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Growth, Reproduction and Blood Characteristics of Hereford Females

Harold R. King

GROWTH, REPRODUCTION AND BLOOD CHARACTERISTICS
OF HEREFORD FEMALES

BY

HAROLD R. KING

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Abstract

HAROLD R. KING

Under the supervision of Professor Lawrence B. Embry

Two hundred forty weanling Hereford heifer calves were used in an experiment utilizing a 2 x 3 factorial design with four replicates per treatment to determine the effects of levels of wintering nutrition and pasture treatments on growth, development and reproductive efficiency of beef females from weaning to 4 1/2 years of age. Two levels of wintering nutrition were used. The higher level (HW) was designed to result in winter gains of about 1.5 lb per head daily during the first drylot period, .5 lb per head daily up to calving time the second winter and to provide for maintenance of fall body weights up to calving time the third and subsequent winters. The lower level (LW) was designed to result in gains of about .75 lb per head daily during the first winter, maintenance of fall weights up to calving time the second winter and a loss of about 10% of the fall body weight up to calving time the third and subsequent winters. The three pasture treatments used with each level of wintering nutrition were as follows: (P1) native grass only for the full pasture season (mixed prairie swards consisting of approximately 50% Kentucky bluegrass, <u>Poa pratensis</u>, 30% western wheatgrass, <u>Agropyron smithii</u>, 10% blue grama, <u>Bouteloua gracilis</u>, 5% green needlegrass, <u>Stipa viridula</u>, and 5% other species); (P2) a short season pasture consisting of a mixture of smooth bromegrass,

Bromus inermis, intermediate wheatgrass, Agropyron intermedium, and Teton alfalfa, Medicago sativa, and (P3) a series of different pastures designed to provide a long grazing period. The pastures in order of grazing were (a) crested wheatgrass, Agropyron desertorum; (b) a mixture of smooth bromegrass, intermediate wheatgrass and Teton alfalfa; (c) sudangrass, Sorghum vulgare sudanense, or switchgrass, Panicum virgatum; (d) regrazing of the bromegrass-intermediate wheatgrass-alfalfa pasture and (e) Russian wildrye, Elymus junceus. The cattle were maintained in drylot on harvested feeds when not on pasture. The different levels of wintering nutrition were obtained by adjustment of the quantities and qualities of feeds fed. The hays utilized included native prairie, alfalfa, brome, crested wheatgrass and various combinations. Corn, Zea mays, and sorghum, Sorghum vulgare, silages were fed and small amounts of oat grain, Avena sativa, were used during the first wintering period. Mineral supplements were offered free choice at all times. Cows were bred by artificial insemination which, in 1968 only, was followed by clean-up bulls. Criteria of performance of the cattle included growth and reproductive performance of the cows and growth of the calves. Blood data, including hematocrit and concentration of hemoglobin in whole blood, and concentrations of calcium, inorganic phosphorus, carotene and vitamin A in blood plasma were obtained periodically from jugular blood of the cows as indicators of the adequacy of the various nutritional treatments during the first 3 years of the study.

Average filled body weights taken at the initiation of the experiment, at the end of the first winter, in November after the first pasture season, and immediately prior to calving and again in November for each succeeding year for HW and LW cows were (lb) 355, 355; 566, 513; 744, 717; 886, 788; 1012, 984; 1116, 989; 1146, 1064; 1197, 1024 and 1124, 1066, respectively. Corresponding weights for P1, P2 and P3 cows were (lb) 356, 356, 352; 547, 539, 532; 732, 726, 734; 826, 847, 838; 973, 960, 1061; 1039, 1020, 1100; 1100, 1132, 1083; 1110, 1118, 1104 and 1060, 1098, 1126, respectively. The numbers of conceptions obtained for HW and LW cows in 1966, 1967 and 1968 were 45, 27; 50, 62 and 105, 87, respectively, and the corresponding number of calves surviving to 72 hours of age were 41, 26; 48, 61 and 101, 86, respectively. Corresponding data for P1, P2 and P3 cows were (conceptions) 23, 23, 26; 37, 31, 44 and 63, 68, 61, respectively, and calves surviving were 22, 23, 22; 37, 28, 44 and 63, 63, 61, respectively. The numbers of calves weaned by HW and LW cows in the above years were 41, 26; 47, 60 and 101, 81, respectively, and by P1, P2 and P3 cows, 22, 23, 22; 37, 26, 44 and 60, 62, 60, respectively. Average observed weaning weights (with preweaning average daily gains in parentheses) for HW and LW calves in 1967, 1968, 1969 and overall were (lb) 345.0 (1.61), 308.1 (1.46); 396.6 (1.58), 358.9 (1.43); 355.1 (1.50), 328.7 (1.42) and 363.2 (1.54), 336.4 (1.43), respectively. Corresponding data for P1, P2 and P3 cows were (lb) 327.5 (1.53), 302.2 (1.40), 363.6 (1.74); 364.3 (1.43), 404.8 (1.62), 367.5 (1.48); 336.8 (1.40), 333.5 (1.45), 360.2 (1.55) and 343.6 (1.43), 343.7 (1.48), 363.3 (1.55), respectively.

All heifers were lighter in weight than desirable at the beginning of the trial. Early development of heifers was especially retarded by LW treatment. Overall, the result of LW treatment was slower growth and development of heifers, lower conception rates (56.0 vs 49.6% of cows exposed), fewer total calves weaned (190 vs 173) which grew slower (1.54 vs 1.43 lb/head/day) and weaned at a lighter weight (363.2 vs 336.4 lb). The long-season series of pastures (P3) resulted in improved performance over the other pasture systems when compared on the basis of these parameters.

Levels of all blood constituents were significantly influenced by level of wintering nutrition, year and season except that wintering nutrition did not significantly affect levels of inorganic phosphorus. However, average blood constituent values for all groups at each sampling date were in excess of values normally considered indicative of adequate nutrient intake for growth, reproduction and lactation.

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Doctor of Philosophy, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser Date

Head, Animal Science Department Date

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HRK

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LIST OF ABBREVIATIONS

AI	artificial insemination
Ca	calcium
DE	digestible energy
g	gram
Hb	hemoglobin
HW	high level of wintering nutrition
H1, H2, H3	high level of wintering nutrition, pasture treatments 1, 2 and 3
IU	international units
kcal	kilocalorie
kg	kilogram
lb	pound
LW	low level of wintering nutrition
L1, L2, L3	low level of wintering nutrition, pasture treatments 1, 2 and 3
Mcal	megacalorie
ME	metabolizable energy
NE	net energy
PCV	packed cell volume
P	phosphorus
P1, P2, P3	pasture treatments 1, 2 and 3
TDN	total digestible nutrients
USP	United States Pharmacopeia
μg	microgram

INTRODUCTION

The production of feeder cattle and finishing of cattle for the slaughter market provide major sources of income to the farmers and ranchers of South Dakota. Consequently, considerable attention has been given to feeding and management during growing and finishing of these cattle. Until recently, relatively little emphasis was placed on the study of feeding and management of cow herds and their calves up to time of weaning. However, a constantly increasing demand for beef plus decreasing availability of quality grazing land coupled with a requirement for overall increased efficiency of production made it imperative that studies of this nature be undertaken. The two major areas in which it appeared that the most progress could be made were related to the nutrition of the cow during wintering and to the quantity and quality of forage during the grazing season.

Feed cost is a major portion of the total winter expense and a reduction in feed cost could add appreciably to the net income of the livestock producer. Studies at other stations have shown that pregnant, nonlactating cows can be wintered satisfactorily on rations which will not maintain their weight. Reproduction of the cows and performance of the calves do not appear to be affected unless the level of winter feeding is overly restricted. However, much of this work has been done under climatic conditions which are not nearly as severe as those found in South Dakota, and few of the data are directly applicable to conditions found in the Northern Great Plains area. Thus, one of the objectives of a long-term experiment from which the data reported herein were derived was to determine what influence level of wintering nutrition would have upon the growth and reproductive performance of beef females under conditions in this area.

Pasture costs account for another major portion of the total annual cost of a cow herd. Much of the land in South Dakota is suited for grazing, but a large amount of that in use does not produce at a high level. Studies at this and other stations have shown that proper pasture management can greatly improve the production from a given area of land. Tame pastures have also shown considerable promise as an alternative to native pastures. The second objective of the major study was to obtain data concerning the relative value of various pasture systems in a cow-calf operation under South Dakota conditions.

As a means of attaining these objectives, a long-term study was established in which different pasture systems in combination with different levels of wintering nutrition of beef cattle constituted the major experimental treatments. These treatments were selected because they represent a range of possible alternative management practices under practical conditions. The cattle used in this experiment were purchased at weaning from a single source to reduce variation in age and breeding. The wintering feeds were harvested from the ranch and consisted of various hays, grain, corn silage and sorghum silage. These feeds were fed to provide different levels of energy intake during the winter feeding phases. Feed following the wintering phase consisted of grazing furnished by the different pasture systems.

The primary objective of the research reported in this thesis was to determine the nutritional adequacy of the two levels of wintering nutrition when followed by the various pasture systems for growth, development and reproductive performance of the heifers from weaning to about 4 1/2 years of age. Criteria used in evaluating the adequacy of these treatments included growth, blood characteristics and reproductive performance of the heifers.

REVIEW OF LITERATURE

The nutritional requirements of the ruminant are complex. However, under usual conditions, a diet for ruminant consumption has only to supply adequate amounts of energy, protein and nonprotein nitrogen, minerals and carotene or vitamin A. The activities of the microbes in the rumen provide sufficient B-complex vitamins and vitamin K to satisfy requirements under normal conditions. Ample vitamin D is obtained from normal periods of exposure to sunlight, and mineral supplements with proper levels of calcium and phosphorus and trace-mineralized salt appear to satisfy mineral requirements under most conditions.

The first portion of the following review of literature will be limited to a discussion of protein, energy, calcium, phosphorus, carotene and vitamin A in relation to the nutritional requirements of the female bovine. Consideration will be given to methods of establishing requirements, to factors which influence requirements and to the requirements for various productive functions. Further discussion will be concerned with the degree of adequacy of the diet in relation to its influence upon growth and other performance characteristics.

Although this review is severely limited with respect to the number of nutritional factors considered, it is fully recognized that many other elements and compounds are required in the diet of the ruminant. Those under consideration appear to be the most important under usual conditions in this area.

Many of the data found in the literature have been reported in terms of the English system of weights and measures and many in the metric system. When deemed essential to the context of the discussion, values cited in this review will be reported in terms of the metric system, proper conversions being made where necessary.

Protein

Methods Used To Determine Protein Requirements

There are several methods by which the protein requirements of ruminants for various functions can be established. Generally speaking, the methods make use of one or more measures of the various physical and physiological changes which may occur as a result of insufficient protein intake.

Rate of growth and the presence or absence of deficiency symptoms have often been used to establish the protein requirements of cattle. One of the first symptoms of protein deficiency is an apparent loss of appetite (Meacham *et al.*, 1963; Bedrak *et al.*, 1964). Feeding trials to establish the protein requirements of ruminants are often designed to make use of this fact. Designs of such experiments incorporate graded levels of protein into otherwise similar diets. Although differences in rate of gain achieved under such conditions are many times the result of a restriction of both protein and energy due to a reduction in feed intake, it is generally considered that a lack of protein is the factor which initially precipitates the decrease in feed intake. Even though a given level of protein intake is maintained, feed intake may decrease (if protein intake is insufficient) to the point at which the animal uses protein as a source of energy. Consequently, utilization of available nitrogen in the ration is further impaired. In such feeding trials, levels of protein intake which provide for optimum rates of gain and the avoidance of deficiency symptoms over a longer period of time are considered adequate under the conditions imposed.

Growth rate and the avoidance of gross deficiency symptoms are often combined with other measures to more fully evaluate adequacy of various levels of protein intake. For replacement heifers, for example, levels of protein intake which may provide for desired rates of gain may not be entirely adequate to provide for maximum conception rates or optimum reproductive performance. It has been shown that inadequate protein intakes by growing heifers may delay puberty (Wiltbank et al., 1957; Clanton et al., 1964), increase the length of the time interval from parturition to first heat (Cruz et al., 1961) and cause irregular and short estrous periods or the cessation of estrus (Palmer et al., 1941; Bedrak et al., 1964). Inadequate protein intakes may also result in lighter calves at birth and weaning (Howes et al., 1960; Bond and Wiltbank, 1970) and calves which may be weaker and have a lower survival rate than calves born to cows fed a more liberal protein intake (Speth et al., 1962). Consequently, one or more of these criteria are often used in conjunction with weight gain data to evaluate the adequacy of various levels of protein intake for breeding females. Levels of protein intake which provide for optimum reproductive performance and normal growth over a long period of time should be considered adequate under the conditions imposed. Results of feeding trials are probably the best estimates of protein requirements of ruminants under practical conditions. Feeding trials, however, require large investments in animals, equipment and labor. The results of feeding trials are probably most meaningful when large numbers of animals are involved.

Various laboratory methods have been developed to study protein requirements of ruminants. One of these methods is the nitrogen balance trial. This method is used occasionally to study the availability of nitrogen from different feed sources as well as to determine protein requirements. The values obtained are close estimates of the actual requirements of an animal under a given set of dietary and environmental conditions. However, different feed and different conditions may appreciably increase or decrease the total amount of protein required. Recommended levels of protein intake for practical conditions are usually set higher than the minimum level determined in a balance trial (Maynard and Loosli, 1962). The use of balance trial data in defining nitrogen requirements of ruminants and in the evaluation of feedstuffs is illustrated by the work of Colburn and Evans (1969) and of Colburn *et al.* (1968). Nitrogen balance trials involve great amounts of labor and laboratory time. Generally, the numbers of animals involved are limited and the results are not strictly applicable to practical conditions.

Protein requirements are occasionally estimated from minimum endogenous nitrogen excretion data. However, determination of the minimum endogenous nitrogen excretion results in a value which reflects only net protein catabolism and does not take into account metabolic nitrogen or other nitrogen losses such as shed hair and epidermal tissues. However, these other losses are generally too small to be of practical concern. Total protein requirements can be estimated from endogenous nitrogen values by mathematical expressions proposed by Brody et al. (1934) and by Smuts (1935). However, the amount of protein calculated by these formulas reflects only that which is needed to replace endogenous losses and thus may be appreciably lower than the actual protein requirement. Smuts (1935) proposed that the calculated value be doubled to obtain a more practical estimate of minimum digestible protein requirements. Like the nitrogen balance method, this method is severely limited in terms of establishing protein requirements under practical conditions.

The amino acid composition of tissues of the species in question can also be used to approximate protein requirements (Williams et al., 1954). After determination of the amino acid composition of both the animal and feedstuffs is made, diets are formulated with the purpose of matching the amino acid composition of the diet protein to that of the animal body. Differences in availability and in losses in digestion and metabolism may reduce the efficiency of the formulated mixture. Because of the degradation of proteins which occurs in the rumen, this method of estimating protein requirements is best suited to studies concerning nonruminant animals.

