depleted by continued submaintenance rations.
Moulton et al. (1921, 1922a, 1922b and 1923) collected a wealth of data on carcass composition as influenced by different levels of nutrition. It was shown that the higher planes of nutrition proved more efficient from the standpoint of the recovery of energy and the production of edible meat.

An investigation was conducted by Ritzman and Benedict (1924) using various levels of nutrition. One of their objectives was to determine the effects of undernutrition on the ability of the animal to recover the weight lost and to fatten subsequently when fed liberally. During a wintering trial, three groups of steers were placed on maintenance, 50 percent maintenance and 40 percent maintenance rations. At the conclusion of the wintering phase, the groups were rearranged into three new groups and placed on either pasture, a high-protein grain ration or a low-protein grain ration. It was found that all steers regained their original weight in about 3 months following the period on submaintenance rations. The most economical gains were made by animals that were pastured 4 months after submaintenance and then fattened with hay and grain. The steers that received only grass did not attain a high degree of fatness. When steers were put on fattening rations immediately after submaintenance, it was found that the feed required to regain the lost weight did not compensate for the feed saved on submaintenance.

Lush et al. (1930) studied the growth of range cattle in southwest Texas from birth to about 30 months of age. Supplements were fed only when it was necessary to bring the cattle through the winter in a condition strong enough to utilize the spring and summer grasses. Data were
collected on weights for 8 years and on body measurements for 4 years. In general, it was shown that weights increased very rapidly in the spring and summer but actually decreased in late winter due to lack of protein and energy. Body growth increased slowly in the fall and winter but very rapidly in the spring and summer. Growth of the head and of the large bones increased at a normal rate regardless of season or pasture condition. Rate of other skeletal growth was intermediate. It was also found that the thinner cattle were in the spring, provided that they were still strong and healthy, the more rapidly they gained on pasture the following season.

Knapp et al. (1942) also studied the effects of low levels of protein and energy on growth. Their work supported the results reported by Lush et al. (1930). The growth of range cattle obtained by the Montana workers showed a striking similarity to the growth of the Texas cattle. The workers stated that this should be expected in view of the fact that range cattle go through two periods, one of plentiful feed and the other of limited feed.

Guilbert et al. (1944) conducted an experiment which was designed to obtain data on the effectiveness of supplemental feed at different periods of the year and at different stages of development of the animal. Two groups of range calves were fed supplements at various levels during three periods of production. In the first period from July to January, group I received approximately 1.6 pounds of rolled barley and 1.6 pounds of cottonseed cake per head daily so as to gain 1 pound daily. Group II, in accordance with common practice, subsisted on range forage alone and lost
weight. From January to June, group I received range forage only while group II was supplemented with approximately 4.6 pounds of a concentrate mixture of rolled barley, cottonseed cake, ground milo and molasses beet pulp. Both groups were full-fed the concentrate mixture from June to September. At the end of the first period, group II, which had no supplement, lost weight and lacked body development. The retarded steers had relatively longer legs, slimmer and shallower bodies, lighter hind quarters and finer bones. Skeletal growth continued during the early part of the period, but it practically ceased toward the end when the feed was poor in quality and less abundant. As a result of the different treatments, group I made 106 pounds more gain on only 70 pounds more supplement. The workers stated that from the standpoint of total feed required to produce a unit of product, the greatest efficiency was obtained from a high plane of nutrition with continuous growth and development.

Winchester (1951) and Winchester and Howe (1955) conducted studies to determine the effects of interrupted growth on carcass quality and feed efficiency of steers. Using twin calves, one member of each pair was fed according to its capacity while the other co-twin was fed a ration limited in energy. The restricted co-twins were fed at three levels, 50 (about maintenance), 62 and 75 percent of a liberal ration for beef calves. During a period of 6 months, calves on maintenance rations lost 4 pounds while the other two restricted-fed groups gained 0.50 and 1.00 pound per head daily. Daily gains of the liberally-fed controls ranged from 1.50 to 2.25 pounds per head. At the end of the period of limited feeding, the experimental steers fed according to their respective capacities grew rapidly and gained weight economically. Both groups
were slaughtered when the individuals reached 1,000 pounds body weight.

Although in most cases the retarded animals reached slaughter weight from 10 to 12 weeks later than did their co-twin, the former attained this weight on approximately the same intake of energy as the later. Skeletal growth of the restricted-fed animals when on a liberal ration was as rapid or more rapid than that of the controls. Body measurements of the control and restricted-fed animals at time of slaughter showed only small differences. Carcass grades and proportion of lean meat to fat in the carcass were not decreased by interruption of growth. It was concluded that under conditions of feed scarcity, beef cattle between the ages of 6 to 12 months can be carried at an energy level as low as maintenance if the nutritional needs other than energy are supplied without later loss in efficiency of feed utilization, meat quality or in the proportion of lean meat to fat and bone in the carcass.

Additional work by Winchester and Ellis (1956) agreed with their previous work. In this trial, each of 10 pairs of identical twin beef calves were subjected to different levels of feed intake between either 3 to 6 months or 4 to 8 months of age. The co-twin within each set was fed a liberal ration. At the end of the restricted feeding period, the restricted animals were placed on a full feed. All animals were slaughtered when they reached a grade of low prime.

The restricted-fed animals made gains with feed requirements comparable to the more liberally-fed animals. Final body measurements indicated no change in conformation due to periods of growth restriction. No evidence was observed that carcass grade, meat quality or proportion.
of lean meat to fat were lowered by delayed growth. It was concluded that calves can be maintained without weight gains on rations that meet their nutritional needs, other than energy, from 3 to 6 months or from 4 to 8 months of age without later loss in feed efficiency, quality of meat or proportion of lean meat to fat and bone in the carcass.

Winchester et al. (1957) conducted an experiment with twin calves to study the effect of various protein levels on various energy levels. One member of each set of twins served as a control while its co-twin received rations with different levels of protein and energy. Different levels of protein were fed with three different levels of energy. The energy levels were established to make no gain, 1 and 2 pounds of gain per head daily. The animals were fed the various rations between the ages of 6 to 12 months. After restriction, each animal was placed on a full feed of a good growing ration. It was found that animals fed at the level of caloric maintenance on low protein levels lost weight or made only small gains. Changes in body weight on caloric maintenance rations were positively correlated with levels of protein intake. Efficiency of feed utilization and carcass and meat quality of co-twins were similar. The calves on the low protein and low energy rations produced a slightly smaller percentage of muscle and a slightly greater percentage of fat than its continuously well-fed co-twin. It was suggested that extremely severe restriction of both protein and energy might influence carcass composition adversely.

The data of Winchester and Hove (1955), Winchester and Ellis (1956) and Winchester et al. (1957) generally confirmed the results of somewhat
similar experiments on growth of animals on maintenance rations reported by Moulton et al. (1921, 1922a and 1922b) and Trowbridge et al. (1915, 1918 and 1919). The work of Winchester et al. also agreed with Waters' (1908) statement that "An animal that is below the normal size for a given age, through poor nourishment, apparently has the capacity when liberally fed to compensate for the loss in a measure at least by an increased rate of gain." It should be pointed out that the results of the above workers were obtained from various levels of restricted feeding on an otherwise nutritionally adequate ration for limited periods.

A study was conducted in South Africa by Joubert (1954) on the influence of restricted winter feeding on growth, reproduction and production of cattle. The worker used the paired feeding method. One animal received supplementary feed during the winter while the other one did not. Growth rate of the low-plane group reached a peak at the end of the summer and the lowest level prior to spring. It was shown that daily rates of gain were closely allied to the nutritive value of the natural grazing. Low levels of protein, energy and other nutrients prevailed during the winter and significantly retarded growth. All anatomical dimensions were not affected to the same degree by the adverse nutritional conditions. Skeletal development slowed down or stopped during the winter and muscular development showed significant decreases. Steers receiving no supplement lost weight during the winter but recovered to some extent during the summer. However, they were unable to completely compensate for the reduced winter gain and required longer periods of time to reach market weight.
An experiment was conducted by Pfander (1955) to determine the effect of different levels of wintering on carcass composition. In this experiment, three levels of winter gains were produced, 1.5, 1.0, and 0.4 pounds per head daily. All lots were grazed during the summer and finished in the dry lot to an average grade of choice. It was observed that the fat distribution in the carcasses from the group of cattle on submaintenance wintering rations was different from cattle on the higher planes of nutrition. Carcasses from the submaintenance group had a significantly greater amount of fat deposited on the outside of the carcass and between the muscles, while carcasses from the cattle on the higher planes of nutrition had a significantly greater amount of fat deposited within the muscles. The proportion of lean that could be physically separated was significantly less in the retarded group due to the increased amount of fat. Carcasses from cattle on the low plane of wintering were not deficient in conformation as indicated by carcass measurements, but they graded lower and showed greater grade variability than the lots on the higher planes of nutrition. No significant differences in tenderness of roasts and steaks were found between the various lots.

The effects of nutrition on carcass composition as reported by Pfander (1955) were similar to the findings of McKeegan (1940 and 1941). Working with swine, McKeegan showed that levels of nutrition had definite effects on carcass composition. Work by Callow (1947 and 1948) also supported some of Pfander's (1955) findings. Callow showed that subcutaneous fat deposition was more rapid than intermuscular fat deposition.
Maynard and Loosli (1956) discussed the rapid rate of recovery after growth retardation and mentioned some important points. They stated that the rapid increase in weight may be to a considerable extent a replacement of lost fat. It was pointed out that this process may take place more rapidly than true growth. The workers stated that "The actual suppression of growth may be less than the weight measure indicates. Cellular development may proceed in important ways and yet not be reflected in any increase in weight."

Most of the work cited above seems to indicate that restriction of protein, energy and other nutrients at levels below maintenance definitely affected growth, subsequent performance and carcass quality. When animals were fed above maintenance levels, the effects of protein, energy and other nutrients on subsequent production were less noted. In some cases when animals were restricted only in energy for a limited period of time, the subsequent over-all performance of the restricted-fed animals were comparable to liberally-fed control animals.

Effects of Various Wintering Regimens on Winter Gains and Subsequent Production

Numerous experiments have been conducted on various levels of feeding of beef cattle. Many of the studies have consisted of wintering trials or restricted feeding of calves and the effects of the level of gain during this period on subsequent production and feed efficiency. Several of the experiments have shown an inverse relationship between gains in one period and gains in a subsequent period of production. In
these experiments, restricted-fed calves which made lower gains than
more liberally-fed calves generally made larger gains during subsequent
periods of liberal feeding (Sheets and Tuckwiller, 1924; Nelson et al.,
1951b; Nelson et al., 1952a; Brouse, 1955; Bohman, 1955; Bohman and
Torell, 1956; Embry et al., 1958).

Some information is available on subsequent feed-lot performance
of steers wintered at low levels and then grazed during the summer.
Stephens et al. (1948a) conducted an experiment to study the effects of
wintering on subsequent grazing and fattening phases of production. Ten
calves in each of six lots were wintered at different rates of gain and
then allowed to graze native pasture for 104 days. At the conclusion of
this grazing period, five calves from each of the first four lots were
placed in dry lot and full-fed for 84 days. The ration consisted of
ground shelled corn, cottonseed meal, alfalfa hay and prairie hay. The
remaining calves were continued on pasture for 84 days. The results
showed that steers which were wintered at the lower levels of gain made
greater gains in the subsequent phases of production than steers wintered
at the higher levels of gain.

Stephens et al. (1948b) conducted a wintering trial to study
various methods of wintering steer calves. Six lots of calves were
wintered on either prairie hay, sorghum silage or range land with the
addition of different levels of either oats or cottonseed meal. In sub-
sequent phases of production (Stephens et al., 1949), the calves of each
lot were allowed to graze pasture for 100 days and then divided into two
groups. One group received a full feed while the other group continued
on pasture. The addition of oats increased wintering gains of calves fed prairie hay and cottonseed meal from 0.61 to 1.13 pounds per head daily. Oats in addition to sorghum silage and cottonseed meal also increased gains of calves from 1.19 to 1.48 pounds per head daily. There was little difference in winter gains between calves fed about 10 pounds of prairie hay and 1 pound of cottonseed meal and calves fed 2 pounds cottonseed meal when grazing winter range.

The results of the early summer grazing phase showed that steers which made the lowest winter gain generally made the greatest pasture gain. Feed lot and late summer pasture gains were generally greater for the cattle making the lowest early summer gain.

Johnson et al. (1952) reported on a series of wintering, grazing and fattening experiments initiated in 1934 and continued through 1950. Steers were fed in three winter groups on different levels of alfalfa hay and barley, and they made winter gains of 0.92, 1.66 and 1.91 pounds per head daily. When allowed to graze pasture, the gains for the three respective groups were 1.42, 1.32 and 1.33 pounds per head daily. Feed-lot gains followed a similar pattern to the pasture gains with respective gains of 2.20, 2.07 and 2.02 pounds per head daily. Steers which made the smallest winter gain made the largest pasture and feed-lot gains. Gains of the other two groups were comparable in subsequent phases of production.

The effects of wintering at different planes of nutrition on subsequent gains of beef steers were reported by Heinemann and Van Keuren (1956). Three groups of calves were wintered on low, medium and high
levels of nutrition. The low and medium-gaining groups received different levels of corn silage and alfalfa hay and gained 0.33 and 1.01 pounds respectively. The high-wintering group received corn silage, alfalfa hay and dried beet pulp and gained 1.29 pounds per head daily. Average daily summer gains on irrigated pastures for the respective groups were 2.45, 1.91 and 1.89 pounds. The three respective groups made average daily gains of 1.96, 2.23 and 2.23 pounds per head during a 54-day grain feeding period. This experiment shows the importance of considering the effects of winter treatment on both pasture and feed-lot fattening gains and the effects on over-all gains from wintering to market.

Some experiments have been conducted with reference made to the best type of wintering rations for subsequent production. Sheets et al. (1925) fed six different wintering rations which consisted of corn, corn silage, cottonseed meal, mixed hay, and wheat straw to 2-year old steers. Winter gains on these rations ranged from -0.07 to 0.69 pound per head daily. When allowed to graze pasture the steers made daily gains which ranged from 1.91 to 2.56 pounds per head. Consequently, winter gains were minimized with an over-all gain which ranged from 1.27 to 1.40 pounds per head daily. The authors stated that the level of wintering had little effect on total over-all gains.

McCampbell and Horlacher (1924) conducted three trials on wintering and summer grazing of steers. In each of the three trials, calves were divided into two groups during the winter; group I received silage plus 1.0 pound of cottonseed cake per head daily while group II received alfalfa hay. The two groups were allowed to graze during the summer and
then marketed. During the first two trials, the calves which received
the silage and cottonseed cake made larger winter gains but lower summer
gains than the group which received the alfalfa hay ration. During the
third trial, group I was restricted in silage and cottonseed cake and
made a lower winter gain but made a larger summer gain. The results
showed that regardless of the ration used, cattle which were wintered at
a small rate of gain produced a larger summer gain.

Potter and Withycombe (1926) discussing results of 10 wintering
and summer grazing trials conducted with 330 cattle again pointed out
the inverse relationship of wintering gains to summer gains. They
stated that gains made in the winter on any kind of ration were very
expensive. The workers reported that the kinds of feed used for winter-
ing did not seem to influence the gains made the following summer on
grass, provided the wintering rations produced the same rates of gain.
It was further pointed out that for every extra 1 pound a steer gained
during wintering at least 0.5 pound less gain was produced the following
summer on grass.

An experiment on wintering and summer grazing of steers was con-
ducted by Kincaid et al. (1945) which supported the observation of Potter
and Withycombe (1926). Steers were wintered at three levels, maintenance,
50 and 100 pounds of gain and then allowed to graze pasture. It was
reported that the levels of winter feeding reduced summer gains in pro-
portion to the amount of gain they produce during the winter. The workers
stated that each additional 1 pound of winter gain reduced summer gain by
0.58 pound.
Reason et al. (1948) conducted an experiment with 6 lots of 16 steers per lot to study the relationship of winter gains made by steer calves to subsequent gains made on pasture. On the average, steers that gained the most on the winter rations gained the least on bluegrass pasture. The workers reported that if calves were to be pastured during the following summer without grain, the winter gain should not be too large or the summer gain would be reduced. It was pointed out that each additional 1 pound of winter gain resulted in 0.2 to 0.5 pound less gain on pasture.

Most of the work cited above showed that performance of steers in subsequent phases of production was greatly influenced by gains obtained during the previous feeding regimen. Steers which were wintered at lower rates of gain made larger gains in subsequent phases of production than steers which were wintered at higher rates of gain. It was also shown that when calves were wintered at higher rates of gain every extra pound of winter gain reduced the subsequent summer gains, in some cases as much as 0.5 pound for each additional pound of winter gain. Studies made on different types of wintering rations showed that the amount of winter gain had more effect than the actual type of winter ration used. Thus, the important and practical aspects which should be considered are the amounts of protein and energy required to produce specific rates of gain. The rate of gain to obtain during the wintering period should then depend upon the subsequent feeding system to be followed and the cost of feeds to be used in the overall feeding program.
Protein Requirements for Different Rates of Wintering Gain

In many of the previously reported experiments, little attention was actually given to the protein levels of the various wintering rations. Some experiments in which the protein requirements for wintering calves were studied more specifically are reviewed in this section.

A series of experiments to determine the value of 20, 30 and 40 percent protein supplements for wintering heifer calves were conducted by Nelson et al. (1951a, 1952b, and 1953) and Ross et al. (1951) and later summarized by Nelson et al. (1954). Calves which averaged 430 pounds were wintered for 153 days in traps on prairie hay and on native range land with protein supplements fed to both groups. At the conclusion of the wintering trial, the heifers were allowed to graze during the summer for 212 days. The results have been summarized in Table I. The average daily winter gains were directly related to the protein content of the supplements. As the protein level of the supplements increased, the wintering gains also increased. The inverse relationship of wintering gains to summer gains was also demonstrated during the following pasture season. The difference in over-all gains of heifers wintered in traps and fed prairie hay was small but slightly larger for heifers which received the higher protein supplements. The difference in over-all gains was small when the 20 and 40 percent protein supplements were fed in equal amounts to heifers grazing the dry native grass during the winter.