The maintenance energy requirement of an animal can be used to estimate its protein requirement because both energy and nitrogen metabolism appear to be related to the same power of body weight (Brody et al., 1934). The relationship existing between body weight, energy requirements and protein requirements has been investigated to a considerable extent. Several excellent discussions of the subject are available (Brody et al., 1934; Smuts, 1935; Crampton, 1964; Preston, 1966; Crampton and Harris, 1969). Although such a relationship exists, energy requirements cannot be precisely defined from body weight alone and environmental conditions can cause large variation in the energy requirement. Young animals are generally fed so as to gain weight and there is much fluctuation in body condition of the adult. The protein requirements established by this method would not indicate total requirements for maintenance and growth nor would it indicate the sufficiency of protein intake for reproductive processes.

A deficiency of protein intake results in the catabolism of body proteins and in certain changes associated with various body constituents, primarily the proteins present in the blood. Some of the changes which have been attributed to a deficiency of protein intake include decreased blood glucose levels in sheep (Wright et al., 1962) and lowered plasma albumin concentrations in pigs (Friend et al., 1961), cattle (Bedrak et al., 1964; Carroll et al., 1964) and sheep (Anderson et al., 1962). Decreased concentrations of total plasma proteins in sheep (Wright et al., 1962) and cattle (Bedrak et al., 1964; Carroll et al., 1964; Meacham et al., 1964) have also been observed. Total blood hemoglobin

(Bedrak et al., 1964; Meacham et al., 1964; Tilton et al., 1964) and hematocrit (Anderson et al., 1962; Bedrak et al., 1964; Meacham et al., 1964) are also lowered. In nonruminant animals, concentrations of the various essential amino acids in the blood plasma have been used to determine the adequacy of given levels of protein intake as well as to indicate the quality of dietary protein (Chance et al., 1962; Clark et al., 1962). Levels of specific essential amino acids in the blood plasma of nonruminants appear to be closely associated with dietary intakes of these amino acids (Clark et al., 1962; Windels et al., 1964). According to Mitchell et al. (1964), the level of a specific amino acid in the blood plasma appears to be a more sensitive criterion than nitrogen balance of the adequacy of intake of a given essential amino acid in swine. In ruminants, however, rumen microorganisms are capable of synthesizing essential amino acids in the process of forming microbial protein. The protein formed is of rather consistent amino acid composition (Weller, 1957). Consequently, it would perhaps be expected that the distribution of specific amino acids would remain approximately the same in the blood plasma of ruminants under a variety of dietary conditions. However, not all dietary protein is degraded and incorporated into microbial protein. Studies have indicated that the extent of conversion of dietary protein to microbial protein may vary considerably with the source of protein (McDonald, 1954; McDonald and Hall, 1957). In later studies, differences in nitrogen sources (Theurer et al., 1968) and in amino acid concentrations in abomasal fluids (Poley and Trenkle, 1963) have been associated with differences in blood plasma amino acid patterns. Several investigations have shown that the substitution of urea for a portion of the natural protein in the diet results in a decrease in the concentration of one or more of the essential amino acids in the blood plasma of ruminants (Freitag et al., 1966; Little et al., 1966; Oltjen and Putnam, 1966; Virtanen, 1966; Oltjen et al., 1971). Urea, although contributing to the protein content of the diet, does not furnish other dietary essentials associated with natural proteins. It is likely that the levels of a given essential amino acid in the blood plasma of a ruminant, and perhaps the associated performance of the animal, may depend in some instances upon the amount of dietary nitrogen which is converted to microbial protein and in other instances upon the amount of protein which escapes microbial conversion but which is later digested and absorbed.

It appears that, until more data become available concerning optimum levels of plasma amino acids and factors concerning the utilization of different sources of dietary nitrogen, the level of blood plasma amino acids in functional ruminants offers little as a measure of the adequacy of protein intake when different sources of nitrogen are involved. Plasma amino acid concentrations appear to be subject to the influence of too many variables to make them a reliable criterion under these conditions. However, it appears that, if the source of protein remains the same in all experimental treatments, plasma amino acid concentrations may provide valuable information concerning the adequacy of protein intake.

Protein fractions of the blood plasma, including alpha-, beta- and gamma-globulins, albumin and total proteins, have been examined as criteria for studying the adequacy of dietary protein intake. Of these criteria, plasma albumin appears to be the most sensitive indicator of the sufficiency of protein intake in both nonruminants (Cahilly et al., 1963; Brooks et al., 1964) and ruminants (Wright et al., 1962; Bedrak et al., 1964).

Hematocrit and hemoglobin concentrations of the whole blood also appear to be good indicators of the adequacy of protein intake in nonruminants (Eaton et al., 1964a) and ruminants (Anderson et al., 1962; Bedrak et al., 1964; Sorenson, 1965). The rapidity with which hemoglobin and hematocrit respond to differences in protein intake does not appear to be as great as that of plasma albumin. This may be due in part to the half-life of the erythrocytes and in part, from a statistical standpoint, to the relatively greater range of these factors as compared to ranges observed in albumin concentrations under normal conditions. Significant changes in albumin concentration generally occur within 2 to 4 weeks after protein intake has been restricted, whereas 6 to 8 weeks may be required to obtain significant differences in hematocrit values or hemoglobin concentrations. The difference in response between the measures appears to be primarily one of time. Consequently, plasma albumin concentration may provide a better measure than hematocrit or hemoglobin concentrations of the adequacy of protein intake in studies concerning limited numbers of animals or where it is desirable to use short experimental periods. Under other conditions, hematocrit and hemoglobin appear to be fully as useful as albumin concentration as a measure of the adequacy of protein intake.

In summary, it appears that there are several reliable means of determining the protein requirements of ruminants under a variety of different conditions. The choice of methods for determining the adequacy of a given level of protein intake should be governed to a great degree by the overall objectives of the study, recognized limitations in terms of animals, equipment, materials and time and by the desired accuracy and practicality of the results obtained.

Factors Which Influence Protein Requirements

Several authors have considered in detail the numerous factors which have been reported to have an influence upon the protein requirement of the ruminant (Morrison, 1959; Maynard and Loosli, 1962; Crampton and Harris, 1969). Generally, the single factor which can have the greatest influence upon the apparent protein requirement is the amount of available energy in the diet as compared to energy requirements. If the available energy supplied is less than required, protein will be utilized to provide energy and nitrogen will be excreted rather than retained. Consequently, statements concerning the protein requirements of any class of livestock are made with the assumption that the energy requirements of the animal have been satisfied.

The amount of protein required by an adult animal is proportional to its body weight (Smuts, 1935; Maynard and Loosli, 1962; Colburn and Evans, 1969; Crampton and Harris, 1969). Maintenance requirements for protein of young cattle and of mature cattle on a caloric maintenance diet have been reported to be related to the .7 power of body weight (Winchester *et al.*, 1957b; Preston, 1966). However, requirements of immature bovines weighing less than 100 kg may be considerably higher (Preston, 1966).

In young animals, rate of growth has perhaps the largest influence upon protein requirements of any of several factors other than energy intake. Much of the tissue added to the body during the early stages of growth is composed of protein, and restrictions on the amount or availability of protein in the diet may reduce the rate of growth of the young animal. Several studies have been conducted on the effects of protein restriction on young growing animals (Winchester *et al.*, 1957a,b; Carroll *et al.*, 1963). Depending upon the extent of the restriction, growing ruminants may continue to add mineral matter to their body during protein restriction but may fail to increase the amount of muscle tissue. The developmental pattern of the body is thus somewhat altered. During subsequent periods of more adequate protein intakes, large amounts of nitrogen will be retained and muscle tissue rapidly developed.

The relationship between rate of growth and protein requirement of the ruminant has been demonstrated by the work of Winchester *et al.* (1957a) and by others. Rapid rates of growth may increase the digestible protein requirements of young animals to two or three times or more the amount required for maintenance by an animal of similar weight and condition.

Reproduction and lactation can also exert a considerable influence on protein requirements. Although protein requirements for reproduction and lactation have apparently not been precisely defined for the bovine, the amount of protein required for successful reproduction does not appear to be greatly in excess of the amount required to provide fully for maintenance. However, much of the dry matter of the products of conception is added during the last trimester of pregnancy, and it is during this period that an increase in protein intake above maintenance may prove beneficial (Morrison, 1959). Maddox (1965) recommends the addition of .045 kg of digestible protein to the maintenance requirement for gestating cows during the ninth month of pregnancy. Crampton and Harris (1969) state that the protein in the increased amount of feed required to take care of additional energy demands during the last month of pregnancy is normally sufficient to provide the additional protein required.

Some concept of the amount of protein required for fetal growth can be determined from the literature. Protein constitutes approximately 19% of the body weight of a calf at birth (Morrison, 1959), or about 6 kg of protein in a 32 kg calf. Additional amounts are present in other products of conception. About one-half of the total is deposited during the last 5 to 6 weeks of gestation (Jakobsen, 1961). It is apparent that the cow should be provided with at least 3.18 kg of additional available protein during the last 30 to 40 days of pregnancy. This would amount to about 82 to 104 g of available protein daily or, if a biological value of about 60% is assumed for dietary protein as suggested by Maynard and Loosli (1962), roughly .14 to .17 kg of crude protein per day. These amounts are equal to about 40% of the total minimum daily protein levels (.41 kg) recommended by the National Research Council (N.R.C., 1970) for maintenance for a 450-kg cow. From a practical standpoint, however, it is difficult to precisely define or compare the protein requirements of mature ruminants under different conditions. For example, the protein requirements for maintenance of dry nonpregnant cows (Klosterman et al., 1968) have been reported as being as high or higher than that of mature gestating cows (Clanton and Zimmerman, 1970). The discrepancies noted here and in other sources may arise from differences in dietary and environmental conditions and from animal variation. It also appears that the importance and usefulness of the protein stores of the animal body in relation to its ability to perform various functions under a variety of conditions have not been fully recognized or investigated.

Lactation can have a much greater effect on protein requirement than does reproduction. The extent of the effect is directly proportional to the amount of milk produced. The amount of dietary protein required to furnish the protein secreted in milk appears to be somewhere between one and six times the total found in milk. According to Crampton and Harris (1969), many dairymen consider the addition to the maintenance requirement of 125% of the amount of protein in the milk to be sufficient. It is interesting to note, however, that present N.R.C. (1971) standards for dairy cows recommend an allowance of about 228% of the amount of protein in the milk. Much of the variation in recommendations concerning protein requirements for lactation may be due to variation in the availability of protein from different feed sources.

Numerous dietary factors have been reported to have an influence upon the apparent protein requirement of the ruminant. Although the digestibility of protein from most sources of the common concentrate feeds is fairly constant (Crampton and Harris, 1969), feeds containing large proportions of indigestible fractions may increase metabolic nitrogen losses, thereby increasing the maintenance requirement (Winchester et al., 1957a; Maynard and Loosli, 1962). Level of feed intake may influence digestion and retention of dietary protein (Asplund and Harris, 1971). The digestible energy content of the diet has also been related to protein digestibility (Stone and Fontenot, 1965) and retention (Stone and Fontenot, 1965; Grier et al., 1970). Level of fat in the diet also appears to influence the utilization of protein (Grier et al., 1970). Other dietary factors, such as the presence or absence of required mineral elements, can have a significant influence upon the utilization of protein (Kleiber et al., 1936; Crampton, 1957). However, feed additives such as diethylstilbestrol or chlortetracycline have little or no effect upon protein requirements except as they influence rate of weight gain and body size. It is apparent that variation in feed quality can have a considerable influence upon the required protein content of the diet and upon the utilization of dietary protein.

Protein Requirements for Maintenance and Growth

Studies have established that the protein requirement of adult animals for maintenance purposes is related to basal energy expenditure or to approximately the .7 power of body weight. Endogenous nitrogen excretion is approximately 2.0 to 2.5 mg per kilocalorie of basal heat produced (Brody et al., 1934), and attempts have been made to estimate protein requirements of adult animals for maintenance on the basis of this relationship (Smuts, 1935; Preston, 1966). Winchester et al. (1957b) suggest that this relationship also holds for young cattle of body weights over 45 kg on caloric maintenance diets, but Preston (1966) states that protein requirements for dairy calves lighter than 100 kg are higher than values calculated by this method.

Protein requirements calculated on the basis of body weight do not take into account the possible influence of body condition. The result is that calculations made on this basis tend to provide more than adequate allowances for fat animals but insufficient amounts for thinner ones. Preston (1966) recognized this factor and stated that the ideal expression would relate protein requirements to specific increases in carcass mass of certain compositions. Others have recognized this relationship as it applies to energy requirements for maintenance in the bovine (Klosterman et al., 1967, 1968).

Considerable discussion exists concerning the minimum protein requirements of the bovine for maintenance. Total crude protein intakes of .04 kg/100 kg of body weight were sufficient to maintain body weight in 226-kg yearling heifers during a 200-day feeding trial reported by

Bedrak et al. (1964). Increasing the protein intake to .09 kg/100 kg of body weight resulted in daily weight gains of about .33 kg with only small increases in total digestible nutrient (TDN) intake. In a second experiment conducted with 2-year-old heifers weighing 300 kg, intakes of .1 kg of crude protein per 100 kg of body weight appeared to be adequate for maintenance and demonstration of estrus, whereas levels of .07 kg were insufficient.

In terms of digestible protein, intakes estimated at about 51 g/100 kg of body weight were sufficient to allow 180-kg heifers to maintain their body weight during a 108-day trial on rations supplying sufficient energy (Carroll et al., 1964). However, changes in carcass composition appeared to have occurred. Although it was questionable as to whether the formation of body protein was prevented when both hide and carcass characteristics were considered, plasma proteins were significantly lower than in control animals. Winchester et al. (1957b) observed that intakes of about 60 g of digestible protein per 100 kg of body weight appeared to be sufficient for maintenance in cows and suggested that, on the basis of growth and carcass data, these requirements could be varied with the .7 power of body weight for younger animals. Calculated requirements for animals weighing 45, 181, 272 and 362 kg would range from 120 to 64 g/100 kg of body weight, respectively. These levels were considered to supply more than sufficient protein for animals in these weight ranges when fed caloric maintenance rations. Metabolism trials had previously indicated that nitrogen intakes of 18 g per day in 181-kg calves (62 g of protein per 100 kg of body weight) appeared to be adequate for maintenance.

Somewhat higher levels of protein appeared to be required by calves used in an experiment conducted by Colburn and Evans (1969). Using nitrogen equilibrium as the criterion, it was determined that an intake of 5.77 g protein per $W_{kg}^{.75}$ was required. Digestible protein requirements of the cattle were 118, 99 and 90 g per 100 kg of live weight for animals weighing 100, 200 or 300 kg, respectively.

In studies with mature cattle, Klosterman et al. (1967) have shown that a protein intake of about 80 g/100 kg of body weight is sufficient for the maintenance of mature, nonlactating cows. These levels would represent intakes of about 55 to 60 g of digestible protein per 100 kg of body weight. Clanton and Zimmerman (1970) reported that the digestible protein requirements of mature gestating cows appeared to be about 46 g/100 kg of body weight daily.

Protein requirements established by the N.R.C. (1970) for young animals making no body weight gains decrease from 70 g of digestible protein per 100 kg of body weight for animals weighing 150 kg to 60 g/100 kg of body weight for 400-kg animals. Requirements for maintenance of 450-kg mature gestating cows are listed as 42 g/100 kg of body weight. These values appear to be minimal for maintenance.

The total effect of growth on protein requirements is influenced by the weight and condition of an animal and the rate with which its body weight increases. Generally speaking, the more rapid the growth rate the greater will be the protein requirement. Growth rates of about .37 kg per head daily were achieved with heifers fed about 160 g of digestible protein per 100 kg of body weight (Wiltbank et al., 1957). The cattle used in this experiment were from about 7 to 30 months of age. The levels reported are in close agreement with those reported by Clanton and Zimmerman (1970) who recommended 150 g of digestible protein per 100 kg of body weight daily for growing heifers. These intakes were sufficient to support daily gains of from .16 to .20 kg per head in replacement heifers.

Goodrich et al. (1961) obtained optimum rates of gain (1.16 kg per head daily) and feed efficiency (875 kg/100 kg weight gain) during a 200-day feeding trial with diets furnishing an average of about 282 g of protein per 100 kg of body weight. The steers used in this trial were fed from average weights of 268 kg to weights of about 500 kilograms. Optimum performance in this experiment was obtained with a calculated average daily digestible protein intake of about 200 g/100 kg of body weight. Digestible protein requirements for these cattle calculated according to the formula developed by Preston (1966) would have been 227 g/100 kg of body weight daily.

The N.R.C. (1970) lists the daily protein requirements of 150-kg animals gaining .25 or .75 kg per head daily as 147 and 190 g of digestible protein per 100 kg of body weight, respectively. Animals weighing 400 kg and making the same rates of gain have digestible protein requirements of about 87 and 128 g/100 kg of body weight daily, respectively. Increasing the rate of gain of an older 400-kg animal to 1.4 kg increases the recommended minimum digestible protein allowance to 200 g/100 kg of body weight daily.

It appears from research conducted that minimum maintenance requirements for protein may be approximately 40 to 45 g of digestible protein per 100 kg of body weight daily for mature cattle and that these quantities can be varied with the .7 power of body weight to estimate the protein requirements of younger cattle held on a caloric maintenance ration. Weanling calves can apparently be maintained on similar levels, but body condition and consideration of other factors may necessitate increasing minimum daily digestible protein allowances to 60 or 70 g/100 kg of body weight. Better utilization of dietary energy may be permitted with the higher protein allowance.

Young cattle allowed to make a moderate rate of gain (.25 to .35 kg per head daily) appear to have protein requirements of 125 to 150 g/100 kg of body weight daily. This requirement may be varied to some degree depending upon their age, condition and weight and desired rate of gain. Rapid rates of gain, such as are sought under finishing conditions, may increase digestible protein requirements to values approaching or surpassing 200 g/100 kg of body weight daily.

Protein Requirements for Reproduction and Lactation

As has been noted previously, the products of conception consist primarily of protein, although the total amount of protein involved is not great. In cows which are in good condition, much of the required protein could be derived from the body of the dam without harm. However, the previous nutritional state of the dam may be such that an increased demand for protein may be deleterious to her health or to her subsequent productive capacities. It is therefore important to determine the effects of nutritional treatments over a span of several years, preferably over the lifetime of the cow and preferably with respect to several criteria. Although this has been done in studies concerning the energy intake of the cow, there appears to have been no such long-term work reported with respect to protein requirements.

In an investigation conducted by Bedrak et al. (1964), total protein intakes of about .04 kg/100 kg of body weight daily appeared to be adequate to maintain body weight of weanling heifer calves over a period of 200 days. However, puberty was retarded and conception rates were reduced. Intakes of .09 kg/100 kg of body weight promoted weight gains with essentially the same TDN intake as obtained with the lower level of protein and resulted in higher conception rates. There appeared to be no advantage in feeding more than .09 kg of protein per 100 kg of body weight on the basis of reproductive performance, although weight gains were further improved with a higher level of protein intake. In a second trial, total protein intakes of .07 kg/100 kg of body weight resulted in body weight losses and reduced conception rates in 2-year-old heifers placed on experiment 112 days prior to breeding. Protein intakes of about .10 kg/100 kg of body weight promoted maximum conception rates.

The level of protein intake prior to calving may have only little influence on postpartum reproductive functions providing that adequate amounts are supplied subsequently. Zimmerman et al. (1961) and Clanton and Zimmerman (1970) demonstrated that protein intakes approximating maintenance requirements (.04 to .05 kg digestible protein per 100 kg of body weight) prior to calving in first-calf heifers which were fed liberally after calving appeared to have little effect upon the length of the interval from calving to first estrus or upon the total conception rate. Energy intake appeared to be the primary factor of influence. Similar observations were made by Bond and Wiltbank (1970) with heifers fed constant levels of protein intake throughout two breeding seasons. In the latter study, however, the lowest level of digestible protein intake, .07 kg/100 kg of body weight, reduced milk production and appeared to reduce the survival rate of calves. It would appear that meeting protein requirements for maintenance and/or reproduction is of higher priority than satisfying requirements for productive functions such as lactation.

Bedrak et al. (1964) and Bond and Wiltbank (1970) state that older animals appear to have slightly lower protein requirements or they appear to be less susceptible to the effects of a low protein intake. Howes et al. (1960) made similar observations. It is likely that the relatively large protein reserve of older animals in good condition is responsible for this apparent tolerance to periods of low protein intake.

Clanton and Zimmerman (1970) state that the digestible protein requirement of pregnant heifers appears to be about .10 kg/100 kg of body weight daily, whereas that of mature cows appears to be about .045 kg per day. The N.R.C. (1970) lists the minimum digestible protein requirement of pregnant 454-kg cows as .19 kg (.042 kg/100 kg of body weight) per day and that of a 400-kg heifer under maintenance conditions as .24 kg (.06 kg/100 kg of body weight) daily.

Although protein requirements for reproduction in the bovine have been studied to some degree, protein requirements for lactation in beef cows have not received extensive investigation. Few reports are available in which milk production has been measured in the beef cow, and in only a small fraction of these has milk production been studied in relation to protein intake.

Clanton and Zimmerman (1970) indicated that, although satisfactory reproduction was obtained by feeding levels of .04 to .05 kg of digestible protein per 100 kg of body weight with adequate energy intakes during the period prior to calving, highest milk production was obtained with a level of about .1 kg of digestible protein. The first-calf heifers used in this trial were fed liberally after calving. Bond and Wiltbank (1970) reported similar results with respect to the effect of protein intake on lactation. In their study, attainment of maximum levels and persistency of milk production required .16 kg of digestible protein per 100 kg of body weight daily when constant levels of protein intake were fed from the time the heifers were weaned until 180 days after they had calved. Levels of .07 kg of digestible protein per 100 kg of body weight resulted in about the same initial level of milk production (2.9 vs 3.0 kg for cows fed .16 and .07 kg digestible protein per 100 kg of body weight, respectively). However, cows fed the lower level of protein declined in production after the first 30-day period, whereas cows fed higher levels of protein reached peak production 60 to 90 days after calving. Effects of low levels of protein or energy intake during the first gestation were carried through into the second gestation.

Present N.R.C. (1970) recommendations for 450-kg cows during the first 3 to 4 months of lactation are .12 kg of digestible protein per 100 kg of body weight. These levels would likely be adequate for cows in good condition.

It is evident that successful reproduction in beef heifers can be supported on levels of protein intake that approximate maintenance requirements. Maintenance appears to require minimum digestible protein intakes of about 50 to 60 g/100 kg of body weight in weanling heifers. Attainment of puberty at an early age with a high conception rate requires a higher level of approximately 70 g of digestible protein per 100 kg of body weight. Obtaining maximum lactation levels and a high degree of persistency in lactation with first- or second-calf heifers may require intakes of about .10 kg of digestible protein per 100 kg of body weight prior to calving with additional allowances for milk production subsequent to parturition.

Minimum protein requirements for reproduction in older cows do not appear to vary markedly from maintenance requirements. Intakes of 40 to 50 g of digestible protein per 100 kg of body weight daily have been satisfactory for both maintenance and reproduction of cows in good condition. This may be due to the apparent ability of the mature cow to build up protein reserves during periods of high nutrient intake and to utilize them during less favorable periods. Heifers and young cows, however, are still growing and do not have access to such reserves.

Thus, their apparent requirement for protein is higher than that of mature cows.

Energy

Methods Used to Determine Energy Requirements

In the presence of adequate nutrients other than energy, rate of growth is directly dependent upon available energy intake above maintenance requirements. A decrease in the rate of growth, or a loss of body weight, is one of the first indications of inadequate energy intake. Thus, energy requirements for maintenance and various rates of growth can be approximated by determining body weight at different levels of energy intake. The results of feeding trials conducted to study energy requirements are generally evaluated in terms of growth rate and efficiency of feed utilization. However, such values do not demonstrate the actual tissue changes which may have resulted from the various nutritional treatments. Carcass studies are often conducted in conjunction with feeding trials to define those changes.

Feeding trials probably give more practical estimates of energy requirements for maintenance and growth than do metabolism trials, principally because they are conducted under more practical conditions. Crampton and Harris (1969) state that maintenance energy requirements as determined by feeding trials are about 20% higher than requirements based on energy balance studies.

Energy requirements for maintenance and growth may be studied by the use of detailed carcass analyses. The composition of the carcasses of experimental animals as compared to the composition of control animals slaughtered at the beginning of the experimental period provides an estimate of the net utilization of energy. Such studies have been reported in numerous instances in the literature (Winchester and Hendricks, 1953; Winchester and Howe, 1955; Winchester et al., 1957b; Garrett et al., 1959; Carroll et al., 1963). Relatively large numbers of animals can be used in slaughter experiments and the data thus obtained appear to provide a reliable basis for estimating energy requirements. The disadvantages of the slaughter method are that considerable laboratory work is involved and the animals utilized are not available for further investigation. Studies of this nature provide the basis for one of the more recently developed feeding programs (Lofgreen and Garrett, 1968).

Metabolism studies, energy balance trials and related investigations are useful for determining the energy requirements of animals for given functions under specific conditions. Basically, such studies are conducted by maintaining an accurate record of the energy supplied an animal and subsequently accounting in detail for its disposition.

Several methods have been devised for measuring or closely approximating the various energy expenditures of an animal. For example, maintenance energy requirements can be measured with direct or indirect calorimetric methods or by calculating requirements from endogenous nitrogen excretion. Requirements for growth, finishing or production may be measured with the aid of digestion or metabolism trials. An engrossing discussion of the development and employment of these methods has been presented by Maynard and Loosli (1962). Generally, these studies are suited only to the use of a limited number of animals and are not well suited to long-term studies. Some, such as direct calorimetry, require rather elaborate equipment and are thus quite expensive. All require considerable labor. However, proper utilization of one or more of these methods will give accurate data concerning the energy requirements of an animal under the conditions imposed. The resulting data, however, are probably not strictly applicable to practical conditions.

Changes in blood constituents have also been used in energy studies, particularly in those in which estimates of energy requirements for maintenance are being determined. Hemoglobin concentrations in cattle (Speth et al., 1962; Stufflebeam et al., 1969), hematocrit in cattle (Stufflebeam et al., 1969) and sheep (Tilton et al., 1964), serum protein in cattle (Stufflebeam et al., 1969) and blood albumins in sheep (Wright et al., 1962) have been reported to decline in energy deficient animals. These changes are probably the result of catabolism of tissue proteins to supply energy needed for the body processes. However, since such changes have also been related to a deficiency of protein, these indicators should not be used as the sole criteria of the sufficiency of energy intake. These measures may be combined with other measures of adequacy of energy intake, such as growth rate, to provide a more complete and precise definition of results.

In addition to the above means, various measures of sufficiency of energy intake in breeding stock have been used. In breeding females, a deficiency of energy intake may result in delay of puberty (Joubert, 1954; Wiltbank et al., 1957; Blakely et al., 1964; Clanton and Zimmerman, 1970) or cessation of estrus (Bond et al., 1958; Wiltbank et al., 1962b; Blakely et al., 1964). The interval from calving to first postpartum estrus may be increased (Zimmerman et al., 1961; Wiltbank et al., 1962b; Dunn et al., 1969; Clanton and Zimmerman, 1970) or postpartum anestrus may occur (Wiltbank et al., 1962b). The overall result may be an increase in the number of services required per conception (Wiltbank et al., 1962b; Clanton and Zimmerman, 1970) or a decrease in conception rates (Wiltbank et al., 1962a,b). Insufficient energy intake in cows may also reduce milk flow and affect calf weaning weight. In males inadequate energy intake may result in retarded physical development of sex organs and reduced sperm producing capacities accompanied by impaired fertility (VanDemark and Mauger, 1957; VanDemark et al., 1960).

These impairments of normal function are often used as criteria in studies concerning energy requirements. Large numbers of data are easily and quickly obtained and processed. When combined with growth data and digestion trials, the results are probably as practical an estimate of requirements under various conditions as can be obtained.

Factors Which Influence Energy Requirements

Adequate supplies of available energy are essential to the success of livestock enterprises. It is therefore of considerable importance that factors which influence energy requirements be recognized and their influence understood.

Of the demands placed upon feed energy supplies, the utilization of energy for maintenance of livestock probably accounts for the largest portion of the total expenditure (Morrison, 1959; Maynard and Loosli, 1962; Crampton and Harris, 1969). Investigations have shown in adult animals that the maintenance requirement for energy is proportional to approximately the .7 power of body weight (Brody et al., 1934; Winchester and Hendricks, 1953; Neville and McCullough, 1969). Requirements of young animals, however, may be considerably higher than estimates calculated on the basis of this relationship (Blaxter, 1962).

Maintenance requirements are subject to the influence of several factors, one of which is activity. Gains of group-fed cows averaged about 10% less than those of cows fed the same ration but on an individual basis in one study (Neville and McCullough, 1968). This is probably a reflection of the influence of competition at the feed bunk. The N.R.C. (1971) states that the maintenance requirements of dairy cattle may be increased 25 to 100% by grazing or feedlot activity as compared to energy requirements of cattle fed in individual stalls. Other factors such as disease and environmental temperature may also exert a considerable influence upon the maintenance energy requirement.

Growth constitutes another important source of demand upon total energy requirements. In immature animals, energy demands for growth are a considerable portion of the entire energy requirement; but, as the animal grows older, growth demands decrease in relation to maintenance requirements. The added increments of body weight in finishing animals under usual conditions contain increasingly higher proportions of lipids as the animal matures. The amount of energy represented by each additional increment increases with increases in the age and weight of the animal. These changes in the composition of incremental additions of body weight are reflected in changes in the optimum protein to energy ratio of the diet as the weight and maturity of the animal advance and in the increased amounts of feed required to obtain a unit of weight gain. Discussions of investigations concerning the energy requirements of ruminants at various stages of growth and gaining weight at various rates have been published (Garrett <u>et al</u>., 1959; Lofgreen and Garrett, 1968).

Both reproduction and lactation place additional demands upon the total energy needs of the ruminant. The fetus and other products of conception contain considerable quantities of energy, about one-half of which is deposited during the last 5 to 6 weeks of gestation (Jakobsen, 1961). Concurrent increases in the rate of udder and mammary gland development add further to energy requirements. Consequently, the increased demand for energy for reproduction is most noticeable during the latter stages of gestation when energy deposition is most rapid.