Winchester et al. (1957) conducted an experiment with twin calves to determine the effects of various protein levels when fed with different
levels of energy in the rations. One member of each set of twins served as a control while its co-twin was subjected to different protein and energy levels. In the study, eight pelleted rations were used ranging from a caloric maintenance with only 2.4 percent digestible protein to high energy rations with 11.4 percent digestible protein. It was observed that animals on low energy and low protein rations lost weight while those on the other rations made gains depending on the quality of the ration and the amount fed. Slaughter of each retarded animal was delayed until its degree of fatness approximated the final condition of its co-twin. In spite of the drastic treatments given some animals, efficiency of feed utilization and quality of carcass of co-twins were similar. It was shown that when energy intake was held near maintenance, changes in body weight were positively correlated with the level of protein intake. From the data, the workers calculated on a tentative basis the protein requirements of young beef cattle on caloric maintenance rations. These requirements along with values of other workers are presented in Table I.

A metabolism study was conducted by Fontenot et al. (1953) using rations similar to those used by Nelson et al. (1954). Steers were fed 7 pounds of prairie hay supplemented with the various levels of 20, 30 and 40 percent protein pellets. The 20 percent pellet was fed at the rate of 1 and 2 pounds per head daily and the 30 and 40 percent pellets were fed each at the rate of 1 pound daily. The coefficients of protein digestibility for the rations with 1 pound of 20, 30 and 40 percent protein pellets were 45.6, 52.2 and 56.1 percent respectively. The
digestibility of protein for the ration with 2 pounds of 20 percent protein concentrate was 51.4 percent. By applying the digestion coefficients to the rations fed by Nelson et al. (1954), the calculated average daily digestible protein intakes per heifer making gains of 0.07, 0.22 and 0.53 pound per head daily were 0.30, 0.41 and 0.50 pound respectively. When compared to levels suggested in Table I, the calculated levels of 0.30 and 0.41 pound of digestible protein per head daily fed by Nelson et al. (1954) which resulted in gains of 0.07 and 0.22 pound per head daily are respectively slightly below and above the suggested level of 0.32 pound of digestible protein for maintenance presented by Winchester et al. (1957). The calculated level of 0.50 pound of digestible protein per head daily which resulted in a daily gain of 0.53 pound is below the minimum level recommended by Morrison (1956) for 0.75 pound gain.

Calculated values obtained by Stephens et al. (1949) and Brouse (1955) and Embry et al. (1958) are also presented in Table I. In general, the calculated values are intermediate to the maintenance levels suggested by Winchester et al. (1957) and the wintering levels recommended by Morrison (1956) and the National Research Council (1959).

The results of the above workers showed that when energy was maintained at a uniform level within an experiment, the resulting gains were directly related to the protein content of the rations. As the protein level of the ration increased, the average daily gain also increased within the protein levels studied.

The data presented in Table I show variation in requirements
## TABLE I. POUNDS OF TOTAL DIGESTIBLE PROTEIN REQUIRED DAILY TO MAINTAIN WEIGHT AND MAKE REGULAR GAINS

<table>
<thead>
<tr>
<th>Body Weight, Pounds</th>
<th>Expected Daily Gains, Pounds</th>
<th>Digestible Protein Required Per Head Daily, Pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
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<tr>
<td></td>
<td>0.00</td>
<td>0.25</td>
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<tr>
<td></td>
<td>0.32\textsuperscript{a}</td>
<td>0.41\textsuperscript{d}</td>
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<tr>
<td></td>
<td>0.30\textsuperscript{d}</td>
<td>0.42\textsuperscript{e}</td>
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<td>0.38\textsuperscript{e}</td>
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<td>0.75\textsuperscript{f}</td>
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\textsuperscript{a} Winchester et al. (1957).
\textsuperscript{b} NRC (1959).
\textsuperscript{c} Morrison (1956).
\textsuperscript{d} Nelson (1954), calculated.
\textsuperscript{e} Brown (1955), calculated.
\textsuperscript{f} Embry (1958), calculated.
\textsuperscript{g} Stephens (1949), calculated.
obtained by various workers. More work is indicated particularly in relation to protein requirements at different levels of energy.

Energy Requirements for Different Rates of Wintering Gain

The energy requirements for wintering calves are presented in our present day feeding standards. The requirements listed have been determined from the results of numerous feeding experiments. Many of the experiments were of short duration and not specifically designed to study energy requirements. While the feeding standards are of significant value to the livestock producer, it should be borne in mind that the recommended requirements should serve only as guides. The requirements may be modified by the producer in accordance with his present feeding conditions and the desired results. Some experiments have been conducted to determine the amount of production obtained from cattle with wintering rations containing different levels of energy. The experiments reviewed were those concerned with these types of rations. Only a few such experiments appear to have been reported where energy requirements were studied at constant levels of protein.

In recent work, Winchester (1953) conducted an experiment to determine the energy requirements of beef calves for maintenance and growth. Data were collected on levels of energy intake and growth rates of 16 pairs of identical twin calves. During the test, one member of each pair received a reduced energy allowance, as low as 30 percent of maintenance in some cases, while its co-twin received a more liberal
energy allowance. From these data, equations were derived for the determination of energy requirements for maintenance and for growth. Maintenance was defined as the energy requirement of an animal that was neither gaining nor losing weight. The energy requirement, expressed as total digestible nutrients (TDN), of a growing animal was found to be:

Energy requirement in pounds TDN = 0.0553 x pounds body weight^{2/3} (1 / 0.805 x pounds daily gain)

The TDN required by young beef cattle for maintenance and for different rates of daily gains as determined by the above formula and some values of other workers are presented in Table II.

Brouse (1955) fed prairie hay and various mixed supplements to 11 lots of calves during the winter of 1946-1947. The supplements consisted of various amounts of alfalfa meal, soybean oil meal, ground corn, urea and steamed bone meal; and they were formulated to supply approximately the same daily intake of protein to each lot. It was observed that winter gains were directly correlated to the TDN intake. The four high gaining lots received 6.66 pounds of TDN per head daily during the 168-day wintering trial and made average daily gains which ranged from 1.07 to 1.11 pounds. The next three high gaining lots gained from 0.89 to 0.96 pounds per head daily with a daily TDN intake of 6.33 pounds. The other four lots gained from 0.68 to 0.77 pound daily with an average daily intake of 5.71 pounds of TDN. The TDN values obtained are comparable to the levels presented in Table II from Morrison (1956) and the National Research Council (1959).

While feeding standards giving recommended requirements for energy have been prepared, they appear to be based largely on experiments not
<table>
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<tr>
<th>Body Weight Pounds</th>
<th>Expected Daily Gains, Pounds</th>
<th>TDM Required Per Head Daily, Pounds</th>
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<td></td>
<td>3.9a</td>
<td>5.5a</td>
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</tbody>
</table>

a Winchester and Hendricks (1953).
b Morrison (1956).
c NRC (1959).
d Brouse (1955).
involving a specific study of these requirements especially at constant levels of protein. More studies are obviously needed particularly on the energy required for various rates of gain and the proportion of energy to protein.

**Digestible Calories as a Measure For\*

**Expressing Energy**

Although total digestible nutrients (TDN) have been well established as a measure of the energy value of feeds, the shortcomings and inaccuracies of TDN values have received considerable attention during the past few years. The simple direct measure of digestible energy by the bomb calorimeter has received much emphasis recently. The direct determination of the total energy content of the feed and of the feces by the bomb calorimeter replaces the long procedure of separating feed and feces into their component parts by chemical analyses. Hence, the chemical analyses and calculations of the digestion coefficients of the various component parts are eliminated. Both digestible energy (DE) and TDN represent the digestible portion of feeds and have the same significance. The choice between the two methods appears to be one of accuracy and saving in time.

*Swift et al. (1950)* in describing TDN determinations made the following statement: "In the determination of total digestible nutrients, the feed and feces are separated in a manner of speaking by empirical chemical analyses into component parts. The digestibility of each component (crude fiber, nitrogen-free extract, etc.) is determined
and, in accord with their respective digestion coefficients, the parts are reassembled to constitute a total digestible nutrient value expressed on weight basis. The underlying energy aspect of the procedure is tacitly recognized by giving the same weight value to digestible protein and carbohydrate and by multiplying the digestible ether extract by 2.25 before including it in the TDN appraisal."

In the past few years, numerous workers have pointed out the inaccuracies of the procedures involved in the determination of TDN as a measure of feed energy. Maynard (1944 and 1953) had pointed out the inherent errors in the use of TDN as a measure of feed energy. Schneider (1954) also pointed out that the TDN system of measuring nutritive energy is lacking in scientific concepts and nutritional theory as compared to other measures of nutritive energy.

With these views in mind, Lofgren (1951), Maynard (1953), Schneider (1954), Crampton (1956) and other workers have expressed the desire of adopting digestible energy in place of TDN. Since that time, the Northeast Regional Technical Committee (Swift, 1957a) has adopted digestible energy as a measure of nutritive value in comparing forages. Other current workers in the field are increasingly using the term "digestible energy" in their reports on nutritional research.

Since most feeding standards used in the United States are based on TDN values, much attention has been placed on the conversion of TDN to digestible energy. Schneider (1947) suggested 1987 kilocalories per pound TDN and it was supported by Maynard (1953). Crampton (1956) presented evidence, based on theoretical considerations, that in swine
rations a pound of TDN should be equivalent to about 2037 kilocalories of digestible energy. With sheep, the value of 1991 kilocalories was equivalent to 1 pound of TDN.

Swift (1957b) collected data from 312 digestion experiments in which both digestible energy and TDN were experimentally determined. The worker reported that 1 pound of TDN was equivalent to 2000 kilocalories of digestible energy. This value was found to apply to sheep and cattle on roughage alone and to cattle on mixed rations.

Crampton et al. (1957) studied the caloric value of TDN in swine rations. From 30 theoretical rations in which both TDN and digestible energy (DE) were calculated, these workers derived a prediction equation by which the TDN-DE conversion factor could be estimated from the gross energy and crude fat content of a specific feed. Calculated conversion factors for a variety of rations and conversion factors experimentally determined from TDN and DE values of digestion trials with swine were in good agreement. It was concluded that the caloric value of TDN was not constant but was dependent upon the ether extract content of the ration. Although the caloric value varied, it averaged close to 2041 kilocalories per pound of TDN.

Work was conducted by Drori and Looali (1959) on the influence of fistulation on the digestibility of feeds by steers. In their study the workers included data on TDN and digestible energy relationships. Alfalfa hay and concentrates which were composed of corn distillers dried grain plus 1.5 percent ground limestone were used in the study. The TDN values obtained from the alfalfa hay and concentrates were 51.9 and 71.9
percent respectively. Digestible energy values per pound of alfalfa hay and concentrates on an air-dry basis were 1097 and 1597 kilocalories. Digestible energy values per pound of TDN for the two feeds were 2114 and 2221 kilocalories respectively.

Barth et al. (1959) made a study on the quantitative relationship between TDN and digestible energy values of forages. The workers reported that when roughages were fed alone to cattle and sheep the ether extract did not seem to affect the magnitude of TDN-DE conversion factor. Although this observation did not agree with Crampton et al. (1957), it may be explained by the fact that roughages contain only a small amount of ether extract of which the apparent digestibility is low. The workers reported that the caloric value of TDN increased as the apparent digestible protein content of the roughages increased.

The value of 2000 kilocalories per pound of TDN was used by the Committee on Animal Nutrition of the National Research Council (1959) when computing digestible energy (DE) requirements for beef cattle. Digestible energy requirements were computed from TDN data with the following formula:

\[
\text{Therm DE} = \frac{\text{lbs. TDN} \times 454 \text{ gm} \times 4.41 \text{ Kcal}}{1000 \text{ Kcal}}
\]

This formula was based on the assumption that each gram of TDN had 4.41 kilocalories (2000 kilocalories per pound TDN) of digestible energy. Digestible energy requirements computed in this fashion are no more reliable than the TDN values listed. However, the Committee pointed out that they felt that the computed DE values should be included with the
hope of stimulating actual analytical digestible energy evaluations of beef cattle feeds in further research. They further stated that digestible energy evaluations can be more easily carried out and made more meaningful than TDN evaluations.

There are many obvious advantages of using digestible energy rather than TDN. One of the main objections to adopting digestible energy as a means of evaluating the energy content of feeds is the great amount of TDN data in relation to digestible energy data available for various feeds. Work has been cited which shows that TDN and digestible energy relationships are relatively constant under many conditions and that present TDN data could be used satisfactorily in arriving at digestible energy.

Digestible energy values of feeds are rather meager at the present time and more comparisons with TDN are needed with different types of rations. Therefore, digestible energy was determined on the rations used in the experiments reported in this thesis. TDN was also determined for additional comparisons of the relationship between TDN and digestible energy.
CHAPTER III

METHODS OF PROCEDURE

The objectives of the experiments were to determine the effects of different protein and energy levels during wintering of steer calves on rates of gain and feed efficiency during wintering and subsequent phases of production. The specific objectives were as follows:

1. To determine the effects of restricted protein and energy intakes on wintering gain and feed efficiency and on performance in subsequent phases of production when followed by a summer period of grazing or all-roughage rations fed in dry lot and then fattened in dry lot.

2. To determine the effects of different levels of protein for wintering steer calves on hay and limited grain rations followed by high concentrate fattening rations after the wintering period.

3. To determine digestible nutrients in the wintering rations and to study the relationship between total digestible nutrients and digestible energy.

Experiments on Restricted Protein and Energy Intakes for Wintering Calves and Effects on Subsequent Production

Two wintering trials were conducted at the Range Field Station, Cottonwood, South Dakota. The objectives of these wintering trials were to determine the effects of restricted intake of protein and energy on wintering beef calves and to study the effects of method of wintering on
performance during a summer grazing or roughage feeding period followed by dry-lot fattening on high-concentrate rations.

1957-1958 Trial

Wintering Phase. The first wintering trial was conducted in 1957-1958. Eighty steer calves (mostly grade Herefords with some showing Shorthorn breeding) were purchased in the fall of 1957. The average weight of the calves was approximately 475 pounds. Prior to the test, the animals were placed on a 28-day preliminary feeding period and received an antibiotic conditioner supplement and a full feed of prairie hay. Salt, mineral supplement and water were supplied free access.

On January 3, 1958, the calves were weighed and allotted according to weight and previous treatment into 8 lots of 10 steers per lot. Lots 1 through 4 received different levels of protein by feeding different ratios of alfalfa and prairie hay. Table III shows the different ratios of alfalfa and prairie hay fed in the experiment. Lot 1 was fed according to appetite and the other lots were limited to the amount of feed consumed by lot 1.

Lots 5 through 8 were subjected to different levels of energy by restricting the feeding of alfalfa and prairie hay. The rations used were the same as fed to lot 4 which consisted of 70 percent alfalfa and 30 percent prairie hay. Lot 5 was fed a full feed while lots 6, 7 and 8 received 88, 76 and 64 percent, respectively, of a full feed based on the consumption of lot 5.

The rations for the different lots were fed once daily. Trace-mineralized salt, a mineral mix of 75 percent bone meal and 25 percent
TABLE III. WINTER RATINGS AND RATE OF FEEDING (WINTERING TRAIL, RANGE FIELD STATION, 1957-1958)

<table>
<thead>
<tr>
<th>Lot Number</th>
<th>Ration</th>
<th>(%)</th>
<th>Rate of Feeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alfalfa hay</td>
<td>10</td>
<td>Full fed</td>
</tr>
<tr>
<td></td>
<td>Prairie hay</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Alfalfa hay</td>
<td>30</td>
<td>Same rate fed lot 1</td>
</tr>
<tr>
<td></td>
<td>Prairie hay</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Alfalfa hay</td>
<td>50</td>
<td>Same rate fed lot 1</td>
</tr>
<tr>
<td></td>
<td>Prairie hay</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Alfalfa hay</td>
<td>70</td>
<td>Same rate fed lot 1</td>
</tr>
<tr>
<td></td>
<td>Prairie hay</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Alfalfa hay</td>
<td>70</td>
<td>Full fed</td>
</tr>
<tr>
<td></td>
<td>Prairie hay</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Alfalfa hay</td>
<td>70</td>
<td>88% of the rate fed</td>
</tr>
<tr>
<td></td>
<td>Prairie hay</td>
<td>30</td>
<td>lot 5</td>
</tr>
<tr>
<td>7</td>
<td>Alfalfa hay</td>
<td>70</td>
<td>76% of the rate fed</td>
</tr>
<tr>
<td></td>
<td>Prairie hay</td>
<td>30</td>
<td>lot 5</td>
</tr>
<tr>
<td>8</td>
<td>Alfalfa hay</td>
<td>70</td>
<td>64% of the rate fed</td>
</tr>
<tr>
<td></td>
<td>Prairie hay</td>
<td>30</td>
<td>lot 5</td>
</tr>
</tbody>
</table>

trace-mineralized salt and water were offered free access to all lots.

The calves in each lot had access to a shed and an outside exercise lot. Hay bunks and salt and mineral boxes were located in each shed for the feeding of hay, salt and mineral supplement. Water was supplied in heated automatic waterers.

After being on test for 1 week, all horns were removed from calves not previously dehorned. Some of the calves which still possessed testicles were castrated at this time. The calves remained on the wintering trial for a period of 145 days.
Representative samples of alfalfa and prairie hay were taken periodically during the feeding trial. The samples were composited, ground and analyzed for chemical composition. All methods of analysis used in the entire experiment were according to A.O.A.C. (1957). The approximate protein contents of the rations fed to lots 1 through 4 were 7.6, 8.7, 9.7 and 10.8 percent respectively. The approximate protein contents of the rations for lots 5 through 8 were the same as for lot 4, 10.8 percent.

**Summer Grazing Phase.** At the conclusion of the wintering trial of 1957-1958, the calves were allowed to graze summer pastures to determine rate of recovery for calves wintered on low protein and low energy rations. Because of shortage of available pasture land, the cattle were pastured at two locations.

Six steers from each of the eight lots were trucked to Reeds’ Ranch, located 80 miles southwest of Pierre, South Dakota, and were pastured on native range grass. During the summer, the steers were supplemented with 1 pound of ground pelleted corn per head daily. Salt, mineral supplement and water were supplied free access. The mineral supplement consisted of 1 part trace-mineralized salt and 3 parts dicalcium phosphate.