The process of lactation requires the expenditure of large amounts of energy. Milk contains considerable quantities of energy and the secretion of the milk also requires energy. The total amount of energy required for lactation will be proportional to the amount of milk produced but will vary somewhat depending upon the fat content of the product. Lactation may also increase the maintenance energy requirement of cows by approximately 30% in addition to the energy secreted in the milk (Neville and McCullough, 1969).

Various factors have been reported to have some degree of influence upon the availability of dietary energy or upon its utilization. While these factors may not affect the actual energy requirement of an animal, they may influence the efficiency with which dietary energy is utilized, thus affecting the amount of feed needed by the animal.

Primary factors which have been noted to have some degree of influence on the utilization of dietary energy include the level of protein in the diet (Gallup and Briggs, 1948; Burroughs and Gerlaugh, 1949; Putnam et al., 1966; Garrett, 1970), dietary fats and oils (Matsushima et al., 1957; Bohman and Lesperance, 1962) and the roughage to concentrate ratio of the ration (Stone and Fontenot, 1965). Type and quality of roughage (Crampton, 1957; Raleigh et al., 1964) and the level of feed intake (Klosterman et al., 1965) are also important. In addition, levels of required minerals such as phosphorus (Kleiber et al., 1936) and calcium (Dowe et al., 1957) can influence the utilization of dietary energy. Associative effects of various feedstuffs may exert a considerable influence, also (Kriss, 1943; Asplund and Harris, 1971). Excellent discussions pertaining to the influence of various factors on the utilization of dietary energy have been presented by Crampton (1957), Morrison (1959), Blaxter (1962), Crampton and Harris (1969) and Maynard and Loosli (1962).

<u>Energy Requirements for Maintenance and Growth</u>

Energy requirements of the bovine for various purposes are generally stated in terms of total digestible nutrients (TDN) or digestible, metabolizable or net energy (DE, ME and NE, respectively). The common unit of expression for TDN is pounds or kilograms, whereas DE, ME and NE are expressed in kilocalories, megacalories or therms. Energy requirements are commonly listed as total amounts of energy required by an animal and as the required dietary energy concentration.

As a result of the diligent labor of the early investigators in the field of energy metabolism in ruminants, it became apparent that the energy requirement (E) of an adult animal is proportional to its body weight (W) and can be approximated closely by mathematical formula, the general form of which is $E = kW^x$. Values of E are expressed in terms of TDN, DE, ME or NE. The constant k is given a numerical value which depends in part upon the units in which W is expressed (pounds or kilograms) and in part upon the unit in which E is expressed. For example, Garrett <u>et al.</u> (1959) developed the following expressions for estimating daily energy requirements for maintenance of adult animals:

$$TDN = .036W^{3/4}$$

$$DE = 76W^{3/4}$$

$$ME = 62W^{3/4}$$

$$NE = 35W^{3/4}$$

In these expressions, TDN and W are expressed in pounds and DE, ME and NE are expressed in kilocalories.

The value of the exponent (x) of weight in the general formula above has been subject to discussion. Values proposed have varied from two-thirds (Winchester and Hendricks, 1953) to three-fourths (Brody et al., 1934). Results of trials based on energy allowances calculated with the latter exponent indicate that this value appears to closely approximate actual requirements (Klosterman et al., 1968).

Even though the theoretical values may closely approximate requirements, there is considerable variation in the reports of various investigators as to the amounts of energy required by cattle for maintenance. Considering the number of factors which can influence the maintenance energy requirement, some variation should be expected. In order to facilitate a comparison of the reports from the various laboratories, the following comparisons are based on the DE requirements of a standard 454-kg animal.

The DE requirements of a 454-kg animal, calculated according to the expressions each investigator has used to describe his data, are (kcal of DE per day per animal) 11,396 (Winchester and Hendricks, 1953); 13,508 (Garrett et al., 1959); 13,769 (Brody et al., 1934) and 16,148 (Neville and McCullough, 1969). Clanton and Zimmerman (1970) and Ewing et al. (1967), on the basis of their data, recommend DE allowances of 14,000 and 14,838 kcal, respectively, for pregnant cows in this weight range. The N.R.C. (1970) lists the DE requirements (minimum TDN required x 4,400 kcal DE/kg TDN) of a 450-kg dry, mature pregnant cow as 14,960 kcal DE, a level of intake which, it is stated, may result in the loss of some body weight.

It appears that the actual maintenance energy requirement of a 454-kg animal may closely approximate 14 Mcal DE per day. However, stress conditions such as severe cold can greatly increase this requirement. It should therefore be considered as an estimation of maintenance requirements under optimum conditions.

Several investigators have developed mathematical expressions which define, according to their data, the energy requirements of the ruminants for weight gain. These expressions follow the same general form as the general formula shown above for the calculation of maintenance energy requirements and have been expressed in similar units. An example of such a formula is that which was proposed by Winchester and Hendricks (1953). It is TDN (lb) = $.0553\ W^{2/3}\ (1 + .805\ g)$, in which body weight (W) and gain (g) are expressed in pounds. Expressions of a similar nature have been developed by Garrett et al. (1959) and Lofgreen and Garrett (1968) from their respective data.

Calculation of the DE required by a 454-kg steer per kilogram of gain using these formulas gives 16,016 kcal (Garrett et al., 1959) and 19,976 kcal (Winchester and Hendricks, 1953). Neville and McCullough (1969) state that the DE required per kilogram of gain in nonlactating beef cows was 7,920 kcal and in open, lactating cows, 10,120 kilocalories. There is considerable variation between the reported values. However, Neville and McCullough's data (1969) were based on regression analyses of data obtained over consecutive 6-week periods, while those of Garrett et al. (1959) and Winchester and Hendricks (1953) were based upon carcass studies and are probably more accurate. Also, there is likely considerable difference with respect to composition of body weight gains by the animals in the studies.

Energy Requirements for Reproduction and Lactation

There appear to be few reports in the literature concerning the energy requirements of the bovine for reproduction. There are a considerable number of problems involved in measuring this requirement, not the least of which is the choice of criteria to be employed in the study. In addition, in many of these investigations, such as those at the Oklahoma station, cows have been fed supplemental feeds while on native ranges during the wintering phase, and it is therefore difficult to measure or estimate accurately their total energy intake. Consequently, the effects of these nutritional treatments on reproductive performance are evaluated not in relation to total nutrient intake but in relation to weight change patterns resulting from these treatments. Such evaluations permit the individual producer to feed in a manner to produce similar results but with a variety of feeds and under different conditions.

The process of reproduction requires energy not only for anabolism of materials in the products of conception but the products themselves represent energy. One approach to determining the energy requirements for reproduction is to determine the total energy of the products of conception and equate this to net energy. Investigations concerning the total energy of the products of conception have been reported. Jakobsen (1961), in work which was cited by Blaxter (1962), determined the combustible energy of the uterine contents of cows at various stages during gestation. At the 40th week of gestation, the total amount of combustible energy present in the uterine contents was about 60 Mcal, approximately one-half of which was deposited during the last 5 weeks of gestation. The energy thus deposited would represent dietary net energy. It is interesting to note that, by using the N.R.C. (1970) net energy for maintenance value of sun-cured alfalfa hay harvested in the early bloom stage (1.35 Mcal/kg of dry matter), it can be shown that the total 60 Mcal of net energy would be supplied by approximately only 50 kg of hay containing 12% moisture.

Jakobsen (1961) developed an equation to describe the rate of energy deposition in the uterus during gestation. It was calculated that at the 280th day of gestation the rate of energy retention as fetus, membranes and fluids would be about 943 kcal per day, an amount of net energy furnished by about .8 kg of the above hay. It is apparent that the energy requirement of an adult cow is increased only a small amount by gestation, even near termination when demand is greatest. This is probably why many investigators prefer to evaluate the effects of various nutritional treatments in the more practical terms of reproductive performance than to attempt to determine the specific amounts of energy required for reproduction.

Feeding trials in Nebraska (Wiltbank _et al_., 1962b) have demonstrated that the energy intake of mature cows prior to calving has a definite influence on the length of the interval from calving to first estrus and that the energy intake in the period immediately after calving significantly influences the conception rate. Later work

(Wiltbank et al., 1964) indicated that the postpartum level of energy intake was of primary importance in determining overall reproductive performance. Findings of a similar nature were reported by Dunn et al. (1969).

Overall, the data of Wiltbank et al. (1962b, 1964) indicate that a daily intake of approximately 4.1 kg of TDN during the wintering period prior to calving is probably slightly in excess of requirements for satisfactory reproductive performance in cows weighing about 498 kg at the beginning of the winter. Intakes of about 7.3 kg of TDN after calving appeared to be adequate. Dunn et al. (1964) reported that postpartum intakes of about 10.4 kg of TDN resulted in higher conception rates in first-calf heifers than did intakes of 5.9 kg of TDN.

In Oklahoma trials, Pinney et al. (1962a,b) have shown that optimum reproductive performance can be obtained when mature cows are wintered at levels of feed intake which result in total wintering phase weight losses of between zero and 10% of the fall weight of the cows. These weight losses approximate the 5 to 9% body weight losses reported by Wiltbank et al. (1962b) as being associated with optimum reproductive performance. Renbarger et al. (1964) reported that heifers which lost a total of 6.8% of their fall weight during the winter returned to estrus sooner after calving and had higher conception rates than those which had lost 9.9% or more of their body weight.

It appears that levels of TDN intake sufficient to result in body weight losses of zero to 10% of the fall weight through the winter, including calving losses, are adequate to insure optimum reproductive performance in cows. First-calf heifers should be wintered at somewhat higher levels, preferably in such a manner that they do not lose weight (Pope et al., 1963; Clanton and Zimmerman, 1970).

In summation, intakes of about 4.1 kg of TDN appear to be slightly in excess of requirements for mature gestating cows (Wiltbank et al., 1962b). Clanton and Zimmerman (1970) recommend an intake of 3.2 kg of TDN (about 14 Mcal DE) for mature gestating cows. This approximates the maintenance requirement (14,838 kcal DE) for cattle of similar size as reported by Ewing et al. (1967) and the requirements reported by others (Brody et al., 1934; Winchester and Hendricks, 1953; Garrett et al., 1959). Present N.R.C. (1970) minimum requirements for 450-kg gestating, mature cows are 3.4 kg of TDN (14,960 kcal DE) which would appear to be a reasonable level of energy intake for gestating cows.

Lactation places a great demand upon the total energy requirement of the female bovine. The level of energy intake of the cow has been related to level of milk production in numerous instances (Pope et al., 1963; Pinney et al., 1962a; Nelson et al., 1962). The correlation between milk production and calf gains is high (Nelson et al., 1962; Pope et al., 1963). Correlations have been reported as high as .75 to .91 for grade Hereford cows (Nelson et al., 1961), .67 to .81 for Angus cows (Klett et al., 1965) and .6 to .7 for Hereford cows (Pope et al., 1963). The importance of insuring adequate energy intakes for lactating cows is clear.

Nutrition both prior to and following parturition has considerable influence on the characteristics of a lactation. Data reported by Swanson and Hinton (1961), Pinney *et al.* (1962a) and by Pope *et al.* (1963) indicate that the level of nutrition prior to calving has an influence upon the level of milk production achieved during lactation. Subsequent reports (Renbarger *et al.*, 1964; Dunn *et al.*, 1965) indicated that the ability of a cow to produce milk is largely determined by prepartum nutrition levels, whereas her actual production is to a considerable degree dependent upon her postpartum level of nutrition, providing, of course, that prepartum levels of nutrition were sufficient to allow the development of potential abilities. Persistency of lactation may be adversely affected by suboptimum nutrient intake prior to calving (Swanson and Hinton, 1961; Pope *et al.*, 1963; Dunn *et al.*, 1965). Pope *et al.* (1963) consider the last 6 weeks of gestation as the critical period during which the lactational capabilities of the beef cow may be most highly influenced by nutritional regime. The effects of inadequate nutrition during gestation appear to have a greater influence upon heifers and young cows than upon mature cows (Howes *et al.*, 1960; Pope *et al.*, 1963).

Reported energy requirements for lactation show some degree of variation. The total amount of energy required for the production of milk is directly related to the total amount of milk produced. Milk from Angus and Hereford cows contains an average of about 772 kcal of energy per kilogram (Anthony *et al.*, 1965). This energy would represent net energy from feed but includes no allowance for the metabolism leading to the milk production.

Ewing *et al.* (1967) state that the production of 6.8 kg of 3% milk for a period of 205 days appears to require approximately 810 kg of TDN, or about 1,157 kcal of DE per kilogram of milk produced. Neville and McCullough (1968) reported that milk production by Hereford cows required between 528 and 968 kcal per kilogram of milk. Later estimates based on a greater number of cows were 1,338 kcal of DE per kilogram of milk (Neville and McCullough, 1969). The N.R.C. (1970) lists the minimum requirements of a 450-kg cow producing about 7.5 kg of milk per day as 5.6 kg of TDN, or 2.2 kg of TDN more than a gestating dry cow of similar size. This would be an allowance of about 1,291 kcal DE per kilogram of milk produced. The N.R.C. (1971) minimum requirement for the production of milk by dairy cows is 1,452 kcal DE per kilogram of milk.

It appears from the results of the several research reports reviewed that the production of milk requires about 1,300 to 1,400 kcal per kilogram of milk produced. This should probably be considered as a minimum value and subject to considerable increase for cows which produce milk with a high fat content.

Vitamin A

All animals require vitamin A to support life processes. However, carotene, a precursor of vitamin A of plant origin, can be converted within the animal body to vitamin A and thus may be utilized in the diet to satisfy the vitamin A requirement. Consequently, requirements are stated in terms of either vitamin A or carotene. Vitamin A requirements are given in terms of international units (IU) or United States Pharmacopeia (USP) units, each of which is equal to .30 µg of pure crystalline vitamin A alcohol.

The amount of carotene needed to satisfy vitamin A requirements is commonly stated in terms of milligrams or international units. The international unit (IU) is equal to the activity of .60 µg of beta-carotene, which is equal to the activity of .30 µg of vitamin A alcohol as determined by rat assay techniques. However, the vitamin A value of carotene for the ruminant is not the same as for the rat and may be influenced by several factors.

Methods Used to Determine Vitamin A Requirements and Status

The classical symptom of vitamin A deficiency is night blindness. This symptom is the first visible sign of a deficiency and is the last to disappear during recovery from a deficiency (Guilbert and Hart, 1934; Guilbert et al., 1937). Night blindness was used as the criterion of adequacy of vitamin A or carotene intake in many of the early studies and offers the advantage of being a relatively quick test which requires few tools for its administration. However, it is not as accurate as many of the newer tests and is subject to some degree of misinterpretation due to differences in the degree of night blindness and to differences in judgment of the technicians administering the test. Possible changes in efficiency of utilization of carotene or vitamin A by the animal due to the effects of a previous deficiency may also affect the results of this test. In addition, this test does not reveal anything concerning the size of an animal's body stores of vitamin A or how they might have changed since the administration of the previous test, both of which may be important factors under some conditions.

Other symptoms of a vitamin A deficiency which have been reported in the literature include watering eyes, nasal discharge, enteritis and intestinal inflammation, abortion, failure of implantation of the fertilized ovum and sterility in both males and females. Diseases such as pneumonia occur more frequently in deficient animals (Sutton et al., 1940). Administration of vitamin A will bring about rapid remission of deficiency symptoms, but secondary infections must be treated separately.

Probably the single most important function of vitamin A in the animal body is the maintenance of the health of the epithelial tissues. It is likely the breakdown of the continuity of epithelial tissues which is the predisposing factor common to many of the deficiency symptoms noted above. In a deficiency, the epithelial tissues cannot fulfill the usual roles of secretion and absorption. The stratified, keratinized tissue which replaces the healthy epithelium is not capable of presenting a fully effective barrier against the entrance of microorganisms into the body. The result of these failures is the occurrence of various symptoms noted above. However, because of the generalized nature of these signs, and because many other factors can be involved, the occurrence of these signs cannot by themselves be used as sole criteria of the adequacy of vitamin A or carotene intake. In addition, most of these symptoms occur in late stages of avitaminosis A.

Vitamin A deficiency results in increases in cerebrospinal fluid pressure and the appearance of related symptoms. Blindness resulting from a lack of vitamin A can be due either to corneal ulceration occurring in cattle of any age or to constriction and degeneration of the optic nerve which is usually observed only in immature cattle. Constriction of the optic nerve results from improper development of the optic foramen caused by increased cerebrospinal fluid pressure (Moore, 1939b; Moore and Sykes, 1940, 1941; Millen and Dickson, 1957). Increased cerebrospinal fluid pressure, which appears to be the first measurable symptom of a vitamin A deficiency (Dehority et al., 1960; Eaton et al., 1964b), results from a decreased rate of absorption of the cerebrospinal fluid (Bitman et al., 1962a,b; Okamoto et al., 1962) rather than from changes in the composition of the fluid (Dehority et al., 1960).

Increased cerebrospinal fluid pressure has been used to determine the occurrence of vitamin A deficiency, but the method involves restraint of the animal to prevent damage to the animal's nervous system and the use of manometric techniques for measuring cerebrospinal fluid pressures. The method is excellent in that it appears to be sufficiently sensitive to determine differences in carotene intake of as little as 4.4 µg/kg of body weight under the proper conditions (Moore et al., 1948). However, only limited numbers of animals can be used in determinations of this type because of possible limitations in time, equipment and assistance. In addition, once the determination has been made, the results do not indicate the extent of or changes in body reserves of the vitamin or the sufficiency of the vitamin A or carotene intake except where a deficiency is determined.

Weight gains and the absence of deficiency symptoms are often used as the criteria by which adequacy of vitamin A intake is measured. However, the use of weight gain as the sole criterion of the adequacy of vitamin A or carotene intake does not appear to be an acceptable procedure. Under most conditions, this criterion must be used with caution because of the possible presence of large body stores of vitamin A. The danger lies in that intakes which appear to be sufficient to provide for optimum growth and the avoidance of deficiency symptoms during short experimental periods may be grossly insufficient for these purposes for longer periods of time. In addition, growth in cattle has been reported to proceed at normal rates (Guilbert et al., 1937; Boyer et al., 1942; Grifo et al., 1960a), or nearly normal rates (Guilbert and Hart, 1934, 1935), in the presence of deficiency symptoms. Low rates of growth have occurred in the presence of gross deficiency symptoms (Boyer et al., 1942). Growth appears to be relatively unaffected until the appetite of the deficient animal is affected (Guilbert and Hart, 1934; Grifo et al., 1960a). This may not occur for several weeks after the observation of other symptoms (Guilbert and Hart, 1934; Boyer et al., 1942). However, intakes of carotene or vitamin A sufficient to prevent the occurrence of deficiency signs and to provide for optimum rates of body weight gain over long periods of time should be considered adequate under the conditions imposed.

Considerable work has been reported in which the concentration of vitamin A, and to a much lesser extent the concentration of carotene, in the blood plasma has been used as an indicator of the adequacy of vitamin A nutritional status. Generally, these criteria are used in combination with body weight gains and the prevention of deficiency symptoms as a means of determining the adequacy of vitamin A or carotene intake. However, there is some dispute among researchers as to what constitutes a minimum acceptable level of carotene or vitamin A in the blood plasma. A portion of the controversy can be attributed to apparent differences in minimum required levels as they are influenced by age. In young calves, concentrations of vitamin A of 10 μg/100 ml (Ellmore and Shaw, 1954) or of 10 to 12 μg/100 ml of plasma (Boyer et al., 1942) have been considered adequate, and levels of 7 to 8 μg/100 ml have been considered bordering on inadequacy (Boyer et al., 1942). Concentrations of 15.6 μg/100 ml have been reported to result in the maintenance of normal cerebrospinal fluid pressures (Eaton et al., 1961).

Plasma vitamin A concentrations necessary to prevent deficiency signs and to result in optimum weight gains have generally been reported to be higher for fattening cattle than for young calves. Plasma vitamin A concentrations of 11 and 16 μg/100 ml (Beeson et al., 1961) and of 15 μg/100 ml (Pope et al., 1961; Kohlmeier and Burroughs, 1964) have been reported to be associated with reduced rates of gain in finishing cattle. Concentrations of 15 to 25 μg/100 ml have been associated with variable performance in finishing cattle, whereas levels of 25 μg/100 ml or more have been adequate and were associated with maximum rates of gain (Kohlmeier and Burroughs, 1964, 1970). On the other hand, in at least two instances (Smith et al., 1961; Jordan et al., 1963), levels of about 26 μg/100 ml have been observed in feedlot cattle which demonstrated apparent deficiency symptoms. It is generally accepted, however, that plasma vitamin A concentrations of more than about 10 μg/100 ml in young calves and about 16 μg/100 ml in older cattle should be considered indicative of adequate vitamin A nutrition.

Blood plasma carotene concentrations have been studied as an indicator of the adequacy of carotene intake. However, there appears to be considerable disagreement concerning the minimum plasma level of carotene which can be considered indicative of adequate intake. Various levels, including 20 μg/100 ml (Moore, 1939a) and 40 μg/100 ml in beef calves (Pope et al., 1961), 50 to 70 μg/100 ml in Holstein calves and 110 to 140 μg/100 ml in Guernsey calves (Boyer et al., 1942), have been considered minimum for the prevention of deficiency symptoms. It would appear that plasma carotene concentrations may not be as sensitive or reliable a measure of the adequacy of carotene intake as is the concentration of plasma vitamin A and that results should be interpreted with major emphasis placed on vitamin A concentrations.

As mentioned previously, body stores of vitamin A can be of relatively large magnitude. Since the early recognition that such stores of vitamin A may occur in the liver and that these stores can be utilized during periods of intake insufficient to meet requirements, studies have been carried out to define more precisely the relationship which exists between dietary, blood and liver concentrations of carotene and vitamin A.

Certain studies have indicated that a mathematically definable relationship may exist between plasma vitamin A and dietary concentrations of the vitamin (Almquist, 1952) or between dietary intake and liver vitamin A concentrations (Rousseau et al., 1956). However, others have shown that a definable relationship probably exists only when the test animals are fed a strictly controlled diet (Diven et al., 1960) or when both the liver and plasma levels of the vitamin have been depleted to low levels (Braun, 1945; Diven et al., 1960). Several investigations have shown there is virtually no mathematically definable relationship between vitamin A intake and plasma and liver vitamin A concentrations with high levels of intake (Lewis and Wilson, 1945; Hale et al., 1961b). Under given conditions, even plasma vitamin A concentration may fail temporarily to reflect vitamin A intake (Braun, 1945; Thomas et al., 1952).

It would thus appear that the level of vitamin A in the blood plasma cannot be used to define the amount of hepatic stores of the vitamin except under conditions of near depletion or when intake is low and strictly controlled. Under these conditions, low plasma concentrations of vitamin A reflect low levels of liver vitamin A stores and may be accompanied by apparent deficiency symptoms. However, high concentrations of vitamin A in the blood plasma would generally indicate considerable stores of vitamin A and/or adequate levels of intake.

Attempts have also been made to correlate carotene intake with plasma and liver concentrations of carotene. Carotene concentrations in the blood plasma may vary considerably over a short period of time due to changes in carotene intake. Consequently, carotene intake may be defined by the level of carotene and vitamin A in the blood plasma and liver only under strictly controlled conditions. In repletion studies carried out with calves, Thomas and Moore (1952) found that liver and plasma concentrations of vitamin A were related to carotene intake until intake levels reached about four times minimum requirements. Under conditions of uncontrolled intake, however, there appears to be no mathematically definable relationship between carotene intake, blood plasma and liver concentrations of vitamin A (Ralston and Dyer, 1959).

These factors, in combination with the numerous difficulties involved in obtaining and processing liver samples from live animals, make the use of the liver biopsy method one of the less desirable methods of assessing the adequacy of vitamin A or carotene intake.

Other methods have also been used to study vitamin A requirements of the bovine. A deficiency of vitamin A may cause certain changes in plasma protein relationships (Madsen et al., 1947; Erwin et al., 1957a), in kidney and adrenal gland tissue (Byers et al., 1956) and in the function of the kidneys (Woelfel et al., 1963) and adrenal glands (Juneja et al., 1966). Although these changes have been used to detect vitamin A deficiency under laboratory conditions, considerable difficulty and labor are involved in such studies. Consequently, other methods are more generally utilized.

Factors Which Influence Carotene and Vitamin A Requirements

There appear to be no important or consistent differences between the carotene and vitamin A requirements of the Hereford, Angus and Shorthorn breeds of cattle (Darlow et al., 1949; Pope et al., 1961). Certain of the dairy breeds, however, may be less efficient in the conversion of carotene to vitamin A, and thus their apparent requirement for carotene may be higher than that of other dairy breeds (Boyer et al., 1942; Moore et al., 1943, 1948). Other than these possible differences, breed appears to have little influence on vitamin A requirements or upon the amount of carotene required to satisfy the requirements.

Sex of cattle also appears to have no influence upon vitamin A requirements or upon the amount of carotene needed to satisfy vitamin A requirements (Guilbert et al., 1937, 1940; Guilbert and Loosli, 1951).

Reproduction and lactation influence apparent vitamin A requirements of the bovine. Vitamin A and carotene do not readily pass through the placenta but both are secreted in milk. Colostrum normally contains relatively high levels of vitamin A in order that the calf will have immediate access to a source of the vitamin. The amount of vitamin A secreted in normal milk appears to depend more highly upon carotene or vitamin A intake during lactation than upon liver stores of vitamin A existing at the initiation of lactation (Baker et al., 1954; Pope et al., 1961).

Age, per se, probably has little influence upon carotene or vitamin A requirements of cattle (Guilbert and Hart, 1934; Guilbert et al., 1937). Older cattle may require longer periods to deplete their vitamin A reserves, probably only because they have greater initial reserves (Riggs, 1940). Factors related to age, such as growth and body size, are of greater importance. Carotene and vitamin A requirements appear to be more closely related to body size than to age as such (Guilbert and Hart, 1934; Guilbert et al., 1937).

Extreme environmental temperatures, either hot or cold, appear to intensify vitamin A deficiency symptoms in cattle (Jones et al., 1943; Page et al., 1958a; Perry et al., 1962). High ambient temperatures appear to have an adverse influence on carotene conversion or increase apparent vitamin A requirements in the bovine (Page et al., 1959), and extremely cold weather has been reported to nearly double the apparent carotene requirements of dairy calves (Keener et al., 1942). The results of some investigations (Stallcup and Ragsdale, 1949; Perry et al., 1962) indicate that differences in feed intake during periods of extremely warm temperatures may be a significant factor in contributing to the apparent severity of vitamin A deficiency symptoms during these periods.

Several investigators have studied the effects of previous carotene intake and vitamin A status on vitamin A metabolism and carotene utilization. A deficiency of vitamin A will apparently result in a decrease in the efficiency with which carotene is subsequently utilized by sheep (Erwin et al., 1959) and calves (Grifo et al., 1960a). Presumably, this effect is due to deleterious changes which have occurred in the epithelial lining of the intestine, tissue which appears to be of primary importance in the conversion of carotene to vitamin A (Olson, 1960; Pope et al., 1961).

Numerous dietary factors have been reported to have an influence upon vitamin A requirements and upon the amount of carotene required to satisfy the requirements. Energy intake may have a minor influence in this respect. Feeding different levels of a vitamin A depletion ration to calves has been reported to have no influence upon the rate of depletion (Rousseau et al., 1954). Different levels of low quality silage fed to finishing steers also had no apparent effect on final liver carotene or vitamin A concentrations (Richardson et al., 1965). On the other hand, diets with high net energy contents have been shown to have an adverse influence on plasma vitamin A concentrations (Willey et al., 1952) and to result in significantly larger depletions of liver vitamin A stores in steers (Hale et al., 1961a; Erwin et al., 1963). These effects may have been due in part to differences obtained in growth rates and in body weights.

The quantity and quality of protein in the diet of nonruminant animals have been demonstrated to have considerable influence upon the conversion of carotene to vitamin A (Berger et al., 1962; Friend et al., 1961; Rechcigl et al., 1962; Eaton et al., 1964a; Nir and Ascarelli, 1967) and upon the utilization of vitamin A (Friend et al., 1961).

Low protein intakes in sheep have been reported to reduce the utilization of intraruminally injected vitamin A but not to interfere with the efficiency of utilization of carotene (Anderson et al., 1962). Low protein intakes in steers may result in a slower turnover of liver vitamin A (Hayes et al., 1968), whereas protein intakes greatly in excess of requirements may cause increases in the rate with which liver vitamin A stores become depleted (Erwin et al., 1963).

Protein source may also have some influence. Feeding high levels of soybeans in the diet of ruminants has been reported to reduce the efficiency of conversion of carotene to vitamin A (Ellmore and Shaw, 1954) and to result in reduced concentrations of vitamin A in plasma and liver (Ellmore et al., 1948; Ellmore and Shaw, 1954). An enzyme, carotene oxidase which is present in raw or insufficiently cooked soybeans, may be responsible for these effects (Ewing, 1963).

Nitrate and nitrite have also been associated with carotene and vitamin A metabolism. Nitrates have had adverse influences on carotene or vitamin A metabolism in many instances (Hale et al., 1961a; Hatfield et al., 1961; Goodrich et al., 1964) but not in others (Zimmerman et al., 1962; Wallace et al., 1964; Davison, 1965). Nitrite appears to exert a more serious and consistent effect upon carotene and vitamin A metabolism than does nitrate. Nitrite appears to exert its influence through some mechanism within the gastrointestinal tract (Emerick and Olson, 1962) in reducing the amount of vitamin A activity which reaches hepatic storage sites. This effect of nitrite is thought to be of more consequence than an accelerated depletion of existing stores in affecting vitamin A status (Hoar et al., 1968).

Numerous other dietary factors have been reported at one time or another to have an influence upon the utilization of carotene or vitamin A. Most have only minor effects.