The remaining 4 steers of each of 8 winter lots were trucked to Brookings, South Dakota, and placed on pasture consisting of 75 percent bromegrass and 25 percent alfalfa. No supplement was fed to this group of steers. Salt, mineral supplement and water were supplied free access. The mineral supplement consisted of 1 part trace-mineralized salt and
3 parts dicalcium phosphate. Several cases of foot rot and pink eye were observed and treated in this group.

Fattening period. The steers were removed from the pasture and regrouped into their original winter lots for the fattening phase conducted at Brookings, South Dakota. All steers were fed the same fattening ration in order to determine effects of the previous wintering treatment on rate of gain and feed efficiency during the fattening period. This procedure also permitted the determination of the effects of winter treatment on total feed required, carcass quality, time and weight necessary to reach a market grade of choice.

The fattening ration consisted of 25 pounds of corn silage per steer daily and a full feed of concentrates. The concentrates consisted of 85 percent rolled shelled corn, 12 percent soybean oil meal, 1 1/2 percent bone meal and 1 1/2 percent trace-mineralized salt. All lots were fed twice daily.

The corn silage was harvested the previous summer from a corn crop with an estimated corn yield of 35 bushels per acre. At the time of feeding, the moisture content of the silage was approximately 69 percent.

Each feed lot consisted of an area (24 feet by 56 feet) with a feed bunk located at one end of the lot. Each lot had an 8-foot strip of concrete by the feed bunk. The lots were open and the cattle did not have access to shelter. Water was supplied free access in heated tanks located at the center edge of each lot.

When each lot of steers reached an average weight of about 1225
pounds, the cattle were trucked to Huron, a distance of 75 miles, for slaughter. A filled weight, 16-hour shrunk weight without feed and water and a market weight were obtained for each steer. Live and carcass grades, area of rib-eye muscles, fat depth over rib-eye muscles and marbling scores were also obtained. Live grades were estimated by a packer buyer at the time of marketing and carcass data were obtained 2 days after slaughter. The carcass grades and marbling scores were determined by a U. S. Federal grader. The area of rib-eye muscles and fat depth over rib-eye muscles were determined from parchment tracings.

1958-1959 Trial

Wintering Phase. A second wintering trial was conducted at the Range Field Station, Cottonwood, South Dakota, in a similar manner during the winter of 1958-1959. Eighty Hereford steer calves were used in this study. The calves were lighter in weight, averaging about 415 pounds, and of better quality than the group of steers used the previous year.

Generally the calves were handled before and during the test in the same manner as the previous year except they were not fed the antibiotic conditioner supplement. The steers were placed on experiment on November 15, 1958, and received rations composed of alfalfa and prairie hay harvested the previous summer. The ratios of alfalfa and prairie hay were the same as in the 1957-1958 trial (Table III). The approximate protein contents of the rations fed lots 1 through 4 were 6.1, 8.0, 10.0 and 12.0 percent. The protein contents of the rations fed lots 5 through 8 were the same as for lot 4, 12.0 percent. The experiment was terminated after 189 days.
**Summer Roughage Feeding Phase.** Upon the completion of the second wintering trial (1958-1959), the steers were trucked to Brookings. They were allotted into their respective 8 winter groups of 10 steers per lot except for one lot. Two steers in lot 4 developed urinary calculi during the previous winter and were removed from the trial, leaving eight steers during the remainder of the study. The cattle were confined to large lots (56 feet by 104 feet) with a shelter belt on the west side. They had free access to water, trace-mineralized salt and a mineral mixture composed of 1 part trace-mineralized salt and 3 parts dicalcium phosphate.

The steers in all lots were fed a ration composed of 2 pounds soybean oil meal and a full feed of corn silage for 31 days. The cattle were then full-fed alfalfa-bromegrass and alfalfa haylage (low-moisture silage stored in gas-tight silo).

The alfalfa-bromegrass haylage contained about 50 percent each of alfalfa and bromegrass harvested in full-bloom. The stand was thin and the forage was short. Fifty acres yielded only 101 tons of haylage (1.1 tons dry matter per acre).

The alfalfa haylage consisted of second-cutting alfalfa harvested in the full-bloom stage. Yield was very low because of drought conditions. About 70 acres yielded only 24.2 tons of haylage averaging 32.83 percent moisture as stored.

The summer feeding trial was terminated on September 22, 1959 and the fattening phase is not included in the results of this thesis.
Experiments on Protein Levels in Rations With Limited Grain for Wintering Calves and Effects on Subsequent Production

Two wintering trials were conducted at the North Central Substation, Eureka, South Dakota. The objectives of these trials were to determine the response of steer calves to different levels of protein in limited grain rations and the effects on subsequent production when fattened in dry lot following the winter feeding period.

1957-1958 Trial

Wintering Phase. The initial wintering trial was conducted in 1957-1958 with 40 steer calves weighing approximately 405 pounds. The calves were mostly grade Herefords with some individuals showing evidence of Shorthorn breeding. Prior to the test, the calves were placed on a preliminary feeding period and received an antibiotic condition supplement and a full feed of prairie hay. Salt, mineral supplement and water were supplied free access.

On January 2, 1958, the steers were weighed and allotted according to weight into 4 lots of 10 steers per lot. Each lot received a ration which consisted of different ratios of alfalfa and prairie hay. Lots were fed to all lots at the rate of 25 percent of the total ration. The rations with the different ratio of hay expressed in percent and the rate of feeding are presented in Table IV.

All lots were fed the same amount of total feed with consumption limited by the intake of lot 1 which received prairie hay.
TABLE IV. WINTER RATION AND RATE OF FEEDING (WINTERING TRIAL,
NORTH CENTRAL SUBSTATION, 1957-1958)

<table>
<thead>
<tr>
<th>Lot Number</th>
<th>Ration</th>
<th>(%)</th>
<th>Rate of Feeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bay Alfalfa (none)</td>
<td>75</td>
<td>Full fed</td>
</tr>
<tr>
<td></td>
<td>Prairie (100%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Whole oats</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Bay Alfalfa (25%)</td>
<td>75</td>
<td>Same rate fed lot 1</td>
</tr>
<tr>
<td></td>
<td>Prairie (75%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Whole oats</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Bay Alfalfa (50%)</td>
<td>75</td>
<td>Same rate fed lot 1</td>
</tr>
<tr>
<td></td>
<td>Prairie (50%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Whole oats</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Bay Alfalfa (75%)</td>
<td>75</td>
<td>Same rate fed lot 1</td>
</tr>
<tr>
<td></td>
<td>Prairie (25%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Whole oats</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

The hay and oats were fed to calves once per day. Trace-mineralized salt, a mineral mix of 75 percent bone meal and 25 percent trace-mineralized salt and water were offered free access.

Representative samples of hay and oats were collected periodically during the feeding trial, ground and analyzed for chemical composition. The protein levels of the rations for lots 1 through 4 were approximately 8.6, 10.0, 11.4 and 12.8 percent.

The calves in each lot were confined to a shed with an outside exercise lot. Hay bunks, salt and mineral boxes were located inside the sheds for the feeding of hay, salt and mineral supplement. A feed bunk was located in the exercise lot for the feeding of oats. Water was
supplied free access in heated automatic waterers.

**Fattening Phase.** Upon completion of the initial wintering trial of 1957-1958, the steers were trucked to Brookings, South Dakota, and placed on a fattening ration to determine effects of previous treatment on rates of gain, total feed requirements, carcass quality and time and weight necessary to reach a market grade of choice. Prior to the fattening phase, the steers were placed on a 9-day feeding program to study the amount of shrink in trucking and rate of recovery. During the first 4 days, the steers received 13 pounds of hay (equal parts alfalfa and prairie hay) and 4 1/3 pounds whole oats. For the remaining 5 days, the steers received their original winter rations.

At Brookings, the steers were fed in four separate outside lots without shade or shelter. The cattle were kept in the same groups as during the winter. However, one steer was removed from lot 1 because of a bad eye and one from lot 4 because of lump jaw. All lots were fed the same ration in order to determine the effects of the winter treatments on later feed-lot performance.

The initial fattening ration consisted of 5 pounds alfalfa hay and a full feed of a concentrate mixture containing 95 percent rolled shelled corn and 5 percent soybean oil meal. Trace-mineralized salt, a mineral mixture composed of 75 percent bone meal and 25 percent trace-mineralized salt and water were offered free access. The cattle were fed twice daily with the amount of hay being kept constant and the concentrate mixture being fed according to appetite.

A ration change was made at the end of 175 days due to the poor
performance of the steers. The soybean oil meal in the concentrate mixture was increased to 10 percent. Bone meal and trace-mineralized salt were included in the ration at the level of 1.5 percent each. Mineral supplement was not offered free access after this date. Vitamin A supplement was added to the concentrate mixture to supply 2000 U. S. P. units of vitamin A per pound of the concentrate mixture.

Two steers were removed during the trial. One steer in lot 1 developed urinary calculi and one in lot 4 was removed because of a condition diagnosed as an abscessed brain. Only the steers completing the trial are considered in the results of the fattening trial.

The cattle in each lot were marketed when the average filled weight for the lot reached approximately 1100 pounds per steer. A filled weight was taken at the end of the experiment. Feed and water were removed and the cattle were shrunk overnight for a 16-hour shrunk weight. After trucking to Huron, a distance of about 75 miles, a market weight was also taken. The time from shrunk weight to market weight was about 3 hours.

Live grades were estimated at time of marketing by a packer buyer. Carcass grades, area of rib-eye muscles, fat depth over rib-eye muscles and marbling scores were obtained 2 days after slaughter. The carcass grades and marbling scores were determined by a U. S. Federal grader. Area of rib-eye muscles and fat depth over rib-eye muscles were determined by parchment tracings.
1958-1959 Trial

Wintering Phase. The second wintering trial was conducted at the North Central Substation, Eureka, South Dakota, in 1958-1959 with 40 Hereford steer calves. The calves were more uniform and of better quality than the group used the previous year. Generally, the steers were handled in a similar manner as the previous wintering group except the antibiotic conditioner supplement was not fed.

The steers were placed on experiment on December 11, 1958, and fed rations similar to those fed in the 1957-1958 trial (Table IV). The protein contents of the rations fed lots 1 through 4 were approximately 7.4, 8.9, 10.3 and 11.7 percent respectively. The experiment was terminated after 155 days.

Digestibility of Rations

Digestion Trials

Digestion trials were conducted to determine digestible nutrients of the rations used in the wintering trials of 1957-1958 and 1958-1959. Twelve grade Hereford steer calves were used in this digestion study. The steers were obtained in the fall of the year and averaged approximately 500 pounds. The animals were assigned to their stanchions at random and placed on a ration of alfalfa and prairie hay for a 3-week preliminary feeding period. During this time the animals were allowed to become accustomed to their stanchions and to being handled.

On December 1, 1958, the animals were weighed and placed on experiment. Twelve different rations, representing the 12 winter rations of
1957-1958, were fed to the group. The rates of feeding were similar to the wintering trials. Four replications of the trial were conducted along with two additional trials to determine the digestibility of the hays when fed alone.

The feeds used consisted of the same hay and oats fed during the previous winter feeding trials. During the winter feeding trials, bales of alfalfa and prairie hay were selected at random from the source being fed and trucked to Brookings. The oats was also selected and handled in the same manner. At Brookings, the hay was stacked in the open in individual stacks and the oats stored in bins until used.

The animals were fed twice daily throughout the experiment with equal amounts of feed being offered in the morning and afternoon. The oats was fed first followed by the hay. All animals were fastened for approximately 3 hours at each feeding to allow plenty of time to consume their feed. They were allowed to exercise between feedings on a concrete floor bedded with ground corn cobs. Water, trace-mineralized salt and a mineral mixture consisting of 75 percent bone meal and 25 percent trace-mineralized salt were offered free access.

Each trial consisted of a 14-day preliminary period and a 5-day collection period. The rate of feeding was determined by the consumption during the preliminary period. At the end of each period, orts were weighed and divided into two portions. One portion was ground with duplicate samples being made for chemical analyses and caloric determinations. The other portion was dried at 90°C for 3 days to determine the moisture content as collected. Samples of the hays and oats fed during
the collection periods were collected and treated in the same manner as the orts.

A total collection method was used for the feces, which were collected in canvas bags attached to the animals by harnesses. The bags were emptied twice daily and the total weight of feces taken. A 3 percent sample from each steer at each weighing was placed in a glass jar and frozen. At the end of each collection period, a representative sample of the feces saved from each animal was ground in a meat grinder with duplicate samples being made. One sample was used for a complete proximate analysis and the other was saved for calorimetric determination. The coefficients of apparent digestibility for dry matter, crude protein, ether extract, crude fiber, nitrogen-free extract and organic matter were calculated in the conventional way.

A second digestion trial was conducted immediately following the first trial using the wintering rations of 1958-1959. Because of a rather poor condition, steer number 11 was replaced by steer number 15. The steers were randomly assigned to the different rations in each of the collection periods. All procedures followed were similar to those of the first digestion trial. Design of each digestion trial is shown in Tables V and VI.

Oxygen Bomb Calorimetry

One of each pair of the duplicate samples of oats, hay, orts and feces which were collected during the digestion trials was used for the calorimetric determination. The energy value of each sample was obtained by the use of the adiabatic oxygen bomb calorimeter.
<table>
<thead>
<tr>
<th>Digestion Period</th>
<th>Range Field Station</th>
<th>Ration Number$^a$</th>
<th>North Central Substation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Steer Number</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5, 11</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>12, 14</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Days Fed Alone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range Field Station</td>
</tr>
<tr>
<td>Alfalfa</td>
</tr>
<tr>
<td>Steer Number</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

$^a$ The rations which the calves received and rate of feeding are shown in Table III and IV.
### TABLE VI. DESIGN OF DIGESTION TRIAL III (1958-1959 RATIONS)

<table>
<thead>
<tr>
<th>Digestion Period</th>
<th>Range Field Station</th>
<th>North Central Substation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Steer Number</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1, 2, 3, 4</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td></td>
<td>Ration Numbera</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5, 6, 7, 8</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3, 5, 7, 14</td>
<td>4, 9, 10, 15</td>
</tr>
<tr>
<td>2</td>
<td>14, 7, 5, 3</td>
<td>4, 9, 15, 10</td>
</tr>
<tr>
<td>3</td>
<td>5, 3, 14, 7</td>
<td>15, 10, 4, 9</td>
</tr>
<tr>
<td>4</td>
<td>7, 14, 3, 5</td>
<td>10, 15, 9, 4</td>
</tr>
</tbody>
</table>

**Hays Fed Alone**

<table>
<thead>
<tr>
<th>Range Field Station</th>
<th>North Central Substation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>Alfalfa</td>
</tr>
<tr>
<td>Prairie</td>
<td>Prairie</td>
</tr>
<tr>
<td>Steer Number</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3, 9, 13, 14</td>
</tr>
<tr>
<td></td>
<td>4, 10, 14, 15</td>
</tr>
<tr>
<td>6</td>
<td>7, 8, 15, 12</td>
</tr>
<tr>
<td></td>
<td>3, 9, 14, 15</td>
</tr>
</tbody>
</table>

* The rations which the calves received and rate of feeding are shown in Table III and IV.
The orts, hays and oats samples which were collected during the digestion trials were handled very similar to the feces, except for drying. These samples were dried at 100°C for 30 hours. Upon reaching constant weight, the samples were burned in the calorimeter.

Procedures used in operating the bomb calorimeter were those outlined by Manual Number 120 of the Parr Instrument Company (1948). Preliminary runs on the calorimeter were made prior to the actual runs for refinement of the technique. Several standard samples of benzoic acid were burned prior to the runs and several times during the runs to check on the accuracy of the calorimeter and technique.

Values obtained and correction factors applied in determining the caloric value of the various hays, oats, feces and orts again followed the procedures outlined in Manual Number 120 of the Parr Instrument Company. The caloric values obtained for the feed, feces and orts were then applied to the digestion trial data in determining digestible energy.
CHAPTER IV

RESULTS AND DISCUSSION

Experiments on Restricted Protein and Energy Intakes for Wintering Calves and Effects on Subsequent Production

1957-1958 Trial

Wintering Phase. The results of the first wintering trial conducted at the Range Field Station, Cottonwood, South Dakota, are presented in Table VII. Average daily gains increased from 0.38 to 0.68 pound for lot 1 through lot 4 as the total protein content of the rations was increased from 7.6 to 10.8 percent. Calculated digestible protein intake, using digestion coefficients obtained in the digestion trials (Table XXII), increased from 0.37 to 0.78 pound for lot 1 through lot 4. Since energy content of the rations was fairly constant, the increase in gain may be contributed to the greater intake of protein. TM and digestible energy intakes were calculated from values presented in Table XXVI. Greatest efficiency of utilization of protein and energy was obtained with the ration which contained the highest level of protein (10.8 percent total protein, equivalent to 6.0 percent digestible protein).