Besides the numerous dietary factors which may be involved, there are factors directly related to carotene itself which may affect its utilization. The term carotene, as applied to feedstuffs in general, includes several carotenoid compounds existing as different isomers and stereo-chemical forms. The most prevalent isomer of carotene, both in quantity and distribution, is beta-carotene. It is this form which accounts for practically all the vitamin A potency of forage crops (Ewing, 1963). Many other forms occur in minor amounts in plant tissues, but their vitamin A activity is considerably less than the vitamin A potency of beta-carotene. The vitamin A activity of many of these forms, in relation to the activity of beta-carotene, has been reported in the literature (Johnson and Baumann, 1947; Karrer and Jucker, 1950; Deuel et al., 1945).

For practical purposes, the mixed carotene from various forages should be of nearly equal biological value on a weight basis. However, the source of carotene affects biological value and this affects the amount of feedstuff required to provide needed amounts of carotene. Carotene from alfalfa meal may have nearly twice the value of carotene from carrot oil for lambs (Hoefer and Gallup, 1947) or dairy cows (Bullis et al., 1958). Forage species may possibly influence the value of carotene (Fonnesbeck and Symons, 1967) although this effect, except in extreme cases, is generally small or negligible (Cullison and Ward, 1965; Miller et al., 1967). Differences in apparent utilization of carotene from different sources may be due primarily to differences in the digestibility of the feedstuffs or to other characteristics of the diet which might influence carotene absorption and conversion.

The level of carotene intake may have an influence upon its comparative vitamin A value. At levels of carotene intake which satisfy minimum requirements of the bovine, the ratio of efficiency of vitamin A to carotene on a weight basis may be on the order of 6 to 1, but at appreciably higher levels of intake the ratio may be 10 to 1 or more (Guilbert et al., 1940; Rousseau et al., 1956; Grifo et al., 1960b). Similar trends have been observed with sheep (Hoefer and Gallup, 1947). Studies with calves (Guilbert and Loosli, 1951; Rousseau et al., 1958) and steers (Erwin et al., 1957b; Page et al., 1958b) have confirmed that carotene is utilized less efficiently as intake is increased above minimum requirements. Liver vitamin A levels do not increase linearly with increases in intake above maintenance requirements in cattle (Lewis and Wilson, 1945; Frey et al., 1947). At least a portion of the apparent decline in the relative value of carotene may be due to decreases in the digestibility of carotene as intake increases (Pope et al., 1961).

Attempts to determine the vitamin A equivalent value of carotene for cattle must be made at levels of carotene intake not greatly in excess of minimum requirements in order to be valid and to have practical application. Typical values reported, in terms of international units of vitamin A activity per milligram of carotene, include values of about 400 (Embry et al., 1962; Record et al., 1963), 425 (Grifo et al., 1960b) and about 500 (Hansen et al., 1963).

The National Research Council (N.R.C., 1970) considers that for beef cattle 1 mg of carotene from a feedstuff is equivalent to 400 IU of vitamin A. This factor was selected after careful consideration of much of the available literature and assigns to carotene a value of about one-eighth that of an equal weight of vitamin A alcohol. This value appears to be a justifiable approximation of the relative vitamin A value of carotene when levels of intake do not greatly exceed minimum requirements.

Carotene and Vitamin A Requirements for Maintenance and Growth

It is a well accepted fact that the vitamin A requirement of the bovine can be satisfied with either the preformed vitamin or with carotene even though the actual requirement appears to be for the vitamin itself. Many rations contain adequate amounts of carotene and no supplementation is required. However, when the total amount of vitamin A activity in the ration is inadequate, supplementation of the ration with either carotene or vitamin A becomes necessary. In some instances, both vitamin A and a source of carotene are added and it is not uncommon for diets to contain both carotene and preformed vitamin A. It is for this reason that feeding standards commonly list requirements both in terms of vitamin A and in terms of the amount of carotene needed to satisfy the requirement. In some, such as the current

Nutrient Requirements of Beef Cattle (N.R.C., 1970), the carotene requirements are calculated from the vitamin A requirements.

Generally speaking, it is normally considered that the requirement for a given nutrient is lowest during maintenance, a period during which the animal is assumed to be neither making changes in body composition nor producing any useful product. Growth increases the requirement for the various nutrients in some proportion to the rate at which the process is achieved.

Vitamin A intakes of as little as 17 IU/kg of live weight have been reported to be sufficient to meet the maintenance requirements of mature cows (Guilbert et al., 1940). Other reports have indicated that the practical minimum requirements may be on the order of 20 to 30 IU/kg of body weight (Guilbert and Hart, 1935; Guilbert et al., 1937). Guilbert and Loosli (1951) recommended practical allowances of about 66 IU/kg of live weight, a level of intake at which small hepatic stores of the vitamin accumulated. Currently listed minimum vitamin A requirements for the maintenance of dry, mature cows range from 34 to 40 IU/kg of live weight per day and from 31 to 40 IU/kg of live weight (N.R.C., 1970) for young stock under maintenance conditions. These levels appear to be adequate for maintenance under normal conditions.

Vitamin A requirements for growth are higher than requirements for maintenance. Intakes of 32 IU/kg of body weight daily prevented night blindness in three of four calves and promoted nearly optimal rates of gain in a study reported by Lewis and Wilson (1945). Maximum rates of gain were achieved with intakes of 64 IU/kg of body weight in this study. Finishing cattle appear to require a minimum of 40 to 44 IU of vitamin A per kilogram of weight for maximum rates of body weight gain (Jones et al., 1943; Embry et al., 1962; Hansen, 1963). The N.R.C. (1970) lists the vitamin A requirements of growing and finishing animals as being from 41 IU/kg of body weight for very low rates of gain to 67 IU/kg of body weight daily for cattle making maximum daily weight gains. These amounts appear to be adequate under normal conditions.

The amount of carotene required to satisfy vitamin A requirements of calves maintained under optimum conditions has been reported to be as low as 26 µg/kg of body weight daily (Keener et al., 1942). However, Guilbert et al. (1937, 1940) reported that levels from 26 to 33 µg/kg represent minimum requirements of calves and levels of 29 µg/kg were sufficient for cows under maintenance conditions. Moore (1939a) later reported the requirements of calves to be about 35 µg/kg of body weight, lower levels of intake being accompanied by vitamin A deficiency signs. Other work (Moore et al., 1943, 1948) demonstrated that the carotene requirements of young dairy type calves may be as high as 66 to 75 µg/kg of body weight. These levels are similar to the 59 µg of carotene per kilogram of body weight reportedly required by beef calves exposed to cold stress (Keener et al., 1942).

The N.R.C. (1970) lists the carotene requirements of dry, mature pregnant cows for maintenance as being from about 85 to 100 µg/kg of body weight and that of steers and heifers under maintenance conditions as being from about 77 to 100 µg/kg of body weight. These values were calculated from vitamin A requirements. Although somewhat higher than minimum values reported elsewhere, these amounts appear to be fully adequate for maintenance.

As is the case with vitamin A, the amount of carotene required to satisfy the vitamin A requirement of growing beef cattle is higher than the amount required for maintenance purposes. Intakes of 39.6 µg (King, 1970) and of 52.8 µg of carotene per kilogram of body weight (Jones et al., 1943) have resulted in satisfactory performance in finishing cattle. Moore (1939a) obtained satisfactory rates of gain in dairy calves with intakes of about 35 µg/kg of body weight. Maximum rates of gain were achievable only with higher carotene intakes. The N.R.C. (1970) states that the amount of carotene required to satisfy vitamin A requirements for growth varies from about 108 to 195 µg/kg of live weight depending upon body weight and rate of weight gain. These levels appear to be adequate under normal conditions for the purposes intended.

Carotene and Vitamin A Requirements for Reproduction and Lactation

A number of studies have been conducted to determine the vitamin A requirement and the amount of carotene necessary to satisfy the vitamin A requirement for beef cows. There is considerable variation in the results reported from many of these studies.

The vitamin A requirement of the beef cow may not be appreciably influenced during gestation until the last 1 or 2 months of the period. Cows with little or no vitamin A reserves maintained on minimum carotene or vitamin A intakes may not successfully complete their gestation if vitamin A intake is not increased sufficiently near the end of gestation.

In an early study concerning the vitamin A and carotene requirements of cattle (Guilbert et al., 1940), it was shown that cows which received carotene or vitamin A intakes which were minimum for maintenance purposes (about 29 µg of carotene or 6 µg of vitamin A per kilogram of body weight daily) gave birth to weak calves, many of which died shortly after birth. Normal calves could be obtained by increasing the vitamin A or carotene intake to three or four times the minimum requirement for maintenance during the last month of pregnancy. As a result of this and other work, Guilbert and Loosli (1951) suggested that reasonable allowances for maintenance and reproduction in beef cows appeared to be about 132 µg of carotene or 66 IU of vitamin A per kilogram of body weight daily.

Results of a 12-year study (Madsen and Davis, 1949) indicated that satisfactory reproduction could be obtained with carotene intakes of as little as 45 µg/kg of body weight daily in many cows and, in one cow family, through four generations. However, other cows in the initial group had reproductive problems from vitamin A deficiency during their second and third gestations with intakes of as much as 60 µg/kg of body weight. Carotene intakes of 90 µg or more per kilogram of body weight provided for optimum reproductive performance and normal calves in all cases.

Results reported from another laboratory (Baker et al., 1954) indicate that total carotene intakes of as much as 60 mg per head daily for stock cows may be insufficient to prevent an increase in the rate of depletion of liver vitamin A stores toward the end of pregnancy. Some degree of depletion can be tolerated as long as reproduction and calf survival are satisfactory. However, this level of intake, when maintained into lactation, was insufficient to prevent deficiency symptoms in the calves. Intakes of 300 mg per head daily during lactation (levels in excess of 66 mg of carotene per 100 kg of body weight) resulted in normal carotene and vitamin A levels in the blood plasma and liver of suckling calves and maintained low levels of hepatic vitamin A stores in cows.

Accomplishment of a normal lactation, as such, may not greatly increase the vitamin A requirement of a cow. In one study, it was concluded that amounts of vitamin A sufficient to promote successful reproduction in dairy cows would promote normal lactation (Swanson _et al_., 1968). For beef animals, however, the criterion is probably not only the milking ability of the dam but whether the calf remains free from avitaminosis A. Under these conditions, what is referred to as the cow's vitamin A or carotene requirement is actually a combination of the cow's requirement plus the amount of vitamin A active material required to promote normal health in the calf when the cow is required to supply the activity via milk. Considering the number of factors which influence vitamin A and carotene utilization, it would not seem unlikely that considerable variation might be encountered in results of studies concerning the carotene or vitamin A requirements of beef cows when calf health becomes the criterion of evaluation.

When the carotene and vitamin A requirements of cows are reasonably well provided for during gestation, the practical carotene or vitamin A requirement during lactation may not be greatly in excess of that required during gestation, primarily because of liver vitamin A stores built up during gestation. However, cows maintained on minimal levels of vitamin A or carotene intake during gestation will likely require considerably greater amounts of vitamin A activity in order to maintain a healthy calf. For example, Madsen and Davis (1949) reported that an intake of 90 µg or more per kg of body weight daily was sufficient to promote reproduction and maintenance of calf health in all cows in their study. On the other hand, Church et al. (1956) stated that, when cows were maintained on minimum levels of carotene intake during the last one-half of gestation, the administration of as much as 440 µg of carotene per kilogram of body weight to the cows would not prevent the occurrence of vitamin A deficiency symptoms in their suckling calves.

The N.R.C. (1970) lists the amount of carotene required daily to satisfy the vitamin A requirements of dry, mature pregnant cows as being from 87.5 to 100.0 µg/kg of body weight and the vitamin A requirements as being from 34.7 to 40.0 IU/kg of body weight. These requirements, by way of comparison, are within the range of the maintenance requirements of immature cattle making little or no weight gain. Morrison (1959) recommends a carotene allowance of about 120 µg/kg of body weight daily for maintenance and gestation.

For lactation in the beef cow, the N.R.C. (1970) lists minimum requirements as 82 to 95 IU of vitamin A or 205 to 237 µg of carotene per kilogram of body weight. Morrison (1959) recommends an allowance of from 180 to 225 µg of carotene per kilogram of body weight daily. These values appear to be adequate for the purposes intended provided vitamin A nutrition has been adequate during gestation.

Calcium and Phosphorus

Methods Used to Determine Calcium and Phosphorus Requirements

Calcium and phosphorus are the primary mineral constituents of bones and teeth and their incorporation into the proteinaceous matrix of these tissues provides the strength characteristic of these materials. Calcium performs certain functions in the soft tissues in relation to enzyme activity, neuromuscular activity and membrane permeability. Phosphorus is found in greater quantities than calcium in the soft tissues and is a component not only of many of the structural compounds of the soft tissue itself but also of many of the enzyme systems which function in those tissues. Without adequate phosphorus, many of the energy-yielding enzymatic reactions could not be carried out or would proceed with reduced efficiency.

The various symptoms characteristic of a deficiency of phosphorus have been described in the literature (Huffman et al., 1933; Theiler, 1934; Bechtel et al., 1935; Kleiber et al., 1936; Morrison, 1959). One of the first visible symptoms of a deficiency of phosphorus is an unthrifty, rough appearance. This may be followed by a loss of appetite and consequent failure of the animal to make normal gains. In finishing animals, the efficiency of feed utilization will be greatly reduced. A deficiency of phosphorus appears to reduce the utilization of dietary protein and energy more markedly than it affects feed intake (Kleiber et al., 1936; Long et al., 1957).

The appearance of a depraved appetite, noted when the deficient animal chews boards, bones or other objects or eats dirt, is characteristic of a phosphorus deficiency. Stiffness of the joints and fragility of the bones have been noted. Unsteadiness, hyperirritability and difficult breathing have been observed (Van Landingham et al., 1935). Females may fail to demonstrate estrus and may not conceive (Palmer et al., 1941). Yield in milking cows may be depressed by a deficiency of phosphorus.

The use of growth and the prevention of deficiency symptoms as indicators for the determination of phosphorus requirements in ruminants has been reported (Van Landingham et al., 1935; Long et al., 1957). Success of the method is determined in part by the growth state of the animal (young rapidly growing animals will demonstrate more severe symptoms than older ones) and the length of the experimental period used. Body stores of phosphorus may be adequate to meet requirements for a considerable period of time, thus studies must be of considerable length.

Feed intake of deficient animals appears to decline slowly over a period of several weeks, whereas the rate of gain, and thus the efficiency of feed utilization, will decrease more rapidly (Long et al., 1957). Gross deficiency symptoms may not occur until after blood plasma inorganic phosphorus levels have sustained a considerable decrease, which may be 3 to 4 months after initiation of feeding of a low phosphorus diet (Van Landingham et al., 1935). Kleiber et al. (1936) reported that weight gains of yearling cattle were nearly normal for 6 months after they were changed to a low phosphorus diet.

Large body stores of calcium are present in healthy animals and considerable time may be required to deplete these stores. The external appearance of a calcium deficient animal may indicate little or nothing because feed intake and efficiency of utilization remain relatively good and the animal remains in good condition. Body weight gains may be slightly depressed, however, and in milking cows milk production may be decreased. The first visible symptom of acalciosis in the bovine may be muscular incoordination followed by partial paralysis. Tetany, often ending in death, follows in severe deficiency states. Bones become fragile and are subject to spontaneous fracture. Growth has been reported to continue at nearly normal rates for as long as 18 months after cattle were placed on diets furnishing only small amounts of calcium (Theiler et al., 1927). It appears that growth rate should not be used as the sole criteria to evaluate adequacy of calcium intake.