The total feed offered to lots 1 through 4 was limited to that consumed by lot 1. When the ration with the highest level of protein was fed ad libitum (lot 5), feed consumption, rate of gain and feed efficiency improved. Restricting the feed intake in lots 6, 7 and 8 to 88, 76 and 64 percent of that consumed by lot 5 reduced gain and increased the
TABLE VII. EFFECTS OF PROTEIN AND ENERGY RESTRICTION ON WINTERING STEERS  
(RANGE FIELD STATION, JANUARY 3-MAY 28, 1958, 145 DAYS)

<table>
<thead>
<tr>
<th>Lot number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of steers</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
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</tr>
<tr>
<td>Ration(^a)</td>
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</tr>
<tr>
<td>Alfalfa hay, %</td>
<td>10</td>
<td>30</td>
<td>50</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Prairie hay, %</td>
<td>90</td>
<td>70</td>
<td>50</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Proximate protein, %</td>
<td>7.6</td>
<td>8.7</td>
<td>9.7</td>
<td>10.8</td>
<td>10.8</td>
<td>10.8</td>
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</tr>
<tr>
<td>Av. initial wt., lb.</td>
<td>476.4</td>
<td>476.0</td>
<td>475.6</td>
<td>477.4</td>
<td>474.4</td>
<td>476.0</td>
<td>474.2</td>
<td>474.4</td>
</tr>
<tr>
<td>Av. final wt., lb.</td>
<td>531.4</td>
<td>558.0</td>
<td>562.0</td>
<td>575.6</td>
<td>595.0</td>
<td>571.4</td>
<td>542.2</td>
<td>515.4</td>
</tr>
<tr>
<td>Av. total gain, lb.</td>
<td>55.0</td>
<td>72.0</td>
<td>86.4</td>
<td>98.2</td>
<td>120.6</td>
<td>95.4</td>
<td>68.0</td>
<td>41.0</td>
</tr>
<tr>
<td>Av. daily gain, lb.</td>
<td>0.38</td>
<td>0.50</td>
<td>0.60</td>
<td>0.68</td>
<td>0.83</td>
<td>0.66</td>
<td>0.47</td>
<td>0.28</td>
</tr>
<tr>
<td>Av. daily ration, lb.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Alfalfa hay</td>
<td>1.3</td>
<td>3.9</td>
<td>6.5</td>
<td>9.1</td>
<td>10.4</td>
<td>9.2</td>
<td>7.9</td>
<td>6.5</td>
</tr>
<tr>
<td>Prairie hay</td>
<td>11.7</td>
<td>9.1</td>
<td>6.5</td>
<td>3.9</td>
<td>4.5</td>
<td>3.9</td>
<td>3.4</td>
<td>2.9</td>
</tr>
<tr>
<td>Digestible protein, lb.</td>
<td>0.37</td>
<td>0.47</td>
<td>0.69</td>
<td>0.78</td>
<td>0.85</td>
<td>0.74</td>
<td>0.59</td>
<td>0.41</td>
</tr>
<tr>
<td>TDN, lb.</td>
<td>5.88</td>
<td>5.59</td>
<td>5.70</td>
<td>5.53</td>
<td>5.86</td>
<td>4.96</td>
<td>4.07</td>
<td>2.64</td>
</tr>
<tr>
<td>Digestible energy, therms</td>
<td>11.88</td>
<td>11.41</td>
<td>11.57</td>
<td>11.10</td>
<td>11.89</td>
<td>9.44</td>
<td>7.97</td>
<td>5.19</td>
</tr>
<tr>
<td>Feed required per cwt. gain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total hay, lb.</td>
<td>3421</td>
<td>2600</td>
<td>2167</td>
<td>1912</td>
<td>1795</td>
<td>1985</td>
<td>2404</td>
<td>3357</td>
</tr>
<tr>
<td>Digestible protein, lb.</td>
<td>97</td>
<td>94</td>
<td>115</td>
<td>115</td>
<td>102</td>
<td>112</td>
<td>126</td>
<td>146</td>
</tr>
<tr>
<td>TDN, lb.</td>
<td>1547</td>
<td>1118</td>
<td>950</td>
<td>813</td>
<td>706</td>
<td>752</td>
<td>866</td>
<td>943</td>
</tr>
<tr>
<td>Digestible energy, therms</td>
<td>3127</td>
<td>2283</td>
<td>1928</td>
<td>1633</td>
<td>1433</td>
<td>1431</td>
<td>1695</td>
<td>1853</td>
</tr>
<tr>
<td>Feed cost per cwt. gain, $(^b)</td>
<td>31.38</td>
<td>24.48</td>
<td>20.84</td>
<td>18.72</td>
<td>17.32</td>
<td>19.28</td>
<td>23.37</td>
<td>31.89</td>
</tr>
<tr>
<td>Feed cost per head, $(^b)</td>
<td>17.26</td>
<td>17.62</td>
<td>18.00</td>
<td>18.38</td>
<td>20.89</td>
<td>18.39</td>
<td>15.89</td>
<td>13.08</td>
</tr>
</tbody>
</table>

\(^a\) Lot 1 was full fed and lots 2, 3 and 4 were fed at the same rate as lot 1. Lot 5 was full fed while lots 6, 7 and 8 were fed 88, 76 and 64 percent, respectively, the rate of lot 5.

\(^b\) Feed prices used: alfalfa hay, $20/ton; and prairie hay, $18/ton.
amount of feed required per unit of gain.

Comparisons of results obtained with calves in lots 1 through 4 and lots 5 through 8 indicate that the performance was influenced more by the level of protein in the ration than by the energy level. Lots 4 and 6 received about the same amount of protein and made approximately the same rate of gain. Lot 6 received 0.57 pound less TDN daily in making this rate of gain. Lot 7 received 0.12 pound more digestible protein, but 1.52 pounds less TDN than lot 2, and made nearly the same rate of gain.

The results indicate from the standpoint of feed efficiency, involving both protein and energy, that a given rate of gain may be obtained most economically by feeding a ration adequate in protein and restricting total feed intake at a level which will give the desired rate of gain. The range in proportion of digestible protein to TDN was not great enough in this trial to determine the most efficient ratio. Digestible protein ranged from 0.06 to 0.14 pound per pound of TDN for lots 1 through 4. The other lots received from 0.14 to 0.16 pound digestible protein per pound of TDN. These results indicate that the ration should contain at least 0.14 pound digestible protein per pound of TDN for most efficient utilization of feed at any level of feeding.

At the conclusion of the 145-day wintering trial, no serious effects of protein and energy restriction were observed in any of the calves. However, the general appearance of the calves receiving the lower protein and energy rations was affected to some extent. The calves on the lower levels of nutrition appeared to be in a thinner condition
with slimmer and shallower bodies. The groups on the higher protein and energy rations appeared to be thriftier with greater body development.

Feed costs per 100 pounds gain for lots 1 through 4 were lower for the calves which received the higher levels of protein. In the last four lots, feed costs per 100 pounds gain were lower for the calves which received the more liberal rations. The lower feed costs were due to the larger gains made by the calves. However, the feed costs per head for wintering were lower for the low gaining lots. The economy of restricting feed intake and reducing feed cost during the wintering period will depend on the influence of the wintering period on later performance and over-all feed requirements from beginning of the wintering period to market.

Summer Grazing Phase. At the conclusion of the 1957-1958 wintering trial, the steers were placed on pasture. The results of this summer grazing phase are presented in Table VIII. During the grazing period, the average daily gains for lots 1 through 4 were 1.35, 1.53, 1.36 and 1.30 pounds respectively. The calves in the first three lots made average gains which were from 8 to 35 pounds greater than lot 4 which received the highest protein ration during the previous wintering trial. The average gains made by lots 6 through 8 were from 47 to 56 pounds greater than lot 5 which received the highest energy ration during the previous wintering trial.

With the exception of lot 1, the summer gains of the lots which received the restricted protein rations during the previous winter (lots 1 through 4) were in the reverse order of their winter gains. Lot 1
<table>
<thead>
<tr>
<th>Lot number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of steers</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Winter ration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay, %</td>
<td>10</td>
<td>30</td>
<td>50</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Prairie hay, %</td>
<td>90</td>
<td>70</td>
<td>50</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Av. daily winter gain, lb.</td>
<td>0.38</td>
<td>0.50</td>
<td>0.60</td>
<td>0.68</td>
<td>0.83</td>
<td>0.66</td>
<td>0.47</td>
<td>0.28</td>
</tr>
<tr>
<td>Av. initial wt., lb.</td>
<td>531.4</td>
<td>548.0</td>
<td>562.0</td>
<td>575.6</td>
<td>595.0</td>
<td>571.4</td>
<td>542.2</td>
<td>515.4</td>
</tr>
<tr>
<td>Av. final wt., lb.</td>
<td>733.1</td>
<td>776.7</td>
<td>765.3</td>
<td>769.5</td>
<td>750.9</td>
<td>770.5</td>
<td>745.2</td>
<td>727.4</td>
</tr>
<tr>
<td>Av. total gain, lb.</td>
<td>201.7</td>
<td>228.7</td>
<td>203.3</td>
<td>193.9</td>
<td>155.9</td>
<td>199.1</td>
<td>203.0</td>
<td>212.0</td>
</tr>
<tr>
<td>Av. daily gain, lb.</td>
<td>1.35</td>
<td>1.53</td>
<td>1.36</td>
<td>1.30</td>
<td>1.05</td>
<td>1.34</td>
<td>1.36</td>
<td>1.42</td>
</tr>
<tr>
<td>Feed cost per cwt. gain, $a</td>
<td>7.39</td>
<td>6.52</td>
<td>7.33</td>
<td>7.68</td>
<td>9.56</td>
<td>7.48</td>
<td>7.34</td>
<td>7.03</td>
</tr>
</tbody>
</table>

*a Feed prices used: pasture, $0.10 per head daily.
still made a slightly better gain than lot 4 and a gain similar to lot 3.
When considering lots 5 through 8, the inverse relationship between
winter and summer gains again was apparent. The lots which made the
lower gains during the winter, made the greater gains during the summer.

Feed costs per head, calculated at 10 cents per head daily, were
identical for all the lots. However, feed costs per 100 pounds of gain
were lower for the lots making the larger summer gains. Generally the
lots which required higher feed costs per 100 pounds of gain the previous
winter required lower feed costs per 100 pounds of gain during the summer.

Fattening Phase. The results of the fattening phase are presented
in Table IX. The average daily gains for lots 1 through 4, respectively,
were 2.84, 3.17, 2.77 and 2.74 pounds per steer and followed in the same
order as the summer gains. With the exception of lot 1, the lots which
made progressively lower winter gains made progressively larger fattening
gains. However, lot 1 still made a larger fattening gain than lots 3 and
4. The average daily gains for lots 5 through 8 were 2.78, 2.88, 3.27
and 3.24 pounds per steer respectively. With the exception of lot 8,
the lots which made progressively lower winter gains made progressively
larger fattening gains. However, lot 8 still made a larger gain than
lots 5 and 6 and a gain similar to lot 7. In both groups, lots 1 through
4 and lots 5 through 8, fattening gains appeared to be influenced more by
wintering gains than by gains on summer pasture. A wintering gain of 0.5
pound daily appeared to be sufficient when followed by summer grazing and
then fattening in dry lot as in this experiment.

Time required during the fattening phase to reach the desired
<table>
<thead>
<tr>
<th>Days on feed</th>
<th>165</th>
<th>137</th>
<th>158</th>
<th>158</th>
<th>158</th>
<th>151</th>
<th>144</th>
<th>151</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lot number</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Number of steers</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>9a</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Av. initial wt., lb.</td>
<td>733.1</td>
<td>776.7</td>
<td>765.3</td>
<td>769.5</td>
<td>750.9</td>
<td>776.6</td>
<td>745.2</td>
<td>727.4</td>
</tr>
<tr>
<td>Av. final wt., lb.</td>
<td>1201.4</td>
<td>1210.6</td>
<td>1203.6</td>
<td>1202.4</td>
<td>1190.0</td>
<td>1211.8</td>
<td>1215.8</td>
<td>1216.2</td>
</tr>
<tr>
<td>Av. total gain, lb.</td>
<td>468.3</td>
<td>433.9</td>
<td>438.3</td>
<td>432.9</td>
<td>439.1</td>
<td>435.2</td>
<td>470.6</td>
<td>488.8</td>
</tr>
<tr>
<td>Av. daily gain, lb.</td>
<td>2.84</td>
<td>3.17</td>
<td>2.77</td>
<td>2.74</td>
<td>2.78</td>
<td>2.88</td>
<td>3.27</td>
<td>3.24</td>
</tr>
<tr>
<td>Av. daily ration, lb.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn - SBOM</td>
<td>15.8</td>
<td>16.5</td>
<td>16.1</td>
<td>16.2</td>
<td>15.5</td>
<td>15.5</td>
<td>16.4</td>
<td>16.0</td>
</tr>
<tr>
<td>Corn silage</td>
<td>24.5</td>
<td>24.8</td>
<td>24.5</td>
<td>24.7</td>
<td>24.2</td>
<td>24.7</td>
<td>24.8</td>
<td>24.6</td>
</tr>
<tr>
<td>Feed per cwt. gain, lb.</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Corn - SBOM</td>
<td>556</td>
<td>520</td>
<td>580</td>
<td>593</td>
<td>559</td>
<td>537</td>
<td>505</td>
<td>495</td>
</tr>
<tr>
<td>Corn silage</td>
<td>864</td>
<td>782</td>
<td>885</td>
<td>902</td>
<td>869</td>
<td>856</td>
<td>759</td>
<td>759</td>
</tr>
<tr>
<td>Feed cost per cwt. gain, $b</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn silage</td>
<td>3.46</td>
<td>3.13</td>
<td>3.54</td>
<td>3.61</td>
<td>3.48</td>
<td>3.42</td>
<td>3.04</td>
<td>3.04</td>
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<tr>
<td>Total</td>
<td>16.80</td>
<td>15.61</td>
<td>17.46</td>
<td>17.84</td>
<td>16.90</td>
<td>16.31</td>
<td>15.16</td>
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</tr>
<tr>
<td>Feed cost per head, $b</td>
<td>78.67</td>
<td>67.73</td>
<td>76.53</td>
<td>77.23</td>
<td>74.21</td>
<td>70.98</td>
<td>71.34</td>
<td>72.93</td>
</tr>
</tbody>
</table>

a One animal was removed from test during the fattening phase due to urinary calculi. Results are for 9 steers in this lot.

b Feed prices used: corn - SBOM, $48/ton; and corn silage, $8/ton.
final weight of approximately 1200 pounds for the eight lots ranged from 137 days for lot 2 to 165 days for lot 1. With the exception of lot 1, steers which were wintered for the lower levels of gain required fewer days to reach market weight than the highest gaining winter lots (lots 4 and 5). Generally it took less time for the group of steers which were restricted in energy the previous winter to reach market weight than the steers which were restricted in protein.

With the exception of lot 1, feed required per 100 pounds of gain for the first four lots was progressively lower for the lots which were wintered at progressively lower rates of gain. However, lot 1 still required less feed per 100 pounds of gain than lots 3 and 4. Feed requirements for the last four lots progressively decreased from lots 5 to 8. Steers which were wintered at lower rates of gain required less feed per 100 pounds of gain with feed costs following the same pattern as feed requirements.

The performance of the steers in the feed lot agree with the findings of Stephens et al. (1948a), Stephens et al. (1949), Johnson et al. (1952) and other workers. These workers reported that feed-lot performance of steers wintered at lower rates of gain was comparable to or better than steers wintered at higher rates of gain.

Over-all Winter, Summer and Fattening Phases. The results of the combined winter, summer grazing and fattening phases are presented in Table X. The average daily gains at the end of the summer grazing period for lots 1 through 4 were 0.87, 1.02, 0.99 and 0.99 pounds respectively. The results of the energy group follow the same pattern as the protein
<table>
<thead>
<tr>
<th>Lot number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of steers</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Days on feed</td>
<td>459</td>
<td>431</td>
<td>452</td>
<td>452</td>
<td>452</td>
<td>445</td>
<td>438</td>
<td>445</td>
</tr>
<tr>
<td>Av. initial wt., lb.</td>
<td>476.4</td>
<td>476.0</td>
<td>475.6</td>
<td>477.4</td>
<td>474.4</td>
<td>480.7</td>
<td>474.2</td>
<td>474.4</td>
</tr>
<tr>
<td>Av. final wt., lb.</td>
<td>1201.4</td>
<td>1210.6</td>
<td>1203.6</td>
<td>1202.4</td>
<td>1190.0</td>
<td>1211.8</td>
<td>1215.8</td>
<td>1216.2</td>
</tr>
<tr>
<td>Av. daily gain, lb.</td>
<td>0.38</td>
<td>0.50</td>
<td>0.60</td>
<td>0.68</td>
<td>0.83</td>
<td>0.66</td>
<td>0.47</td>
<td>0.28</td>
</tr>
<tr>
<td>Winter phase</td>
<td>0.87</td>
<td>1.02</td>
<td>0.99</td>
<td>0.99</td>
<td>0.94</td>
<td>1.00</td>
<td>0.92</td>
<td>0.86</td>
</tr>
<tr>
<td>Winter and summer phase</td>
<td>1.58</td>
<td>1.70</td>
<td>1.61</td>
<td>1.60</td>
<td>1.58</td>
<td>1.64</td>
<td>1.69</td>
<td>1.67</td>
</tr>
<tr>
<td>Total feed per head, lb.</td>
<td>190</td>
<td>568</td>
<td>948</td>
<td>1326</td>
<td>1508</td>
<td>1327</td>
<td>1147</td>
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<tr>
<td>Alfalfa hay</td>
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<td>568</td>
<td>646</td>
<td>569</td>
<td>492</td>
<td>414</td>
</tr>
<tr>
<td>Prairie hay</td>
<td>149</td>
<td>149</td>
<td>149</td>
<td>149</td>
<td>149</td>
<td>149</td>
<td>149</td>
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</tr>
<tr>
<td>Pasture days</td>
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<td>2258</td>
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<td>2455</td>
<td>2339</td>
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<td>3903</td>
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<tr>
<td>Corn silage</td>
<td>49</td>
<td>77</td>
<td>130</td>
<td>183</td>
<td>211</td>
<td>182</td>
<td>155</td>
<td>126</td>
</tr>
<tr>
<td>Feed per cwt. gain, lb.</td>
<td>235</td>
<td>181</td>
<td>130</td>
<td>78</td>
<td>90</td>
<td>78</td>
<td>66</td>
<td>56</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>558</td>
<td>462</td>
<td>533</td>
<td>538</td>
<td>533</td>
<td>510</td>
<td>482</td>
<td>500</td>
</tr>
<tr>
<td>Prairie hay</td>
<td>420</td>
<td>448</td>
<td>451</td>
<td>469</td>
<td>440</td>
<td>390</td>
<td>358</td>
<td>358</td>
</tr>
<tr>
<td>Corn silage</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>21</td>
<td>21</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Total air dry roughage</td>
<td>359</td>
<td>307</td>
<td>349</td>
<td>354</td>
<td>343</td>
<td>320</td>
<td>320</td>
<td>327</td>
</tr>
<tr>
<td>Corn-SBOM</td>
<td>15.29</td>
<td>13.65</td>
<td>15.03</td>
<td>15.24</td>
<td>15.37</td>
<td>14.26</td>
<td>13.77</td>
<td>13.60</td>
</tr>
<tr>
<td>Feed cost per cwt. gain, $</td>
<td>110.83</td>
<td>100.25</td>
<td>109.43</td>
<td>110.51</td>
<td>110.00</td>
<td>104.27</td>
<td>102.13</td>
<td>100.91</td>
</tr>
<tr>
<td>Total feed cost per head, $</td>
<td>123.86</td>
<td>123.76</td>
<td>123.66</td>
<td>124.12</td>
<td>123.34</td>
<td>124.98</td>
<td>123.29</td>
<td>123.34</td>
</tr>
<tr>
<td>Initial cost per head @ $26/cwt.</td>
<td>308.67</td>
<td>297.92</td>
<td>312.27</td>
<td>306.43</td>
<td>309.78</td>
<td>311.64</td>
<td>303.73</td>
<td>312.52</td>
</tr>
<tr>
<td>Av. selling price per head</td>
<td>73.98</td>
<td>73.91</td>
<td>79.18</td>
<td>73.80</td>
<td>76.44</td>
<td>82.39</td>
<td>78.31</td>
<td>88.27</td>
</tr>
</tbody>
</table>

a Corn silage on a 12 percent moisture basis is included in total air dry roughage.
b Feed prices used are shown in Tables VII, VIII and IX.
c Selling price used: $44.83 and $42.21 per cwt. for U. S. Choice and U. S. Good respectively, based on carcass selling price.
group with daily gains of 0.94, 1.00, 0.92 and 0.86 pound, respectively, for lots 5 through 8.

When considering both groups, but excluding the two lowest gaining lots (lots 1 and 8), calves which were restricted in protein or in energy during the previous winter had made over-all gains by the end of the summer grazing period comparable to, or greater than, calves which received higher protein and higher energy wintering rations.

The average daily gains per steer at the end of the fattening period for lots 1 through 4 were 1.58, 1.70, 1.61 and 1.60 pounds respectively. In considering the over-all average daily gains, the lots which made the lower winter gains due to protein restriction made gains which approached, or slightly exceeded, the gain of lot 4 which made the highest winter gain on the higher protein ration. Lots 5 through 8 made over-all average daily gains at the end of the fattening period of 1.58, 1.64, 1.69 and 1.67 pounds per steer respectively. In this group, all lots which made lower winter gains due to energy restriction made slightly larger over-all gains than the highest gaining winter lot 5.

Feed required per 100 pounds of over-all gain for the first four lots correspond to the average daily gain. Lot 2 required less feed per 100 pounds of gain and was followed by lots 3, 4 and 1. With the exception of lot 1, lots which made lower winter gains due to protein restriction were more efficient than the highest gaining lot during the wintering period (lot 4). Feed requirements per 100 pounds over-all gain for lots 5 through 8 also followed in the same order as the average daily gain. Lot 7 was the most efficient with lots 8, 6 and 5 following in descending order. In this group, all lots which made lower winter gains
due to energy restriction were more efficient in feed conversion than the highest gaining lot during the wintering period (lot 5).

The over-all total feed cost per head followed in the same order as feed cost per 100 pounds gain. Generally it was more economical to restrict energy rather than protein during the winter feeding period. However, under systems of full feeding, it may be more convenient to control gain by regulating the amount of protein in the ration. This may be an economical practice also under conditions of plentiful supplies of low quality roughages.

When considering returns per head for all lots, animals restricted in either protein or energy made average over-all returns slightly greater than the more liberally-fed animals. However, when discussing feed cost per 100 pounds of gain, feed cost per head and returns one must consider that feed costs and selling prices will vary. Therefore, in considering the results of the experiment, less emphasis should be applied to costs and returns than what may have been indicated in the tables and discussions.

The performance of the lots restricted in gain seems to agree with the findings of Winchester (1951), Winchester and Hendricks (1953), Winchester and Howe (1955), Winchester and Ellis (1956), Winchester et al. (1957) and other workers. These workers reported that generally calves which are restricted in one feeding phase did as well, or better, than the liberally-fed calves in subsequent production phases. Performance from the wintering period to market will depend some on the degree of restriction during the winter period. The results of this experiment
showed that with the type of feeding program used calves which were wintered to gain at a rate as low as 0.5 pound per day either by restriction of protein (lot 2) or energy (lot 7) made either comparable or larger pasture and fattening gains than calves wintered at somewhat higher levels. Calves which were wintered below 0.5 pound per day (lots 1 and 8) did not exceed the more liberally-fed groups in total gain by the end of the summer grazing period. However, differences which existed in the gains were small. These results indicate that 0.5 pound daily would be the most economical winter gain for calves that are to be turned to pastures capable of producing 1 to 1.5 pounds daily gain without supplemental feeding.

The low wintering gains of 0.38 and 0.28 pound daily (lots 1 and 8 respectively) were below the minimum recommendation of Morrison (1956) who states that calves should almost always be fed to gain at least 0.5 pound per head daily. Likewise, gains of 0.28 and 0.38 pound daily are considerably below the daily gain of 1 pound suggested as a desirable goal for producers by the National Research Council (1959). However, despite the low winter gains, the calves made larger summer gains and a total gain which approached the respective control lots (lots 4 and 5).

Carcass Quality. The results on market and carcass weights, shrink and carcass quality are presented in Table XI. The amount of shrink varied somewhat between lots with no specific trend. The total shrink from final filled weight to market ranged from 4.56 percent for lot 4 to 6.32 percent for lot 2. However, there did not appear to be any correlation between amount of shrink and previous treatments.
<table>
<thead>
<tr>
<th>Lot number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of steers</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>9a</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Av. filled wt., lb.</td>
<td>1201.4</td>
<td>1210.6</td>
<td>1203.6</td>
<td>1202.4</td>
<td>1190.0</td>
<td>1211.8</td>
<td>1215.8</td>
<td>1216.2</td>
</tr>
<tr>
<td>Av. shrunk wt., lb.</td>
<td>1161.0</td>
<td>1176.3</td>
<td>1162.4</td>
<td>1160.4</td>
<td>1145.0</td>
<td>1171.1</td>
<td>1175.6</td>
<td>1172.8</td>
</tr>
<tr>
<td>Av. market wt., lb.</td>
<td>1146.0</td>
<td>1134.0</td>
<td>1146.0</td>
<td>1147.5</td>
<td>1130.5</td>
<td>1146.7</td>
<td>1155.5</td>
<td>1156.5</td>
</tr>
<tr>
<td>Av. overnight shrink, lb.</td>
<td>40.4</td>
<td>34.3</td>
<td>41.2</td>
<td>42.0</td>
<td>45.0</td>
<td>40.7</td>
<td>40.2</td>
<td>43.4</td>
</tr>
<tr>
<td>Av. market shrink, lb.</td>
<td>15.0</td>
<td>42.3</td>
<td>16.4</td>
<td>12.9</td>
<td>14.5</td>
<td>24.4</td>
<td>20.1</td>
<td>16.3</td>
</tr>
<tr>
<td>Av. total shrink, lb.</td>
<td>55.4</td>
<td>76.6</td>
<td>57.6</td>
<td>54.9</td>
<td>59.5</td>
<td>65.1</td>
<td>60.3</td>
<td>59.7</td>
</tr>
<tr>
<td>Overnight shrink, %</td>
<td>3.36</td>
<td>2.83</td>
<td>3.42</td>
<td>3.49</td>
<td>3.78</td>
<td>3.36</td>
<td>3.31</td>
<td>3.57</td>
</tr>
<tr>
<td>Market shrink, %</td>
<td>1.25</td>
<td>3.49</td>
<td>1.36</td>
<td>1.07</td>
<td>1.22</td>
<td>2.01</td>
<td>1.65</td>
<td>1.34</td>
</tr>
<tr>
<td>Total shrink, %</td>
<td>4.61</td>
<td>6.32</td>
<td>4.78</td>
<td>4.56</td>
<td>5.00</td>
<td>5.37</td>
<td>4.96</td>
<td>4.91</td>
</tr>
<tr>
<td>Av. carcass wt., lb.</td>
<td>704.2</td>
<td>675.2</td>
<td>708.1</td>
<td>688.0</td>
<td>698.5</td>
<td>699.4</td>
<td>693.3</td>
<td>700.9</td>
</tr>
<tr>
<td>Av. dressing percent</td>
<td>61.75</td>
<td>59.54</td>
<td>61.79</td>
<td>59.96</td>
<td>61.79</td>
<td>61.00</td>
<td>60.00</td>
<td>60.61</td>
</tr>
<tr>
<td>Av. live grade scoreb</td>
<td>8.1</td>
<td>7.7</td>
<td>7.9</td>
<td>7.5</td>
<td>7.7</td>
<td>7.6</td>
<td>7.3</td>
<td>7.6</td>
</tr>
<tr>
<td>Av. carcass grade scoreb</td>
<td>6.9</td>
<td>6.5</td>
<td>6.7</td>
<td>7.2</td>
<td>7.1</td>
<td>7.0</td>
<td>6.9</td>
<td>7.2</td>
</tr>
<tr>
<td>Av. rib-eye muscle area, sq. in.</td>
<td>10.80</td>
<td>10.61</td>
<td>11.49</td>
<td>11.24</td>
<td>12.03</td>
<td>11.38</td>
<td>11.01</td>
<td>11.20</td>
</tr>
<tr>
<td>Av. depth of fat over rib-eye muscle, cm.</td>
<td>1.80</td>
<td>1.64</td>
<td>1.80</td>
<td>1.73</td>
<td>1.47</td>
<td>1.81</td>
<td>1.64</td>
<td>1.90</td>
</tr>
<tr>
<td>Av. marbling scorec</td>
<td>5.1</td>
<td>5.2</td>
<td>5.1</td>
<td>5.8</td>
<td>5.4</td>
<td>5.6</td>
<td>5.6</td>
<td>5.3</td>
</tr>
</tbody>
</table>

---

a One animal removed during the fattening phase due to urinary calculi.

b Live and carcass grade scores used: Choice ±, 9; Choice, 8; Choice -, 7; Good ±, 6; Good, 5; and Good -, 4.

c Marbling score used: moderate, 7; modest, 6; small amount, 5; slight amount, 4; and traces, 3.
The average dressing percent was also somewhat variable but there was a trend for the lots making the lower gains during the fattenning period to have a slightly higher dressing percent.

The average live grade scores, with values of 5, 6, 7, 8 and 9 assigned to grades of Good, Good /', Choice --, Choice and Choice J', respectively, ranged from 7.3 to 8.1 for all lots. The differences which existed were small and showed no definite trend. The average carcass grade scores, using the same scoring system as for the live grade scores, ranged from 6.5 to 7.2 for all lots. The differences in carcass grades were small and have little significance with the number of animals used per lot in this experiment.

The difference in area of rib-eye muscle, average depth of fat over rib-eye muscle and degree of marbling were small. The highest gaining winter lot (lot 5) did have the largest average rib-eye muscle area with less fat covering. There appeared to be a slight tendency toward a smaller rib-eye muscle in lots receiving lower levels of protein during wintering (lots 1 and 2).

As the carcass data indicate, the restriction of either protein or energy within the limits of this experiment during wintering had little, if any, effect on carcass composition. The results obtained are in agreement with the findings of Winchester and Bowe (1955), Winchester and Ellis (1956) and Winchester et al. (1957). These workers reported little or no difference in carcass composition when animals were maintained for limited periods on low protein and energy rations followed by fattenning on liberal rations. Differences which existed in this study
were small, but generally were slightly more favorable for the high gaining winter lots. As discussed previously, work by Pfander (1955) showed that wintering calves below maintenance produced lower carcass grades with large fat deposits on the outside of the carcass. However, the low gain of -0.4 pound per head daily which was obtained by Pfander was considerably lower than the gain of 0.28 pound made by lot 8. It would appear that as long as calves are wintered above maintenance followed by summer grazing and then fattened in dry lot, no serious effects will be observed in carcass composition.

1958-1959 Trial

Wintering Phase. The results of the second wintering trial are presented in Table XII. Winter gains for all lots were larger than those obtained during the previous year. Alfalfa and prairie hay were fed in the same ratios as in the previous trial. The alfalfa hay used in this trial contained a higher percent of protein which probably resulted in better weight gains than were obtained in the first trial.

Average daily gains for calves in the first four lots ranged from 0.39 to 0.63 pound and increased as the amount of protein in the ration was increased. Digestible energy in the rations remained fairly constant between these lots.

Average daily gains for calves restricted in feed intake decreased from 1.06 to 0.48 pounds as the feed intake was restricted to 88, 76 and 64 percent of that fed lot 5. The results show that the rate of gain was influenced more by the protein consumed by the calves than by energy. Lot 8 received 0.24 pound more digestible protein but 3.01 pounds less
### TABLE XII. EFFECTS OF PROTEIN AND ENERGY RESTRICTION ON WINTERING STEERS  
(RANGE FIELD STATION, NOVEMBER 14, 1958-MAY 22, 1959, 189 DAYS)

<table>
<thead>
<tr>
<th>Lot number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of steers</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>8a</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Ration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay, %</td>
<td>10</td>
<td>30</td>
<td>50</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Prairie hay, %</td>
<td>90</td>
<td>70</td>
<td>50</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Proximate protein, %</td>
<td>6.1</td>
<td>8.0</td>
<td>10.0</td>
<td>12.0</td>
<td>12.0</td>
<td>12.0</td>
<td>12.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Av. initial wt., lb.</td>
<td>413.4</td>
<td>413.8</td>
<td>413.4</td>
<td>427.0</td>
<td>414.8</td>
<td>415.2</td>
<td>417.8</td>
<td>418.8</td>
</tr>
<tr>
<td>Av. final wt., lb.</td>
<td>486.6</td>
<td>542.6</td>
<td>559.2</td>
<td>583.0</td>
<td>615.8</td>
<td>586.0</td>
<td>543.0</td>
<td>509.0</td>
</tr>
<tr>
<td>Av. total gain, lb.</td>
<td>73.2</td>
<td>128.8</td>
<td>145.8</td>
<td>156.0</td>
<td>201.0</td>
<td>170.8</td>
<td>125.2</td>
<td>90.2</td>
</tr>
<tr>
<td>Av. daily gain, lb.</td>
<td>0.39</td>
<td>0.68</td>
<td>0.77</td>
<td>0.83</td>
<td>1.06</td>
<td>0.90</td>
<td>0.66</td>
<td>0.48</td>
</tr>
<tr>
<td>Av. daily ration, lb.</td>
<td>1.3</td>
<td>3.8</td>
<td>6.4</td>
<td>8.9</td>
<td>10.3</td>
<td>9.1</td>
<td>7.8</td>
<td>6.6</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>11.5</td>
<td>8.9</td>
<td>6.4</td>
<td>3.8</td>
<td>4.4</td>
<td>3.9</td>
<td>3.4</td>
<td>2.8</td>
</tr>
<tr>
<td>Prairie hay</td>
<td>0.30</td>
<td>0.44</td>
<td>0.68</td>
<td>0.83</td>
<td>1.07</td>
<td>0.86</td>
<td>0.73</td>
<td>0.54</td>
</tr>
<tr>
<td>Digestible protein, lb.</td>
<td>5.32</td>
<td>5.27</td>
<td>5.08</td>
<td>5.22</td>
<td>6.01</td>
<td>4.68</td>
<td>3.59</td>
<td>2.31</td>
</tr>
<tr>
<td>TDN, lb.</td>
<td>10.27</td>
<td>10.32</td>
<td>10.09</td>
<td>10.68</td>
<td>12.14</td>
<td>9.50</td>
<td>7.31</td>
<td>4.78</td>
</tr>
<tr>
<td>Feed required per cwt. gain</td>
<td>3282</td>
<td>1882</td>
<td>1662</td>
<td>1542</td>
<td>1387</td>
<td>1464</td>
<td>1697</td>
<td>1958</td>
</tr>
<tr>
<td>Total hay, lb.</td>
<td>77</td>
<td>65</td>
<td>88</td>
<td>100</td>
<td>101</td>
<td>96</td>
<td>111</td>
<td>112</td>
</tr>
<tr>
<td>Digestible protein, lb.</td>
<td>1364</td>
<td>775</td>
<td>660</td>
<td>629</td>
<td>567</td>
<td>520</td>
<td>544</td>
<td>481</td>
</tr>
<tr>
<td>TDN, lb.</td>
<td>2632</td>
<td>1517</td>
<td>1310</td>
<td>1286</td>
<td>1145</td>
<td>1056</td>
<td>1108</td>
<td>994</td>
</tr>
<tr>
<td>DE, therms</td>
<td>33.78</td>
<td>20.14</td>
<td>18.63</td>
<td>18.17</td>
<td>16.26</td>
<td>16.84</td>
<td>19.86</td>
<td>23.20</td>
</tr>
<tr>
<td>Feed cost per cwt. gain, $</td>
<td>24.73</td>
<td>25.94</td>
<td>27.16</td>
<td>28.35</td>
<td>32.68</td>
<td>28.76</td>
<td>24.86</td>
<td>20.93</td>
</tr>
<tr>
<td>Feed cost per head, $</td>
<td>$c</td>
<td>$c</td>
<td>$c</td>
<td>$c</td>
<td>$c</td>
<td>$c</td>
<td>$c</td>
<td>$c</td>
</tr>
</tbody>
</table>

---

*a* Two steers were removed from lot 4 due to urinary calculi.

*b* Lot 1 was full fed and lots 2, 3 and 4 were fed at the same rate as lot 1. Lot 5 was full fed while lots 6, 7 and 8 were fed 88, 76 and 64 percent, respectively, of the rate of lot 5.

*c* Feed prices used: alfalfa hay, $25/ton; and prairie hay, $20/ton.
total digestible nutrients than lot 1 and gained at a slightly faster rate. Greatest total feed efficiency appeared to be obtained with a digestible protein and TDN ratio of approximately 0.16:1 when feed intake was not restricted (lots 1 through 4).

Feed cost per 100 pounds of gain increased as the protein intake was restricted. The cheaper rations, however, resulted in less feed cost per head. In contrast to the previous year, total feed costs generally were lower for the lots restricted in protein as compared to the lots restricted in feed intake. The difference can be attributed to a wider spread in cost per ton of the alfalfa and prairie hay.

As observed in the initial trial, no serious effects of protein and energy restriction were noted. Generally calves appeared to be thriftier than the previous wintered group. This appearance may be attributed to the larger winter gains.

**Summer Roughage Feeding Phase.** The summer phase of this trial consisted of dry lot feeding for 31 days on corn silage and protein supplement and then 91 days on low moisture alfalfa-brome grass and alfalfa silage (haylage). The results of the summer phase are presented in Table XIII. Average daily gains ranged from 2.14 pounds for lot 6 to 2.46 pounds for lot 4 with an average of 2.23 pounds. Only lot 4 varied an appreciable amount from the average.