Levels of calcium and phosphorus intake sufficient to prevent the occurrence of deficiency symptoms and to maintain optimum rates of production and efficiency of feed utilization over long periods of time should be considered adequate under the conditions imposed. Studies in which growth rate and avoidance of gross deficiency symptoms are used as criteria of the adequacy of calcium and phosphorus intake are suited to the use of large numbers of animals. The results are useful because they are determined under practical conditions.

Bovine requirements for calcium and phosphorus have often been studied by means of mineral balance studies. Such studies have been reported by Hart et al. (1930), Long et al. (1957), Ammerman et al. (1957) and Tillman et al. (1959). Considerable work done at the South Dakota station on the relationship of vitamin D to calcium and phosphorus retention was done with balance trials (Wallis, 1937, 1938; Wallis et al., 1935).

Balance studies provide accurate means of determining mineral requirements but have certain disadvantages. Only limited numbers of animals can be utilized at a given time because of limitations on equipment and labor. The results of such studies are indicative of requirements only under controlled conditions of environment and feed and may not necessarily be indicative of requirements under other conditions. Stresses may also severely alter mineral balance and differences in stress conditions between laboratory and field situations may cause considerable difference between requirements under the two different sets of conditions. Balance studies are not easily adapted to field use. Because of these limitations, the use of balance studies is limited.

Of the several means of studying adequacy of calcium and phosphorus intake, the state of bone mineralization is perhaps the most reliable. The effects of dietary deficiency of either mineral on levels of these minerals in blood plasma are corrected by mobilization of bone mineral. Thus, dietary inadequacies result in changes in the mineral content of bones. Various means have been devised to determine the state of ossification of bone. The methods include bone ash (McCann and Barnett, 1922; Huffman and Duncan, 1935), the line test (McCollum et al., 1922; Thomas et al., 1954), radiography (McCann and Barnett, 1922; Thomas, 1952) and various modifications or combinations of these tests.

Each of these measures has certain limitations. For example, methods involving the determination of bone ash require the use of bones which demonstrate maximum changes in ossification due to small differences in calcium or phosphorus intake. One such is the costochrondral junction at the ventral end of the ribs. This area appears to show to a greater degree the same changes displayed by the humerus, femur, metacarpus and metatarsus in calves (Bechtel et al., 1936). Ossification of the ulnar epiphyseal cartilage is a good indicator in young calves, but the use of the method becomes impractical when the age of the calves exceeds about 8 months (Thomas et al., 1954). One major drawback to methods involving the measurement of bone ossification is that, with the exception of x-ray techniques, the animals from which the samples are taken generally have to be killed. Labor, equipment and materials are generally major cost factors in radiographic studies. Although these methods are reliable, other methods or combinations of methods are perhaps better suited to practical conditions.

Acalciosis or aphosphorosis each result in characteristic changes in the blood plasma. Aphosphorosis is characterized by a decrease in the inorganic phosphorus content of the blood plasma (Henderson and Weakley, 1930; Eckles et al., 1932). Depending upon the extent of body stores and the extent of deficiency of intake, the decrease in level of inorganic phosphorus may not be demonstrated for a considerable period. However, almost immediate responses have been noted with severely deficient diets (Van Landingham et al., 1935).

Although considerable variation exists between many reports concerning minimum acceptable concentrations of inorganic phosphorus in the blood plasma of various classes of cattle, it is generally considered that levels consistently less than 4 to 5 mg of inorganic phosphorus per 100 ml of plasma are indicative of phosphorus deficiency in range cattle (Stanley, 1938). Such a level appears to be adequate. Optimum growth rates have been achieved in finishing cattle in the presence of concentrations of 4.3 and 4.5 mg/100 ml of plasma, whereas levels of 2.9, 2.8 and 2.4 mg/100 ml have been accompanied by decreased feed consumption and greatly reduced rates of weight gain (Long et al., 1957).

In addition to dietary levels of phosphorus, several nondietary factors may apparently influence the level of inorganic phosphorus in the plasma. Inorganic phosphorus concentrations appear to increase up to 6 to 10 months of age in cattle (Palmer et al., 1930; Van Landingham et al., 1935) and subsequently decline slowly with increasing age (Palmer et al., 1930; Henderson and Weakley, 1930; Henderson and

Van Landingham, 1932; Van Landingham et al., 1935). Darlow et al. (1949) have also noted an apparent effect of age on plasma inorganic phosphorus concentrations.

Parturition causes a sharp but temporary decrease in plasma inorganic phosphorus concentration, but severe exercise causes an increase (Palmer et al., 1930). Considerable day-to-day variation may also occur (Henderson and Van Landingham, 1932).

Plasma calcium levels appear to be fairly well regulated under normal conditions and do not appear to have a great range of variation (Van Landingham et al., 1935; Copp, 1960). Normal concentrations of plasma calcium are generally considered to be between about 9 and 12 mg/100 ml of plasma in cattle (Palmer and Eckles, 1930; Lamb et al., 1934; Knox et al., 1941; Savage and Heller, 1947; Dowe et al., 1957). Extreme values as high as 24.4 mg and as low as 4.0 mg have been observed (Palmer and Eckles, 1930).

A negative calcium balance will eventually result in a decline in plasma calcium concentration due to depletion of body stores of the mineral. This decline has been considered as being the first measurable symptom of rickets (Bechtel et al., 1936; Thomas, 1952). Plasma calcium levels of 8 mg/100 ml or less have been observed in calves afflicted with rickets (Kuhlman and Gallup, 1939), and a value of 2.8 mg per 100 ml was observed in one cow down with milk fever (Palmer and Eckles, 1930). On the other hand, concentrations of plasma calcium as low as 7.1 and 7.6 mg/100 ml have been considered adequate (Van Landingham et al., 1935).

Concentration of calcium and inorganic phosphorus in the blood plasma appears to be indicative of the adequacy of the supplies of these minerals available for metabolism. However, observed values which fall within ranges accepted as normal are not by themselves proof of adequate intake of available minerals, since, as in the case of lactating cows, considerable depletion of body stores can be occurring in the presence of these levels under completely normal conditions. Such depletion is not harmful to the health of the animal provided that stores are repleted during a subsequent period. Plasma levels of calcium and phosphorus below ranges normally accepted as adequate appear to be reasonably good indicators of depletion of reserves and thus of inadequate intake. Because of the factors noted above, concentrations of calcium and phosphorus in the blood plasma should be used with other indices to improve the accuracy of studies to determine calcium and phosphorus requirements of ruminants. However, calcium and phosphorus concentrations are easily and quickly obtained and large numbers of such determinations can be handled with a minimum of equipment and labor.

Factors Which Influence Calcium and Phosphorus Requirements

The rate of growth has a great influence upon the amount of calcium and phosphorus required by an animal. Inadequate supplies of either or both of these minerals result eventually in a slowing or cessation of growth and other deleterious effects as has been discussed. As growth rate decreases, that is as the skeleton of the animal matures, requirements for the minerals decrease due to decreased rate of skeletal ossification. Phosphorus requirements are not directly proportional to body weight gains alone but are influenced to a considerable degree by the rate of skeletal growth (Van Landingham et al., 1935).

Differences in the maintenance requirements of cattle of various age groups, stated as amount per unit of body weight, appear to be primarily a reflection of differences in the rate of skeletal ossification. Early work showed that phosphorus requirements, per unit of body weight, may be as little as one-third as high for 2-year-old cattle as for calves. Total phosphorus requirements may not increase greatly during growth, but increased body weight reduces the requirements per unit of body weight.

Because phosphorus and calcium are both incorporated into additional increments of body mass during true growth as well as during finishing, requirements are greater for rapidly gaining cattle at a given weight than for cattle making less rapid weight gains (Preston and Pfander, 1964).

Gestation creates another demand for additional calcium and phosphorus due to the minerals which are stored in the body of the fetus. Although the total amount of calcium and phosphorus in the body of the newborn calf is not great, the total being somewhat less than a kilogram, the majority of it appears to be deposited during the last 2 months of pregnancy (Ellenberger et al., 1950; Hogan and Nierman, 1927; Hansard et al., 1966). Thus, the importance of providing adequate calcium and phosphorus to the gestating dam during this period is obvious.

Lactation places a very large demand on the bovine for calcium and phosphorus. Each kilogram of cow's milk contains about 1.2 g of calcium and about 1.0 g of phosphorus (N.R.C., 1971; Morrison, 1959). A deficiency of dietary calcium during lactation may result in reduced milk yields, but the concentration of calcium in the milk is maintained (Converse, 1954).

Dietary factors may also influence apparent calcium and phosphorus requirements. Most of the literature dealing with the availability of calcium and phosphorus from various sources concerns nonruminant animals. It appears that problems involving the availability of these minerals from different sources for ruminants are not numerous.

Statements concerning calcium and phosphorus requirements and the availability of the minerals from feedstuffs are based on the assumption that adequate amounts of vitamin D have been supplied. Vitamin D is essential to absorption of calcium and phosphorus by ruminants. Adequate supplies of the vitamin may be insured by exposure of animals to sunlight or by feeding materials known to contain sufficient amounts of the vitamin.

The availability of calcium and phosphorus in feedstuffs may have considerable influence upon the total amount required in the diet to satisfy requirements. For example, although the availability of phosphorus in most feedstuffs is about 70% (N.R.C., 1970), the availability of calcium and phosphorus from various supplemental sources may be considerably higher or lower (Ammerman <u>et al.</u>, 1957;

Morrison, 1959; Arrington et al., 1962). Thus, the source of needed supplemental mineral is an important factor in determining the effectiveness of that source in providing supplemental mineral in a ration.

Other factors, such as the ratio of calcium to phosphorus, may be important in the utilization of these minerals, particularly in the case of nonruminants (Brown et al., 1932; Shohl and Wolbach, 1936). The ratio appears to be much less critical in the case of ruminants. Excess calcium in the diet of steers has been reported to reduce feed consumption and rate of gain but to have no apparent influence upon phosphorus utilization (Dowe et al., 1957). In these trials, the highest calcium to phosphorus ratio used was 13.7 to 1 with phosphorus intakes of about 11.7 g per head daily.

Other dietary factors, such as phytic acid and oxalic acid, which have been shown to exert considerable influence on the availability of calcium and phosphorus in nonruminant diets, do not appear to be a problem in the utilization of these minerals by ruminants. There is, however, at least one report (Cook and Stoddart, 1953) in which sheep apparently suffered from a deficiency of calcium as a result of consuming weeds which contained large amounts of oxalic acid.

Calcium and Phosphorus Requirements for Maintenance and Growth

Considerable attention has been given to the study of the phosphorus requirements of the bovine. Calcium requirements do not appear to have been studied as extensively, however, perhaps because of the relative ease with which calcium requirements can be satisfied and the relatively insignificant number of problems encountered in satisfying calcium requirements under practical conditions. There is not in all cases close agreement between reports as to the amount of the minerals required for cattle of various ages with given rates of gain. Much of the apparent discrepancy appears to be due to the influence of one or more of the many factors which can affect requirements. In addition, the criterion used to determine the adequacy of a given intake of the mineral in question may also have a significant influence upon the amount which appears to be required.

Calcium and phosphorus requirements are normally stated in terms of the total amounts of the mineral required per day for animals of various weights or in terms of required concentrations of the minerals in the rations of these animals.

Calcium requirements for growth and maintenance in the bovine have been reported to be 4.4 g/100 kg of body weight, or about .17% calcium in the diet on a dry matter basis (Hansard et al., 1954). Others have reported that maintenance in the mature bovine required a minimum of about .18% calcium in the diet (Mitchell, 1947). These values appear to be fully adequate for maintenance. Bushman et al. (1968) reported that levels of about .15% of calcium in an all-concentrate diet satisfied the calcium requirement of finishing steers. It was estimated that the water given the cattle in this experiment may have contributed as much as .05% calcium to the total diet. The average calcium intake from feed in this trial was about 3.3 g/100 kg of body weight.

Dowe et al. (1957) reported that maximum rates of gain with calves weighing an average of about 261 kg were achieved with calcium intakes of about 15.6 g per head daily during each of two 140-day feeding trials. This was the lowest level of calcium intake used and would be the equivalent of 5.9 g of calcium per 100 kg of body weight daily.

Calcium requirements for maintenance of beef cattle of various weights as stated by the N.R.C. (1970) are in a one-to-one ratio to the amounts of phosphorus considered adequate. For maintenance purposes in immature animals, the values listed range from about 3.3 g/100 kg of body weight for animals weighing about 150 kg to about 2.5 g/100 kg of body weight for animals weighing up to 400 kilograms. Maintenance requirements for mature cows are listed as 2.2 to 2.6 g/100 kg of body weight. Morrison (1959) recommends an allowance of 20 g of calcium for maintenance of pregnant beef cows weighing from 409 to 545 kilograms. These amounts are probably adequate for the purposes intended.

Phosphorus requirements for maintenance in beef cattle can be related to calcium requirements. Calcium and phosphorus are retained in a ratio of approximately two parts of calcium to one of phosphorus (Wallis et al., 1935). However, differences in the availability of phosphorus from different feedstuffs combined with the relative deficiency of phosphorus in many feedstuffs may necessitate the use of somewhat higher levels of phosphorus.

Dietary phosphorus levels of less than .13% of the diet as fed to growing beef heifers from 14 to 20 months of age were inadequate in a trial conducted by Kleiber et al. (1936). These levels were used to obtain a deficiency state under which energy metabolism was studied. Long et al. (1957) reported that levels of .11 and .15% appeared to be in a critical range, whereas .19% of phosphorus in the diet of young beef cattle weighing from 160 to 230 kg appeared to be adequate. Wise et al. (1958) state that the minimum phosphorus requirement of calves 12 to 18 weeks of age is about .22% of the diet. Dowe et al. (1957) reported that diets furnishing 4.4 g of phosphorus per 100 kg of body weight were sufficient to obtain maximum rates of gain in weanling Hereford steers during trial periods of 140 days. Van Landingham et al. (1935) reported that phosphorus intakes of 8.4 g, but not of 2.9 g, per 100 kg of body weight daily were sufficient to prevent deficiency symptoms in dairy heifer calves. However, requirements of these females at 24 months of age appeared to be about 2.6 g/100 kg of body weight.

Total phosphorus intake of about 10.3 g (about 4 g/100 kg of body weight) appeared to be adequate to meet the requirements of heifers between 3 and 6 months of age in other studies (Huffman et al., 1933). Total intakes of 10 g per head daily were adequate from weaning to first parturition. Similar levels of phosphorus intake were determined to be adequate for wintering beef cattle up to 360 kg in weight (Preston and Pfander, 1964). Ammerman et al. (1957) reported that phosphorus intakes of as little as 2.4 g/100 kg of body weight maintained phosphorus equilibrium in steers weighing about 340 kg during a series of metabolism trials. On the other hand, Tillman et al. (1959) reported that intakes of 4.4 g of phosphorus per 100 kg of body weight did not meet the requirements of weanling Hereford steers when weight gains and efficiency of feed utilization were used as criteria. When plasma inorganic phosphorus levels and autoradiographic data were used as criteria, 4.4 g/100 kg of body weight were adequate.