Gains for all the lots on this type of feeding system were considerably higher than gains obtained on pasture the previous year. This system of feeding did not result in an inverse relationship between winter and summer gains as was observed the previous year. In this experiment,
### TABLE XIII. EFFECTS OF PROTEIN AND ENERGY RESTRICTION ON SUMMER ROUGHAGE FEEDING
(RANGE FIELD STATION, MAY 22-SEPTEMBER 21, 1959, 122 DAYS)

<table>
<thead>
<tr>
<th>Lot number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of steers</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>8a</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Winter ration</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>10</td>
<td>30</td>
<td>50</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Prairie hay</td>
<td>90</td>
<td>70</td>
<td>50</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td><strong>Av. daily winter gain, lb.</strong></td>
<td>0.39</td>
<td>0.68</td>
<td>0.77</td>
<td>0.83</td>
<td>1.06</td>
<td>0.90</td>
<td>0.66</td>
<td>0.48</td>
</tr>
<tr>
<td><strong>Av. initial wt., lb.</strong></td>
<td>486.6</td>
<td>542.6</td>
<td>559.2</td>
<td>583.0</td>
<td>615.8</td>
<td>586.0</td>
<td>543.0</td>
<td>509.0</td>
</tr>
<tr>
<td><strong>Av. final wt., lb.</strong></td>
<td>759.8</td>
<td>806.2</td>
<td>835.2</td>
<td>833.2</td>
<td>879.8</td>
<td>848.0</td>
<td>803.6</td>
<td>784.4</td>
</tr>
<tr>
<td><strong>Av. total gain, lb.</strong></td>
<td>273.2</td>
<td>263.6</td>
<td>276.0</td>
<td>300.2</td>
<td>264.0</td>
<td>262.0</td>
<td>260.6</td>
<td>275.4</td>
</tr>
<tr>
<td><strong>Av. daily gain, lb.</strong></td>
<td>2.24</td>
<td>2.16</td>
<td>2.26</td>
<td>2.46</td>
<td>2.16</td>
<td>2.15</td>
<td>2.14</td>
<td>2.26</td>
</tr>
<tr>
<td><strong>Silage, as fed</strong></td>
<td>8.1</td>
<td>8.6</td>
<td>8.8</td>
<td>8.8</td>
<td>8.8</td>
<td>8.2</td>
<td>8.4</td>
<td>8.2</td>
</tr>
<tr>
<td><strong>SBOM</strong></td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Haylage, as fed</strong></td>
<td>23.5</td>
<td>24.5</td>
<td>24.6</td>
<td>25.7</td>
<td>24.8</td>
<td>24.9</td>
<td>23.8</td>
<td>24.6</td>
</tr>
<tr>
<td><strong>Haylage, dry matter</strong></td>
<td>13.8</td>
<td>14.4</td>
<td>14.4</td>
<td>15.1</td>
<td>14.5</td>
<td>14.6</td>
<td>14.0</td>
<td>14.4</td>
</tr>
<tr>
<td><strong>Feed required per cwt. gain, lb.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silage</td>
<td>380</td>
<td>397</td>
<td>389</td>
<td>360</td>
<td>406</td>
<td>383</td>
<td>395</td>
<td>365</td>
</tr>
<tr>
<td>SBOM</td>
<td>22</td>
<td>23</td>
<td>22</td>
<td>20</td>
<td>23</td>
<td>23</td>
<td>23</td>
<td>22</td>
</tr>
<tr>
<td>Haylage, as fed</td>
<td>1049</td>
<td>1136</td>
<td>1087</td>
<td>1044</td>
<td>1144</td>
<td>1159</td>
<td>1116</td>
<td>1090</td>
</tr>
<tr>
<td>Haylage, dry matter</td>
<td>616</td>
<td>667</td>
<td>637</td>
<td>614</td>
<td>671</td>
<td>680</td>
<td>656</td>
<td>640</td>
</tr>
<tr>
<td><strong>Feed cost per cwt. gain, $</strong></td>
<td>9.22</td>
<td>10.01</td>
<td>9.61</td>
<td>9.19</td>
<td>10.10</td>
<td>10.12</td>
<td>9.87</td>
<td>9.76</td>
</tr>
<tr>
<td><strong>Feed cost per head, $</strong></td>
<td>25.19</td>
<td>26.40</td>
<td>26.52</td>
<td>27.58</td>
<td>26.67</td>
<td>26.52</td>
<td>25.72</td>
<td>26.88</td>
</tr>
</tbody>
</table>

---

a Two steers were removed from lot 4 due to urinary calculi.
b Silage and SBOM were fed for the first 31 days, followed by haylage.
c Feed prices used: silage, $8/ton; SBOM, $75/ton; haylage, $25/ton (dry matter).
winter gains up to one pound daily did not reduce subsequent gains under this summer feeding system which produced an average gain of 2.23 pounds daily.

Average daily feed consumption was generally higher for calves wintered to make the most gain. These steers were larger at the beginning of the summer phase and thus would require a larger feed intake. Steers making larger summer gains generally required less feed per 100 pounds of gain.

Over-all Winter and Summer Phases. The fattening phase of the 1958-1959 trial was not included in this thesis. Over-all results of the wintering and summer roughage feeding trials are presented in Table XIV. The average daily gains followed a pattern similar to the winter gains. Lots which produced the higher winter gains also produced higher over-all gains since the lots wintered at the higher levels generally gained as well during the summer as the lots wintered for the lower rates of gain.

Lots which produced the larger winter gains required less feed and lower feed cost per 100 pounds of over-all gain. A greater difference existed between lots which were restricted in protein rather than in energy. This confirms the results of the first wintering trial in that it was more economical to restrict gain by limiting total feed on a high protein ration than by full feeding a low protein ration. Total feed costs per head were lower for the lots making the lowest winter gain.
TABLE XIV. EFFECTS OF WINTERING ON OVER-ALL WINTER AND SUMMER PERFORMANCE
(RANGE FIELD STATION, NOVEMBER 14, 1958-SEPTEMBER 21, 1959, 311 DAYS)

<table>
<thead>
<tr>
<th>Lot number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of steers</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Winter ration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>10</td>
<td>30</td>
<td>50</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Prairie hay</td>
<td>90</td>
<td>70</td>
<td>50</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Av. daily winter gain, lb.</td>
<td>0.39</td>
<td>0.68</td>
<td>0.77</td>
<td>0.83</td>
<td>1.06</td>
<td>0.90</td>
<td>0.66</td>
<td>0.48</td>
</tr>
<tr>
<td>Av. initial wt., lb.</td>
<td>413.4</td>
<td>413.8</td>
<td>413.4</td>
<td>427.0</td>
<td>414.8</td>
<td>415.2</td>
<td>417.8</td>
<td>418.8</td>
</tr>
<tr>
<td>Av. final wt., lb.</td>
<td>759.8</td>
<td>806.2</td>
<td>835.2</td>
<td>883.2</td>
<td>879.8</td>
<td>848.0</td>
<td>803.6</td>
<td>784.4</td>
</tr>
<tr>
<td>Av. total gain, lb.</td>
<td>346.4</td>
<td>392.4</td>
<td>421.8</td>
<td>456.2</td>
<td>465.0</td>
<td>432.8</td>
<td>385.8</td>
<td>365.6</td>
</tr>
<tr>
<td>Av. daily gain, lb.</td>
<td>1.11</td>
<td>1.26</td>
<td>1.36</td>
<td>1.47</td>
<td>1.50</td>
<td>1.39</td>
<td>1.24</td>
<td>1.18</td>
</tr>
<tr>
<td>Av. daily ration, lb.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>0.8</td>
<td>2.3</td>
<td>3.9</td>
<td>5.4</td>
<td>6.3</td>
<td>5.5</td>
<td>4.8</td>
<td>4.0</td>
</tr>
<tr>
<td>Prairie hay</td>
<td>7.0</td>
<td>5.4</td>
<td>3.9</td>
<td>2.3</td>
<td>2.7</td>
<td>2.4</td>
<td>2.0</td>
<td>1.7</td>
</tr>
<tr>
<td>Silage</td>
<td>3.2</td>
<td>3.4</td>
<td>3.5</td>
<td>3.5</td>
<td>3.4</td>
<td>3.2</td>
<td>3.3</td>
<td>3.2</td>
</tr>
<tr>
<td>SBOM</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Haylage, as fed</td>
<td>9.2</td>
<td>9.6</td>
<td>9.6</td>
<td>10.1</td>
<td>9.7</td>
<td>9.8</td>
<td>9.4</td>
<td>9.7</td>
</tr>
<tr>
<td>Haylage, dry matter</td>
<td>5.4</td>
<td>5.7</td>
<td>5.7</td>
<td>5.9</td>
<td>5.7</td>
<td>5.7</td>
<td>5.5</td>
<td>5.7</td>
</tr>
<tr>
<td>Feed required per cwt. gain, lb.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>70</td>
<td>185</td>
<td>286</td>
<td>370</td>
<td>419</td>
<td>396</td>
<td>384</td>
<td>341</td>
</tr>
<tr>
<td>Prairie hay</td>
<td>627</td>
<td>431</td>
<td>286</td>
<td>159</td>
<td>180</td>
<td>170</td>
<td>164</td>
<td>146</td>
</tr>
<tr>
<td>Silage</td>
<td>284</td>
<td>266</td>
<td>255</td>
<td>237</td>
<td>231</td>
<td>232</td>
<td>267</td>
<td>275</td>
</tr>
<tr>
<td>SBOM</td>
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<td>13</td>
<td>13</td>
<td>14</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Haylage, as fed</td>
<td>827</td>
<td>763</td>
<td>711</td>
<td>687</td>
<td>699</td>
<td>701</td>
<td>754</td>
<td>821</td>
</tr>
<tr>
<td>Haylage, dry matter</td>
<td>486</td>
<td>448</td>
<td>471</td>
<td>404</td>
<td>381</td>
<td>412</td>
<td>443</td>
<td>482</td>
</tr>
<tr>
<td>Feed cost per cwt. gain, $c</td>
<td>144.11</td>
<td>133.41</td>
<td>127.30</td>
<td>122.60</td>
<td>127.69</td>
<td>127.70</td>
<td>131.12</td>
<td>130.74</td>
</tr>
<tr>
<td>Feed cost per head, $c</td>
<td>49.92</td>
<td>52.35</td>
<td>53.70</td>
<td>55.93</td>
<td>59.37</td>
<td>55.27</td>
<td>50.59</td>
<td>47.80</td>
</tr>
</tbody>
</table>

a Two steers were removed from lot 4 due to urinary calculi.
b Silage and SBOM were fed for the first 31 days, followed by haylage.
c Feed prices used: silage, $8/ton; SBOM, $78/ton; and haylage, $25/ton (dry matter).
Experiments on Protein Levels in Rations With Limited
Grain for Wintering Calves and Effects on
Subsequent Production

1957-1958 Trial

Wintering Phase. These experiments were conducted at the North Central Substation, Eureka, South Dakota, and the results of the wintering trial are presented in Table XV. The average daily gains for lots 1 through 4 were 1.29, 1.35, 1.24 and 1.49 pounds per steer respectively. With the exception of lot 3, there was an increase in gain as the amount of alfalfa hay, and thus the protein level and digestible protein intake, was increased. It is believed that this effect is primarily related to the level of protein since the rations did not differ greatly in TDN and digestible energy.

The results are not as clear as to the proper protein level for maximum gain with this type of ration due to the performance of lot 3. Since lot 4 made a somewhat better gain than lots 1 and 2, it would indicate that rations up to 10.2 percent protein which supplied 0.74 pound of digestible protein daily (lot 2) is not high enough for maximum gains on rations composed of 75 percent hay and 25 percent oats. The results for lot 3 did not appear to be a ration effect since the gain was lower than the rations with either 25 or 75 percent alfalfa hay.

With the exception of lot 3, total feed requirements per 100 pounds of gain were greater for the lots which received the lower protein rations. These lots also required more TDN and digestible energy per 100 pounds of gain. The greater requirements were correlated with smaller
TABLE XV. EFFECTS OF PROTEIN LEVELS ON WINTERING CALVES (NORTH CENTRAL
SUBSTATION, JANUARY 2-MAY 27, 1958, 145 DAYS)

<table>
<thead>
<tr>
<th>Lot number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of steers</td>
<td>8^a</td>
<td>10</td>
<td>10</td>
<td>8^a</td>
</tr>
<tr>
<td>Ration^b</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay, %</td>
<td>none</td>
<td>25</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Prairie hay, %</td>
<td>100</td>
<td>75</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>Proximate protein, %</td>
<td>8.5</td>
<td>10.2</td>
<td>12.0</td>
<td>13.7</td>
</tr>
<tr>
<td>Av. initial wt., lb.</td>
<td>401.9</td>
<td>407.8</td>
<td>408.1</td>
<td>398.6</td>
</tr>
<tr>
<td>Av. final wt., lb.</td>
<td>589.4</td>
<td>604.0</td>
<td>587.9</td>
<td>614.0</td>
</tr>
<tr>
<td>Av. total gain, lb.</td>
<td>187.5</td>
<td>196.2</td>
<td>179.8</td>
<td>215.4</td>
</tr>
<tr>
<td>Av. daily gain, lb.</td>
<td>1.29</td>
<td>1.35</td>
<td>1.24</td>
<td>1.49</td>
</tr>
<tr>
<td>Av. daily ration, lb.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>---</td>
<td>2.9</td>
<td>5.8</td>
<td>8.6</td>
</tr>
<tr>
<td>Prairie hay</td>
<td>11.5</td>
<td>8.6</td>
<td>5.8</td>
<td>2.9</td>
</tr>
<tr>
<td>Whole oats</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
<td>Digestible protein, lb.</td>
<td>0.53</td>
<td>0.74</td>
<td>0.97</td>
<td>1.13</td>
</tr>
<tr>
<td>TDN, lb.</td>
<td>6.75</td>
<td>6.92</td>
<td>6.74</td>
<td>6.82</td>
</tr>
<tr>
<td>DE, therms</td>
<td>13.43</td>
<td>13.83</td>
<td>13.72</td>
<td>13.56</td>
</tr>
<tr>
<td>Feed required per cwt. gain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total hay, lb.</td>
<td>891</td>
<td>852</td>
<td>927</td>
<td>772</td>
</tr>
<tr>
<td>Oats, lb.</td>
<td>295</td>
<td>281</td>
<td>306</td>
<td>255</td>
</tr>
<tr>
<td>Digestible protein, lb.</td>
<td>41</td>
<td>55</td>
<td>78</td>
<td>76</td>
</tr>
<tr>
<td>TDN, lb.</td>
<td>523</td>
<td>513</td>
<td>544</td>
<td>458</td>
</tr>
<tr>
<td>DE, therms</td>
<td>1041</td>
<td>1025</td>
<td>1107</td>
<td>910</td>
</tr>
<tr>
<td>Feed cost per cwt. gain, $^c</td>
<td>13.53</td>
<td>13.20</td>
<td>14.63</td>
<td>13.10</td>
</tr>
<tr>
<td>Feed cost per head, $^c</td>
<td>25.37</td>
<td>25.90</td>
<td>26.30</td>
<td>26.22</td>
</tr>
</tbody>
</table>

Period between Winter and Fattening Trials - 9 days

| Av. final wt., lb. | 551.9 | 574.6 | 576.4 | 598.9 |
| Av. loss per steer, lb. | 37.5 | 29.4 | 11.5 | 15.1 |
| Av. daily ration, lb. | | | | |
| Prairie hay | 8.7 | 6.9 | 5.1 | 3.3 |
| Alfalfa hay | 1.4 | 3.3 | 5.1 | 6.9 |
| Whole oats | 3.8 | 3.8 | 3.8 | 3.8 |

^a Two steers were removed from lot 1, one for a bad eye and one for urinary calculi. Two steers were removed from lot 4, one for lumpy jaw involving the bone and one for a condition diagnosed as an abscessed brain.

^b The rations consisted of 75% hay and 25% whole oats.

^c Feed prices used: alfalfa hay, $20/ton; prairie hay, $18/ton; and oats, $0.60/bu.
weight gains. Lot 4 made the largest wintering gain and required considerably more digestible protein than the other lots but was more efficient in utilization of total feed and energy.

Data from the 9-day shrink and recovery study showed an average loss of weight per head which ranged from 11.5 pounds for lot 3 to 37.5 pounds for lot 1 (Table XV). Lots 2 and 4 showed intermediate average weight losses per head of 29.4 and 29.5 pounds respectively. The low shrink for lot 3 seemed to indicate that this lot did not have a fill comparable to the other lots at the final weighing of the wintering trial. This could partially account for the low wintering gain.

Fattening Phase. The results presented in Table XVI show that calves which received the lower protein rations during the 1957-1958 wintering trial made larger fattening gains. Lots 1 and 2 made average daily gains of 2.58 and 2.54 pounds per head. Lots 3 and 4 which were wintered on higher protein rations made lower daily fattening gains of 2.24 and 2.21 pounds respectively. The larger daily gains of lots 1 and 2 enable these lots to reach the desired final weight of 1,100 pounds 2 weeks before lots 3 and 4.

Feed required per 100 pounds of gain was lowest for the highest gaining lot (lot 1) which required 192 pounds of alfalfa and 627 pounds of concentrates. The second highest gaining lot (lot 2) was the second most efficient lot, while lots 3 and 4 followed with similar feed efficiencies.

Feed costs per 100 pounds of gain for the four lots followed a pattern similar to the average daily gains. The lots which made the
TABLE XVI. EFFECTS OF PROTEIN LEVELS ON SUBSEQUENT FATTENING PERFORMANCE (NORTH CENTRAL SUBSTATION, 1957-1958 TRIAL)

<table>
<thead>
<tr>
<th>Lot number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of steers</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Number days fed</td>
<td>220</td>
<td>220</td>
<td>234</td>
<td>234</td>
</tr>
<tr>
<td>Av. initial wt., lb.</td>
<td>551.9</td>
<td>574.6</td>
<td>576.4</td>
<td>598.9</td>
</tr>
<tr>
<td>Av. final wt., lb.</td>
<td>1120.5</td>
<td>1112.8</td>
<td>1100.0</td>
<td>1115.5</td>
</tr>
<tr>
<td>Av. gain, lb.</td>
<td>568.6</td>
<td>538.2</td>
<td>523.6</td>
<td>516.6</td>
</tr>
<tr>
<td>Av. daily gain, lb.</td>
<td>2.58</td>
<td>2.45</td>
<td>2.24</td>
<td>2.21</td>
</tr>
<tr>
<td>Av. daily ration, lb.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Concentrate mixture</td>
<td>16.2</td>
<td>16.2</td>
<td>15.5</td>
<td>15.8</td>
</tr>
<tr>
<td>Feed per cwt. gain, lb.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>192</td>
<td>204</td>
<td>222</td>
<td>227</td>
</tr>
<tr>
<td>Concentrate mixture</td>
<td>627</td>
<td>664</td>
<td>692</td>
<td>708</td>
</tr>
<tr>
<td>Feed cost per cwt. gain, $b</td>
<td>16.34</td>
<td>17.31</td>
<td>18.14</td>
<td>18.55</td>
</tr>
<tr>
<td>Feed cost per head, $</td>
<td>92.91</td>
<td>93.16</td>
<td>94.98</td>
<td>95.83</td>
</tr>
</tbody>
</table>

a Rolled shelled corn, 95% and SBOM, %. After November 25, rolled shelled corn, 87%; SBOM, 10%; bone meal, 1.5%; trace-mineralized salt, 1.5%; and 2000 U.S.P. units vitamin A per pound.

b Feed prices used: alfalfa hay, $0.20/ton; shelled corn, $1.12/bu.; and SBOM, $0.78/ton.
largest daily gains had the least feed costs per 100 pounds of gain.

**Over-all Winter and Fattening Phases.** The results of the combined winter and fattening phases are presented in Table XVII. Differences in over-all average daily gains were small but slightly larger for lots 1 and 2 which received the lower levels of protein during wintering. Average daily gain ranged from 1.92 pounds for lot 1 to 1.78 pounds for lot 3.

Lot 1, fed the lowest protein wintering ration composed of only prairie hay and oats, required the least feed per 100 pounds gain. Lots 2, 4 and 3 followed in order with progressively larger feed requirements. The lots which made the larger over-all average daily gains required less feed per hundred pounds of gain.

Over-all feed costs per 100 pounds of gain for the four lots were in the same order as feed requirements per 100 pounds of gain. Lot 1 required the least feed cost per 100 pounds of gain and was followed by lots 2, 4 and 3 respectively. Over-all feed costs per head followed the same pattern as the winter feed costs per head. The lots which were wintered at a lower feed cost were also fattened at a lower feed cost.

The results of this trial indicate that calves wintered at lower protein levels with gains of 1.25 pounds daily did as well or better in over-all performance as calves wintered at a higher protein level with gains up to 1.49 pounds daily. Lots 1 and 2 made slightly larger over-all gains with lower feed requirements and reached market 2 weeks earlier than lots 3 and 4. The inverse relationship between winter and summer gains also applied to this type of feeding program where steer calves were wintered for over 1 pound daily gain followed by full feeding
### TABLE XVII. EFFECTS OF PROTEIN LEVELS ON OVER-ALL WINTERING AND FATTENING PERFORMANCE (NORTH CENTRAL SUBSTATION, 1957-1958 TRIAL)

<table>
<thead>
<tr>
<th>Lot number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of steers</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Days on feed</td>
<td>374</td>
<td>374</td>
<td>388</td>
<td>388</td>
</tr>
<tr>
<td>Av. initial wt., lb.</td>
<td>401.9</td>
<td>407.8</td>
<td>408.1</td>
<td>398.6</td>
</tr>
<tr>
<td>Av. final wt., lb.</td>
<td>1120.5</td>
<td>1112.8</td>
<td>1100.0</td>
<td>1115.5</td>
</tr>
<tr>
<td>Av. gain, lb.</td>
<td>718.6</td>
<td>705.0</td>
<td>691.9</td>
<td>716.9</td>
</tr>
<tr>
<td>Av. daily gain, lb.</td>
<td>1.29</td>
<td>1.35</td>
<td>1.24</td>
<td>1.49</td>
</tr>
<tr>
<td>Winter phase</td>
<td>1.92</td>
<td>1.89</td>
<td>1.78</td>
<td>1.85</td>
</tr>
<tr>
<td>Winter and fattening phase</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total feed per head, lb.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>1106</td>
<td>1542</td>
<td>2042</td>
<td>2487</td>
</tr>
<tr>
<td>Prairie hay</td>
<td>1738</td>
<td>1316</td>
<td>882</td>
<td>447</td>
</tr>
<tr>
<td>Oats</td>
<td>689</td>
<td>593</td>
<td>591</td>
<td>593</td>
</tr>
<tr>
<td>Concentrate mixture$^a$</td>
<td>3568</td>
<td>3572</td>
<td>3622</td>
<td>3659</td>
</tr>
<tr>
<td>Feed per cwt. gain, lb.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>154</td>
<td>219</td>
<td>295</td>
<td>347</td>
</tr>
<tr>
<td>Prairie hay</td>
<td>242</td>
<td>187</td>
<td>127</td>
<td>62</td>
</tr>
<tr>
<td>Oats</td>
<td>82</td>
<td>84</td>
<td>85</td>
<td>83</td>
</tr>
<tr>
<td>Concentrate mix$^a$</td>
<td>497</td>
<td>507</td>
<td>523</td>
<td>510</td>
</tr>
<tr>
<td>Feed cost per cwt. gain, $^b$</td>
<td>16.67</td>
<td>17.10</td>
<td>17.74</td>
<td>17.32</td>
</tr>
<tr>
<td>Total feed cost per head</td>
<td>119.80</td>
<td>120.54</td>
<td>122.75</td>
<td>124.17</td>
</tr>
<tr>
<td>Initial cost per head, $^c$</td>
<td>104.49</td>
<td>106.03</td>
<td>106.11</td>
<td>103.64</td>
</tr>
<tr>
<td>Total cost, $</td>
<td>224.29</td>
<td>226.57</td>
<td>228.86</td>
<td>227.81</td>
</tr>
<tr>
<td>Av. selling price per head, $^d$</td>
<td>282.06</td>
<td>284.93</td>
<td>284.64</td>
<td>290.44</td>
</tr>
<tr>
<td>Return per head over initial cost and feed, $</td>
<td>57.77</td>
<td>58.36</td>
<td>55.78</td>
<td>62.63</td>
</tr>
</tbody>
</table>

$^a$ Rolled shelled corn, 95%; and SBOM, 5%. After November 25, rolled shelled corn, 87%; SBOM, 10%; bone meal, 1.5%; trace-mineralized salt, 1.5%; and 2000 U.S.P. units vitamin A per pound.

$^b$ Feed prices used: alfalfa hay, $20/ton; prairie hay, $18/ton; oats, $0.60/bu.; shelled corn, $1.12/bu.; and SBOM, $78/ton.

$^c$ Initial cost used: $26/cwt.

$^d$ Selling price used: $44.96/cwt. for U. S. Choice and $42.08/cwt. for U. S. Good, based on carcass selling price.
on high-concentrate rations.

Carcass Quality. The results of market and carcass weights, shrink and carcass quality for this trial are presented in Table XVIII. Total shrink for the four lots ranged from 3.38 percent for lot 4 to 4.51 percent for lot 1. The lots which made the larger fattening gains had greater total shrink. However, differences in shrink may have been affected by the different times of marketing. The differences in dressing percent, carcass grade, rib-eye muscle area, depth of fat over rib-eye muscle and degree of marbling were small. However, the differences which existed were in favor of the high gaining winter lot in most cases. The effects of feeding systems on carcass quality in beef cattle needs further study with greater variability in feeding systems than used in these experiments.

1958-1959 Trial

Wintering Phase. A second wintering trial was conducted at the North Central Substation and the results are presented in Table XIX. The average daily gains for lots 1 through 4 were 1.16, 1.27, 1.48 and 1.40 pounds per head. Gains increased as the total protein content of the rations was increased from 7.4 to 10.3 percent. The gains made by the calves in lot 4, fed a ration with 11.7 percent total protein, was slightly lower than that obtained with the ration containing 10.3 percent protein (lot 3).

The increased protein content resulted in an increased digestible protein intake which increased from 0.46 to 1.04 pounds per head daily. The protein intake per pound of TDN increased from 0.07 pound for lot 1
<table>
<thead>
<tr>
<th>Lot number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of steers</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Av. filled wt., lb.</td>
<td>1120.5</td>
<td>1112.3</td>
<td>1100.0</td>
<td>1115.5</td>
</tr>
<tr>
<td>Av. shrunk wt., 16 hrs., lb.</td>
<td>1089.2</td>
<td>1079.0</td>
<td>1075.0</td>
<td>1089.5</td>
</tr>
<tr>
<td>Av. market wt., lb.</td>
<td>1070.0</td>
<td>1063.5</td>
<td>1057.0</td>
<td>1075.6</td>
</tr>
<tr>
<td>Av. shrink, 16 hrs., lb.</td>
<td>31.3</td>
<td>33.8</td>
<td>26.0</td>
<td>26.0</td>
</tr>
<tr>
<td>Av. market shrink, lb.</td>
<td>19.2</td>
<td>15.5</td>
<td>18.0</td>
<td>13.9</td>
</tr>
<tr>
<td>Av. total shrink, lb.</td>
<td>50.5</td>
<td>49.3</td>
<td>43.0</td>
<td>39.9</td>
</tr>
</tbody>
</table>

| Shrink, 16 hrs., % | 2.79 | 3.04 | 2.27 | 2.33 |
| Market shrink, % | 1.72 | 1.39 | 1.64 | 1.25 |
| Total shrink, % | 4.51 | 4.43 | 3.91 | 3.58 |

| Av. carcass wt., lb. | 647.4 | 641.2 | 639.7 | 646.0 |
| Av. dressing percent | 60.50 | 60.29 | 60.52 | 60.06 |
| Av. live grade scorea | 7.9 | 7.7 | 7.7 | 8.0 |
| Av. carcass grade scorea | 6.8 | 7.4 | 7.3 | 7.5 |
| Av. rib-eye muscle area, sq. in. | 10.34 | 11.67 | 10.83 | 11.08 |
| Av. depth of fat over rib-eye muscle, cm. | 1.75 | 1.80 | 1.89 | 1.64 |
| Av. marbling scoreb | 5.4 | 5.8 | 6.1 | 6.1 |

---

a Live and carcass grade scores used: Choice f, 9; Choice, 8; Choice -, 7; Good f, 6; Good, 5; and Good -, 4.
b Marbling score used: moderate, 7; modest, 6; small amount, 5; slight amount, 4; and traces, 3.
### TABLE XIX. EFFECTS OF PROTEIN LEVELS ON WINTERING CALVES (NORTH CENTRAL SUBSTATION, DECEMBER 11, 1958-MAY 14, 1959, 155 DAYS)

<table>
<thead>
<tr>
<th>Lot number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of steers</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Rationa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa, %</td>
<td>None</td>
<td>25</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Prairie, %</td>
<td>100</td>
<td>75</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>Proximate protein, %</td>
<td>7.4</td>
<td>8.9</td>
<td>10.3</td>
<td>11.7</td>
</tr>
<tr>
<td>Av. initial wt., lb.</td>
<td>404.2</td>
<td>404.5</td>
<td>404.5</td>
<td>404.3</td>
</tr>
<tr>
<td>Av. final wt., lb.</td>
<td>583.5</td>
<td>600.7</td>
<td>634.6</td>
<td>621.0</td>
</tr>
<tr>
<td>Av. total gain, lb.</td>
<td>179.3</td>
<td>196.2</td>
<td>230.1</td>
<td>216.7</td>
</tr>
<tr>
<td>Av. daily gain, lb.</td>
<td>1.16</td>
<td>1.27</td>
<td>1.48</td>
<td>1.40</td>
</tr>
<tr>
<td>Av. daily ration, lb.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>---</td>
<td>2.9</td>
<td>5.8</td>
<td>8.7</td>
</tr>
<tr>
<td>Prairie hay</td>
<td>11.7</td>
<td>8.7</td>
<td>5.8</td>
<td>2.9</td>
</tr>
<tr>
<td>Whole oats</td>
<td>3.9</td>
<td>3.9</td>
<td>3.9</td>
<td>3.9</td>
</tr>
<tr>
<td>Digestible protein, lb.</td>
<td>0.46</td>
<td>0.65</td>
<td>0.89</td>
<td>1.04</td>
</tr>
<tr>
<td>TDN, lb.</td>
<td>6.20</td>
<td>6.03</td>
<td>6.56</td>
<td>6.43</td>
</tr>
<tr>
<td>DE, therms</td>
<td>11.86</td>
<td>11.50</td>
<td>12.88</td>
<td>12.76</td>
</tr>
<tr>
<td>Feed required per cwt. gain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total hay, lb.</td>
<td>1000</td>
<td>913</td>
<td>784</td>
<td>829</td>
</tr>
<tr>
<td>Oats, lb.</td>
<td>336</td>
<td>307</td>
<td>264</td>
<td>279</td>
</tr>
<tr>
<td>Digestible protein, lb.</td>
<td>40</td>
<td>51</td>
<td>60</td>
<td>74</td>
</tr>
<tr>
<td>TDN, lb.</td>
<td>534</td>
<td>475</td>
<td>443</td>
<td>459</td>
</tr>
<tr>
<td>DE, therms</td>
<td>1022</td>
<td>906</td>
<td>870</td>
<td>911</td>
</tr>
<tr>
<td>Feed cost per cwt. gain, $b</td>
<td>16.98</td>
<td>16.10</td>
<td>14.21</td>
<td>15.61</td>
</tr>
<tr>
<td>Feed cost per head, $b</td>
<td>30.45</td>
<td>31.59</td>
<td>32.70</td>
<td>33.83</td>
</tr>
</tbody>
</table>

a The ration consisted of 75% hay and 25% whole oats.

b Feed prices used: alfalfa hay, $25/ton; prairie hay, $20/ton; and oats, $0.64/bu.
up to 0.16 pound for lot 4. The most efficient gains were obtained with lot 3 where the intake of digestible protein to TDN was 0.14:1. These results agree closely with the results of the first wintering trial and of the wintering trials conducted at the Range Field Station with all hay rations fed at different levels of protein. These trials indicate that the most efficient wintering was obtained with a digestible protein to TDN ratio of 0.14-0.16:1.

As in the previous year, feed required per 100 pounds of gain was the largest for the lot making the smallest winter gains. Total hay and oats required per 100 pounds of gain were higher than in the 1957-1958 wintering trial. However, with the exception of lot 3, digestible protein and TDN requirements per 100 pounds of gain for all lots were very similar to the corresponding lots of the previous year.

Feed cost per 100 pounds of gain was larger for the lot making the smallest winter gains. Lots receiving rations composed largely of prairie hay had lower feed cost for wintering than lots receiving rations containing higher levels of alfalfa hay. Differences in wintering feed cost were due to a higher cost of alfalfa hay. These observations agree with the results of the previous year. However, feed costs were lower in the initial wintering trial because of the lower prices charged for the feeds. As pointed out previously, less emphasis should be placed on feed cost than may be indicated in the discussion.
Digestibility of Rations Containing Different Levels of Protein and Energy

1957-1958 Digestion Trial

The objectives of the digestion trials conducted with different wintering rations were to determine the digestibility of the complete wintering rations and of the individual feeds making up the ration. This allowed comparisons of digestible nutrients calculated from digestion coefficients obtained when feeding the complete rations and when feeding the individual constituents of the rations. Digestible energy was determined for comparisons of the caloric value of TN. Chemical composition of the feeds used in the rations, daily consumption of different nutrients and coefficients of digestibility of the nutrients are shown in Tables XX, XXI and XXII.

The major differences in chemical composition of the prairie hay and alfalfa hay were higher protein content and lower nitrogen-free extract in the alfalfa hay. Both the alfalfa and prairie hay fed at the North Central Substation were of better quality than that fed at the Range Field Station as indicated by the protein and crude fiber contents.

When feed intake was held constant and the amount of protein varied due to different ratios of alfalfa and prairie hay (lots 1 through 4), the only consistent changes in digestibility of the rations were increases in apparent digestibility of protein and decreases in digestibility of crude fiber with each increase in level of protein. Restricting feed (lots 5 through 8) resulted in a consistent lowering of apparent digestibility of all nutrients except ether extract, which was
<table>
<thead>
<tr>
<th></th>
<th>Dry Matter %</th>
<th>Crude Protein %</th>
<th>Ether Extract %</th>
<th>Crude Fiber %</th>
<th>NFE %</th>
<th>Organic Matter %</th>
<th>Energy kcal per gm.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Range Field Station</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>95.30</td>
<td>13.83</td>
<td>1.52</td>
<td>37.76</td>
<td>38.00</td>
<td>91.10</td>
<td>4.353</td>
</tr>
<tr>
<td>Prairie hay</td>
<td>95.53</td>
<td>7.66</td>
<td>1.72</td>
<td>37.76</td>
<td>43.98</td>
<td>91.11</td>
<td>4.341</td>
</tr>
<tr>
<td><strong>North Central Substation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>94.84</td>
<td>17.13</td>
<td>1.27</td>
<td>34.43</td>
<td>37.05</td>
<td>89.88</td>
<td>4.280</td>
</tr>
<tr>
<td>Prairie hay</td>
<td>95.14</td>
<td>8.90</td>
<td>2.39</td>
<td>34.57</td>
<td>43.78</td>
<td>89.64</td>
<td>4.324</td>
</tr>
<tr>
<td>Oats</td>
<td>95.00</td>
<td>13.90</td>
<td>5.57</td>
<td>11.69</td>
<td>64.78</td>
<td>95.94</td>
<td>4.506</td>
</tr>
</tbody>
</table>

All values are on a moisture-free basis with the exception of dry matter which are the values at time of analysis.
TABLE XXI. DAILY NUTRIENT CONSUMPTION OF 1957-1958 WINTERING RATIONS AND OF HAY FED ALONEa

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Restricted Protein Rations Fed at Range Field Station</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>9.37</td>
<td>.78</td>
<td>.16</td>
<td>3.63</td>
<td>3.93</td>
<td>8.51</td>
<td>18.15</td>
</tr>
<tr>
<td>2</td>
<td>9.47</td>
<td>.92</td>
<td>.17</td>
<td>3.63</td>
<td>3.88</td>
<td>8.59</td>
<td>18.36</td>
</tr>
<tr>
<td>3</td>
<td>9.47</td>
<td>1.05</td>
<td>.17</td>
<td>3.58</td>
<td>3.79</td>
<td>8.59</td>
<td>18.37</td>
</tr>
<tr>
<td>4</td>
<td>9.56</td>
<td>1.19</td>
<td>.17</td>
<td>3.60</td>
<td>3.72</td>
<td>8.67</td>
<td>18.58</td>
</tr>
<tr>
<td><strong>Restricted Energy Rations Fed at Range Field Station</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>9.22</td>
<td>1.15</td>
<td>.16</td>
<td>3.44</td>
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a Consumption of rations and hay are based on an average of four and six steers, respectively, on a moisture-free basis.
b Rations used are presented in Tables III and IV.
### TABLE XXII. APPARENT DIGESTION COEFFICIENT OF 1957-1958
WINTERING RATIONS AND OF HAY FED ALONE

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<th>Ration Number</th>
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<th>Crude Protein %</th>
<th>Ether Extract %</th>
<th>Crude Fiber %</th>
<th>NFE %</th>
<th>Organic Matter %</th>
<th>Energy %</th>
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</table>

* Rations used are presented in Tables III and IV.
somewhat variable. The depression in digestibility was greatest with
the lowest feed intake (lot 8--64 percent of lot 5). This effect pro-
ably was more apparent than real because of the low consumption of the
various nutrients.

Digestibility of rations with limited grain (25 percent oats), fed
at the North Central Substation, differed mainly from the all-bay rations
fed at the Range Field Station in higher digestibility of ether extract
and nitrogen-free extract. Digestibility of protein increased as the
protein level of the ration was increased. The digestion coefficients
were similar as obtained with the all-bay rations.

1958-1959 Digestion Trials

The chemical composition of the feeds, daily consumption of
nutrients and coefficients of digestibility of nutrients for the second
digestion trial are presented in Tables XXIII, XXIV and XXV. The alfalfa
hay used at both stations was higher in protein and lower in ether
extract and nitrogen-free extract than the prairie hay; the crude fiber
content was somewhat similar. The protein content of the feeds was
lower than for the previous year with the exception of the alfalfa hay
used at the Range Field Station which was considerably higher for that
used in the first experiment.

When the rations were fed at a uniform rate of intake, lots 1
through 4 at the Range Field Station and the four lots at the North
Central Substation, the digestion coefficients of protein increased as
the protein content of the rations increased. Generally digestion
coefficients for dry matter and nitrogen-free extract increased slightly
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a All values are on a moisture-free basis with the exception of dry matter which are the values at time of analysis.
### TABLE XXIV. DAILY NUTRIENT CONSUMPTION OF 1958-1959 WINTERING RATIONS AND OF HAY FED ALONEa

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a Consumption of rations and hay are based on an average of four and six steers, respectively, on moisture-free basis.

b Rations used are presented in Tables III and IV.
### TABLE XXV. APPARENT DIGESTION COEFFICIENTS OF 1958-1959 WINTERING RATIONS AND OF HAY WHEN FED ALONE

<table>
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<th>Ration Number</th>
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<th>Crude Protein %</th>
<th>Ether Extract %</th>
<th>Crude Fiber %</th>
<th>NFE %</th>
<th>Organic Matter %</th>
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</table>

* Rations used are presented in Tables III and IV.*
while they decreased for crude fiber. When feed intake was limited, lots 5 through 8, the digestion coefficients of all nutrients decreased with the greatest decrease occurring in lot 8 which received the least amount of feed.

Although feed consumption was higher for all rations in the second digestion trial, the digestion coefficients obtained generally were lower than for the previous trial. This may be partly due to a period effect. Each digestion trial with six collection periods required 18 weeks for completion. Since the first trial was started in the winter of 1958, the collection periods for the second digestion trial extended into the summer of 1959.

Experimentally Determined and Calculated Digestible Nutrients and Caloric Value of TDN

Digestible protein and TDN determined from digestion coefficients obtained with each ration as fed and calculated from digestion coefficients obtained with each hay fed alone are presented in Tables XXVI and XXVII for the 1957-1958 and 1958-1959 trials. Caloric value of TDN was calculated and also presented in these tables. Digestion trials were not conducted with oats fed alone and digestible nutrients were not calculated in the above manner for the rations with limited grain.

In the initial wintering trial, the percent of digestible protein determined from feeding of the complete rations to lots 1 through 4 at the Range Field Station were higher than when calculated from values obtained by feeding each hay alone. This condition was reversed except with the ration containing the lowest amount of alfalfa hay (lot 1) in
<table>
<thead>
<tr>
<th>Ration Number</th>
<th>Protein Determined with Ration(^a) %</th>
<th>Calculated(^b) %</th>
<th>Protein Determined with Ration %</th>
<th>Calculated %</th>
<th>Energy Kcal/lb. ration</th>
<th>Digestible Energy Kcal/lb. TDN</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
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\(^{a}\) Determined from digestion coefficients obtained on each ration as fed.

\(^{b}\) Calculated from digestion coefficients determined with each hay fed alone and applied in the ratio each hay was in the ration.
TABLE XXVII. DETERMINED AND CALCULATED DIGESTIBLE NUTRIENTS FOR 1958-1959 WINTERING RATIONS

<table>
<thead>
<tr>
<th>Ration Number</th>
<th>Protein Determined with Ration</th>
<th>Calculated</th>
<th>Protein Determined with Ration</th>
<th>Calculated</th>
<th>Energy Kcal/lb.</th>
<th>Digestible Energy Kcal/lb.</th>
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<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>ration</td>
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<td>Restricted Energy Rations Fed at Range Field Station</td>
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<td>Limited Grain Rations Fed at North Central Substation</td>
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a Determined from digestion coefficients obtained on each ration as fed.
b Calculated from digestion coefficients determined with each hay fed alone and applied in the ratio each hay was fed in the ration.
the 1958-1959 trial.

In lots 5 through 8, considerable differences existed between values obtained from the two methods of determining digestible protein in the rations. The values for digestible protein decreased as feed intake decreased when determined from apparent digestion coefficients obtained from the rations as fed. Values calculated from individual coefficients remained constant because of the constant ratio of alfalfa and prairie hay in these rations.

TDN calculated from values obtained when each hay was fed alone was lower in each comparison than TDN values obtained from the rations as fed to lots 1 through 4 in both years.

TDN obtained from rations fed to lots 5 through 8 decreased as the feed intake decreased. When calculated as described for digestible protein above, it remained constant because of the constant ratio of alfalfa to prairie hay.

The differences in digestible protein and TDN obtained from the two methods may be explained by the magnitude of differences in digestion coefficients obtained when feeding each hay alone and those obtained from the rations as fed. This illustrates the shortcomings of calculating digestible nutrients from digestion coefficients of nutrients in feeds determined when fed at one level but included in rations at other levels.

In the initial wintering trial, the percent of TDN for the first four lots varied from 47.30 to 50.27 percent with the highest value being obtained with the low alfalfa hay ration. Gross energy per pound of feed
was about the same for alfalfa hay and prairie hay resulting in similar gross energy values for rations containing different proportions of the two kinds of hay. Digestible energy per pound of feed for the various wintering rations was in the same order as the TDN values. This gave similar values for digestible energy per pound of TDN for all rations with an average of 2023 kilocalories.

The limited-grain rations fed at the North Central Substation were similar in TDN content and only slightly higher than the all-hay rations fed at the Range Field Station. With one slight exception, digestible energy per pound of ration followed in the same order as the TDN values. Digestible energy per pound of TDN averaged 2003 kilocalories with less than 2 percent variation from this average value.

When feed was restricted in the 1957-1958 wintering trial (lots 5 through 8), the TDN and digestible energy contents of the rations declined with the amount of feed restriction. The amount of digestible energy per pound of TDN was lower than with the full-fed rations, with or without grain, and averaged 1965 kilocalories for the four rations. More variation in the relationship of digestible energy to TDN was experienced here than with the other rations in the 1957-1958 trials. It appears that rations fed in limited amounts, as was done here, are not satisfactory for determining TDN or digestible energy of the rations.

Digestibility of the rations fed in the second digestion trial using feeds from the 1958-1959 feeding trials was lower than in the previous trial even though consumption of total feed and the various nutrients was higher. Values for TDN and digestible energy were also lower.
in most instances for similar type rations. The values for digestible energy per pound of TDN for lots where feed intake was not restricted were generally lower than in the first digestion trial.

The results, particularly from the second digestion trial, indicate that the relationship between TDN and digestible energy may be somewhat variable. These variations do not necessarily indicate inaccuracy of the digestible energy determinations but show the values obtained may be influenced by the digestion coefficients obtained in the TDN method. These digestion coefficients are subject to some inaccuracies as discussed in the review of literature and they influence the size of the TDN values obtained.

In discussing the variability of the relationship of digestible energy to TDN, Crampton et al. (1957) reported that the caloric value of TDN is not constant but depends upon ether extract content of the ration. Work by Barth et al. (1959) showed that the caloric value of TDN increased as the apparent digestible protein content increased.

Even though some variation was encountered in these experiments, an average value of 1992 kilocalories of digestible energy per pound of TDN was obtained from all rations. This value is similar to that of 2000 kilocalories per pound of TDN reported by Swift (1957) and other workers. It would appear that existing TDN values could be used in calculating digestible energy content of rations as accurately as in calculating TDN, which may also be subject to some inaccuracies as discussed previously. The value of 2000 kilocalories per pound of TDN appears to be a satisfactory one for this purpose. More work is needed on this problem.
CHAPTER V

SUMMARY AND CONCLUSIONS

In this investigation, four wintering trials involving 240 steer calves were conducted over a 2-year period to determine the effects of different levels of protein and energy on wintering and on subsequent phases of production. In the initial wintering trials, 80 steer calves were wintered on restricted protein and energy levels, placed on a summer grazing program and then fattened in the feed lot. In the following year, 80 steer calves were wintered in a similar manner but were then placed on a high roughage summer feeding program.

During each of the two winters, an additional 40 steer calves were wintered on various levels of protein on a limited grain ration. Steers from the first trial were placed on a fattening ration after the wintering phase.

The digestibility of rations used in each of the wintering studies was determined by two digestion trials with six collection periods each. Digestible energy of the wintering rations was also determined by the use of the adiabatic oxygen bomb calorimeter. In this study, practical considerations were given to effects of protein and energy levels on wintering and subsequent production, gain and feed requirements for each phase of production, total gain and total feed requirements, time required to reach market weight and carcass quality.

At the Range Field Station, Cottonwood, South Dakota, the first of two wintering trials was conducted in 1957-1958. Eighty steer calves
were divided equally into eight lots and were wintered on alfalfa and prairie hay rations. Four lots received different ratios of alfalfa and prairie hay to establish different protein levels while four lots received different levels of feed intake to establish different levels of energy. The ratios of alfalfa and prairie hay fed to obtain the different levels of protein were 10/90, 30/70, 50/50 and 70/30 with an approximate protein content of 7.6, 8.7, 9.7 and 10.8 percent, respectively, when adjusted to a 10 percent moisture basis. The other four lots received rations which contained 70 percent alfalfa and 30 percent prairie hay with approximately 10.8 percent total protein. The rate of feeding for the lots fed different levels of protein was based on the feed consumption of the lot fed the least amount of protein (7.6 percent). The lots restricted in feed were fed at the rate of a full feed and 86, 74 and 64 percent of a full feed. Average daily gain for calves fed rations with different levels of protein increased from 0.38 to 0.68 pound per head as the average daily digestible protein intake increased from 0.37 to 0.78 pound per head. Total digestible nutrients and digestible energy remained fairly constant. Animals which were restricted in feed intake made average daily gains which decreased from 0.83 to 0.28 pound per steer. The apparent digestibility of nutrients decreased as feed was restricted. Steers receiving the higher levels of digestible protein generally made the most efficient gains but had a higher cost for wintering.

At the completion of the wintering trial, the steers were placed on pasture to determine the effects of wintering on subsequent production.
Pasture gains ranged from 1.05 to 1.53 pounds per steer daily. Steers which were restricted either in protein or energy and which made lower winter gains produced larger summer gains than steers which were wintered at the higher rates of gain. Overall winter and summer gains for calves wintered at the lowest level of wintering gain were comparable to or exceeded the highest gaining winter lots.

At the completion of the summer grazing trial the steers were placed on a ration of 25 pounds of corn silage and a full feed of rolled shelled corn and soybean oil meal. The average daily gains per steer for all lots ranged from 2.74 to 3.27 pounds. Steers wintered at lower gains made larger feed-lot gains than steers wintered at the highest rate of gain which was similar to the pasture performance. The calves making the larger gains generally required less feed per hundred pounds of gain. Overall gains for the restricted-fed wintering steers were comparable to, or larger than, the liberally-fed wintering steers. Overall total feed requirements generally were lower for the calves making larger overall gains. Differences in shrink, live and carcass grade, rib-eye muscle area, fat over rib-eye and marbling score were small and varied among lots. The highest gaining winter lot (lot 5) did have the largest average rib-eye muscle and less fat covering.

A second wintering trial was conducted in 1958-1959. Eighty Hereford steer calves of lighter weight and better quality than the previous year were used in this study. Similar rations were used with protein contents which ranged from 7.5 to 11.7 percent. Average daily gains per steer of the 1958-1959 wintering trial increased from 0.39 pound to
0.83 pound as the digestible protein intake of the steers increased from 0.30 to 0.83 pound per steer daily. The average daily gain per steer for the restricted energy lots decreased from 1.06 to 0.48 pounds. As in the initial wintering trials, calves which received the higher protein and higher energy rations required less feed per 100 pounds of winter gain but a higher cost for wintering.

At the conclusion of the second wintering trial (1958-1959), the steers were placed on a high roughage summer feeding program in dry lot. For a period of one month, the steers received 2 pounds of soybean oil meal and a full feed of corn silage. After this period, the steers were fed an alfalfa-brome grass and alfalfa haylage ration (low-moisture silage) for 91 days. Average daily gains ranged from 2.14 to 2.46 pounds and were considerably higher than gains obtained on pasture the previous year. Winter gains of 1 pound did not result in reduced summer gains under this system of feeding. Consequently higher winter gains may be obtained when followed with a more liberal feeding program. Lots which produced the larger winter gains required less feed and had lower feed cost per 100 pounds of over-all gain.

The first of two wintering trials concerned with protein levels on limited grain rations was conducted in 1957-1958. Forty steer calves were divided equally into four lots and received an alfalfa and prairie hay ration with whole oats fed at the rate of 25 percent of the entire ration. The ratios of alfalfa and prairie hay fed were 0/100, 25/75, 50/50 and 75/25 with an approximate protein content which ranged from 8.5 to 12.8 percent on a 10 percent moisture basis. The average daily winter-
ing gains per steer for the lots ranged from 1.24 to 1.49 pounds. With the exception of one lot, the winter gains increased as the protein content of the ration increased resulting in a digestible protein intake which increased from 0.37 pound to 0.78 pound. Differences in TDN and digestible energy content of the rations were small.

Upon completion of the wintering trials, steers were placed on a fattening ration consisting of 5 pounds of alfalfa hay and a full feed of corn and soybean oil meal. The steers were marketed when each lot averaged about 1100 pounds per head.

With the exception of one lot, feed-lot gains were in the reverse order of the winter gains. Fattening gains ranged from 2.21 to 2.58 pounds daily. The two lots which were fed the lower levels of protein the previous winter made greater feed-lot gains and reached the desired market weight of 1100 pounds per steer 2 weeks earlier than the lots which were fed more liberal levels of protein the previous winter. Feed requirements and feed costs per 100 pounds of gain were lower for the higher gaining fattening lots. The over-all average daily gains for both the winter and summer feeding trials ranged from 1.78 to 1.92 pounds per steer. Feed requirements and costs per 100 pounds of gain generally were lower for the higher over-all gaining lots. Carcass results were variable and differences were small. Generally, the highest gaining winter lot had a slightly higher carcass grade, slightly larger rib-eye muscle area, less fat over the rib-eye muscle and slightly more marbling than the other three lots.

A second wintering trial was conducted in 1958-1959 with 40 Hereford steer calves. Generally the calves were more uniform and of better
quality. The steers received similar rations composed of oats, alfalfa
and prairie hay. The protein content of the rations ranged from 7.4 to
11.7 percent. The average daily gains for the lots ranged from 1.16 to
1.48 pounds per head. As in the previous year, gains increased as the
protein content of the rations was increased to 10.3 percent total pro-
tein. Increasing the protein level of the ration to 11.7 percent result-
ed in no further increase in rate of gain. TDN and digestible energy
were similar in all lots. Feed required per 100 pounds of gain was
larger for lots making the smaller winter gains.

The average daily gains for all wintering trials are presented in
Figure 1. As shown by the graph, average daily gains increased as the
average daily digestible protein intake increased. When energy intake
was increased, gains also increased as indicated by the larger gains pro-
duced by the cattle at the North Central Substation fed rations with
25 percent oats. In many cases, the protein intake of these steers was
similar to the steers fed at the Range Field Station, but the additional
increase in energy resulted in higher gains.

There were considerable variations in the digestible protein and
TDN determined from digestion coefficients obtained with each ration as
fed and calculated from digestion coefficients obtained with each hay fed
alone. The differences may be explained by the magnitude of differences
in digestion coefficients obtained when feeding each hay alone and those
obtained from the rations as fed. This illustrates the shortcomings of
calculating digestible nutrients from digestion coefficients of nutrients
in feeds determined at one level but included in rations at other levels.
Figure 1. Relationship of Gain to Protein Intake.
In comparisons of the caloric value of TDN, it was found to be quite variable but averaged 1992 kilocalories per pound of TDN for all rations. The variations encountered do not necessarily indicate inaccuracy of the digestible energy determinations but show that the values obtained may be influenced by the digestion coefficients obtained in the TDN method.

The average value obtained in these experiments (1992 kcal./lb. TDN) is about the same as the average value of 2000 kcal./lb. TDN suggested by other workers to use in converting TDN to digestible calories. The variability encountered shows some inaccuracy would be encountered in using a single value to convert existing TDN values to digestible calories. However, this is also true in calculating TDN from existing digestion coefficients as discussed in this thesis.
LITERATURE CITED