Phosphorus requirements for maintenance in beef cattle of various weights are listed by the N.R.C. (1970) as being from 3.3 g/100 kg of body weight with weights of about 150 kg to about 2.5 g/100 kg of body weight at 400 kilograms. These levels are the equivalent of about .18 to .19% of the dry matter of a maintenance ration for cattle in these weight ranges.

Calcium and Phosphorus Requirements for Reproduction and Lactation

Calcium and phosphorus requirements for reproduction and lactation in the beef animal do not appear to have received extensive consideration. Much of the available information concerns phosphorus supplementation studies conducted with beef cattle grazing native ranges. In many of these studies, levels of 1 to 2% of phosphorus added to a protein or energy supplement fed at the rate of .45 to .90 kg per head daily have resulted in significant improvement in the criteria considered. Calcium and phosphorus requirements for reproduction are probably not greatly different from those for maintenance and the mineral required by the fetus could likely be derived from the skeleton of the dam without significantly affecting the health of the dam, providing that the dam was in good condition initially.

Calcium and phosphorus requirements of pregnant, nonlactating beef cows, as listed by the N.R.C. (1970), are from 2.2 to 2.6 g of each mineral per 100 kg of body weight. Morrison (1959) lists recommended levels of 20 g of calcium and 17 g of phosphorus for cows of all weights from about 400 to 550 kilograms. Morrison's values are recognized as being recommended allowances, whereas those of the National Research Council are minimum requirements. Preston and Pfander (1964) list the available phosphorus requirements of 450- to 550-kg cows as being 12 g per head daily.

Lactation, as has been discussed, places additional demands upon the cow for calcium and phosphorus. Preston and Pfander (1964) list the available phosphorus requirements for lactating cows as being about 21 g per head daily, with the total ration calcium being in a 2 to 1 ratio to ration phosphorus. Morrison (1959) recommends that lactating cows weighing 400 to 500 kg be given at least 30 g of calcium and 24 g of phosphorus. The values listed by the N.R.C. (1970) closely approximate those of Morrison (1959). The N.R.C. (1970) minimum requirements for calcium (25 to 28 g per head daily) and for phosphorus (20 to 23 g per head daily) for cows nursing calves during the first 3 to 4 months postpartum were obtained by addition of 2.2 g of calcium and 1.6 g of phosphorus per kilogram of milk produced to the maintenance requirement of the cow. These calculations were made on the basis of an average milk production of 7.5 kg per day and using an average availability of 70% for the calcium and phosphorus from all feedstuffs.

Effects of Level of Nutrition Upon Growth and Reproductive Capacities of the Beef Female

Although certain of the nutritive requirements of the beef female for growth, reproduction and lactation have been established with a fair degree of accuracy, certain practical considerations often influence the nutritional management of the cow herd. It may become necessary, for example, to severely limit the amount of feed consumed by cows. Under these conditions, it becomes necessary to know how best to allocate feed to the groups of animals within the herd without restricting production significantly.

Only within perhaps the last 20 to 25 years has it gradually become generally recognized that the total lifetime production of a beef female is influenced not only by her immediate past or present nutritional status but may also be significantly influenced by her nutritional status as a weanling calf and by her treatment as a young maturing cow. Consequently, considerable research has been reported in the last decade concerning the performance of beef females as influenced by various nutritional planes imposed during their growth and development as well as later in their productive life. In some instances, this research has taken the form of a study concerning the lifetime performance of beef females from weaning to removal from the breeding herd as a response to different nutritional treatments. The treatments most generally imposed in these studies are levels of protein and/or energy intake.

The present section of this review of literature will be directed toward a somewhat cursory review of some of the various aspects of the response of the beef female to her nutritional status, particularly as a heifer and as a young cow.

Probably the most common deviation from adequate nutrient intake in growing animals is undernutrition rather than excessive feeding. The results of undernutrition on the young feedlot animal have been studied to some extent (Winchester and Howe, 1955; Winchester _et al._, 1957b; Carroll _et al._, 1963, 1964). The results of these studies indicate that, in general, restriction of protein, but particularly of energy, will slow or stop growth of the soft tissues of the body. Skeletal growth may proceed but generally at a slow rate. The end result may be an animal with a relatively large frame and one which will make large compensatory gains if allowed sufficient nutrient intake. Such cattle may reach slaughter condition with carcass grades equal to but carcass weights lighter than those of cattle fed more liberally on a continuous basis.

However, the effect of a restriction of nutrient intake upon carcass composition is probably of little or no interest to the breeder who finds that he must severely limit the amounts of feed he gives to his breeding cow herd. More important to him is knowledge concerning the effect of limited nutrient intake on the growth and subsequent production of his heifers and cows. In other situations, it is not a case of how much feed can be deleted from the ration but how much supplementary feed must be added to the ration in order to obtain satisfactory performance.

A common practice in many areas is to winter the breeding herd and replacements on native ranges or native grass hay. Under many conditions, range grass does not contain a sufficient concentration of nutrients to support optimum growth and development. In an early trial (Pinney et al., 1962b), weanling Hereford heifers were fed one of three levels of supplemental winter feed, .45 kg of cottonseed meal, 1.13 kg of cottonseed meal or 1.13 kg of cottonseed meal plus 1.36 kg of oats. The cattle were pastured year-long on native pasture and the supplemental feed was given from about the middle of October to the first of April each winter. At the time the cows were 14 years of age, the cumulative results of the trial indicated that the low level of wintering nutrition resulted in greater cow longevity, a greater apparent resistance to disease and a larger number of calves born and weaned. Cows fed the low level of winter supplement gained less or lost more weight during the winter periods and gained more weight during the summer than those fed the other levels of wintering nutrition. Mature weight of the low level cows, as compared at about 8.5 years of age, was about 23 kg less than the weight of cows fed the highest level of winter supplement.

In later studies (Pinney et al., 1963), even lower levels of wintering nutrition were used. Feeding heifers at a level sufficiently low to cause them to lose 73 g per head daily during the first winter and a total of 71 kg during the second winter resulted in a significant difference in body weight at 2.5 years of age as compared to cows which were fed more liberally. However, only slight differences (statistically nonsignificant) existed in height, length and width measurements. A similar study, but one in which a higher level of winter nutrition was used as the highest plane of winter nutrition, resulted in similar findings (Pinney et al., 1960).

Other investigations have also shown that severely restricting the body weight gain of heifers during their first and subsequent winters may lengthen the time required for them to reach mature weight and may result in slightly reduced mature weights (Ludwig et al., 1967). Large compensatory weight gains on pasture for cattle fed restricted rations the previous winter have been a common observation in these studies.

The effects of greatly excessive levels of wintering nutrition have also been studied. Ludwig et al. (1967) reported the effects of a full feed of a 50% concentrate diet fed to heifers during their first and subsequent winters. This level of nutrition, administered for eight consecutive winters, resulted in cows which were excessively fat, reduced milk production and produced a tendency toward increased incidence of disease and calving problems. Arnett and Totusek (1963) reported similar results from their study and indicated that another effect of such a high level of wintering nutrition appeared to be an increase in the number of services required per conception. Greatly increased cow maintenance cost was observed in both studies. It is apparent that the energy intake of growing heifers and cows can be too high to provide optimum development. A possible alternative would be to provide relatively high levels of nutrition for the first year or two and reduce it in subsequent winters.

Only a few data are available at present concerning the effects of switching level of wintering nutrition early in the life of the cow. In one such trial (Smithson et al., 1963), one group of heifers was fed to maintain their weight during the first winter and to prevent a loss of more than 5% of their fall weight the second winter. Heifers in a second group were fed to gain about .45 kg per head daily the first winter and then allowed to lose up to 20% of their fall weight the second winter. A third group was fed at the higher level during both winters. At 2.5 years of age, little difference existed in physical dimensions between cows from the three groups. In another trial, Ludwig et al. (1967) found that switching from a full feed of a high-concentrate diet during the first three winters to a level of feed which permitted a loss of 10% of the fall body weight during the fourth and subsequent winters produced well-grown cows. However, such treatment appeared to reduce the longevity of the cows and to reduce the rate of gain of their calves. Damage done during the early winters to the milk producing ability of the cows by the high level of nutrient intake appeared to be irreversible. However, subsequent reproductive performance of cows treated in this manner was comparable to that of cows fed more moderate levels of wintering nutrition. Thus, it appears that excessive levels of nutrition have some effects that cannot be corrected by later changes in nutrition.

The results of these studies indicate that cows of satisfactory size having adequate skeletal development and body condition can be produced with levels of wintering nutrition which permit daily weight gains of from .2 to .3 kg during the first winter and which result in losses of up to 10% of the fall body weight during the second and subsequent winters. Attainment of body weights equal to or nearly equal to those attained by cattle fed more liberally during their growth may require as much as 4 to 5 years. However, effect of early nutrition on the growth rate of the cow is probably secondary in importance to a consideration of its effect on the reproductive capacities of the cow and performance of her calf.

One means of increasing the lifetime returns of the beef cow is to increase the number of calves which she produces. A common means of achieving this end is to attempt to breed the heifer at about 15 months of age so that her first calf is produced at the time she is about 2 years of age. Provided that the heifer is sufficiently well developed, breeding at or shortly after puberty to obtain the first calf at a cow age of 2 years has no apparent adverse effect on the cow or her lifetime reproductive performance (Pinney _et al_., 1962b; Turman _et al_., 1963a,b). However, management is of greater importance when heifers are bred to calve first at 2 years of age. A greater incidence of calving difficulty may be encountered.

If heifers are to be bred to calve at 2 years of age, they must have reached sexual maturity and established a regular estrual cycle by 15 months of age. Several factors have been shown to influence the age at which puberty occurs in beef cattle, including breed (Reynolds et al., 1963; Wiltbank et al., 1966), heterosis (Kaltenbach, 1962; Wiltbank et al., 1966) and ambient temperature (Dale et al., 1959). Turman et al. (1963b) state that the most important factor in bringing about early puberty in beef females is the nutritional level at which the heifers are maintained from weaning to puberty.

Considerable variation is present in the age at which puberty has been reported to occur in Hereford heifers managed under apparently adequate nutritional regimes. Arije and Wiltbank (1969) reported a study of 298 heifers sired by 27 different bulls. The average age at puberty in these heifers, as indicated by the sterile bull technique, was 436 days and the average weight at puberty was 251 kilograms. Turman et al. (1963b), however, state that the average age at which first estrus occurred in Hereford heifers in their study, as determined by the same technique, was about 371 days and the average weight was 232 kilograms. Clanton and Zimmerman (1970) reported that Hereford heifers fed levels of protein and energy sufficient to promote weight gains of .37 kg per head daily during their first winter reached puberty at 384 days of age. The weight at which puberty occurred was not indicated, although 93% of the heifers had cycled by the time the average weight of the group was 225 kilograms.

It appears that the age and weight at which puberty is attained are subject to considerable influence from factors not directly associated with the nutritional status of the animal. Genetics appear to play a considerable role. Thus, a direct comparison of the results of one study with those of another on a nutritional basis alone is probably not an entirely valid procedure.

It is clear from these studies, however, that the nutritional treatment of the weanling heifer can influence to a considerable degree both the weight and age at which a heifer attains puberty. Turman et al. (1963b) reported that heifers initially weighing 199 kg and fed to gain approximately 0, .02 and .45 kg per head daily during their first winter, after which they were placed on native pasture, reached puberty at an age of about 386, 373 and 353 days, respectively, and weighed 205, 229 and 248 kg, respectively. The low level of wintering resulted in delayed puberty, delayed time of conception and reduced the total number of heifers which conceived.

Several other investigators have reported that a low level of wintering nutrition, one which results in little gain or loss of weight during the first winter, delays puberty in the Hereford female (Pinney et al., 1960, 1963; Ludwig et al., 1967). Total gains as high as 9.98 kg per head (about 59 g per head daily during a 165-day wintering phase) have also been associated with delayed puberty as compared to the performance of heifers which gained 23.31 or 39.92 kg during the first winter (Pinney et al., 1962b). Levels of feeding which resulted in gains of about .28, .45 and .68 kg per head daily during a 132-day wintering period resulted in ages at puberty of 433, 411 and 388 days, respectively (Short and Bellows, 1971). However, in a study in which a full feed of a 50% concentrate ration was used as the highest level of wintering for several consecutive winters, no advantage was observed with respect to calving date (which can be used as a rough indicator of the occurrence of puberty under the proper conditions), over feeding to obtain a weight gain of .45 kg daily the first winter and allowing a loss of less than 10% of the fall body weight in subsequent winters (Pinney et al., 1962a; Ludwig et al., 1967).

The effect of low levels of wintering nutrition with respect to delay in breeding and conception at puberty also extend into later reproductive cycles, causing subsequent calf crops to be dropped at a later average date than those from cows fed more moderately. This effect may be seen up to about the fourth calf crop (Turman et al., 1965; Ludwig et al., 1967). A portion of the effect of a low level of wintering nutrition the first winter can be overcome by switching to a higher one during the second winter prior to the first parturition (Smithson et al., 1963). The reverse process, changing from a high level the first winter to a low level the second winter, may result in a delay in rebreeding.

Restricting protein intake can also influence the onset of puberty. Feeding levels of protein approximating 60% of the N.R.C. (1958) levels recommended for calves gaining .45 kg per head daily delayed puberty about 75 days as compared to the age at puberty of heifers fed 100% of the recommended level (Clanton et al., 1964). A comparable delay was obtained by restricting energy intake to about 80% of the level recommended for heifers gaining .45 kg per head daily, and a greater delay resulted when both energy and protein were restricted. Similar effects of protein and/or energy restriction have been reported by Bond and Wiltbank (1970).

Restricting the energy intake of beef females during the first and subsequent winters may result in reduced conception rates (Pinney et al., 1960, 1963; Smithson et al., 1963) and in slight reduction in the birth weight of calves born to these cows (Renbarger et al., 1964; Smithson et al., 1966). However, these effects are reduced as the cow nears maturity. It is also apparent from these studies that adequate energy intake is probably more critical than adequate protein intake, although both must be supplied in adequate amounts to obtain maximum reproductive efficiency.

The weaning weight of calves from cows severely restricted in nutrient intake during growth is also reduced, most particularly during the first and second calf crops. This effect appears to be due primarily to reduced milk production and consequent slow growth of the calf (Howes et al., 1960; Swanson and Hinton, 1961; Renbarger et al., 1964).

The importance of the quantity of milk produced by a cow as a factor influencing calf gains from birth to weaning has been well established (Nelson et al., 1961; Pope et al., 1963; Melton et al., 1967; Serwanja et al., 1969). Milk production of the cow during the first 3 to 4 months of the calf's life appears to be of greater importance than that produced later (Pope et al., 1963; Howes et al., 1960). However, as the cow attains mature size and weight, differences in milk production due to level of wintering nutrition diminish. The performance of older females appears to be less affected by either low or high planes of nutrition.

Many of the reproductive problems encountered with young cows, particularly that of rebreeding for the second calf, appear to be related to inadequate protein and/or energy intake prior to and subsequent to the birth of the first calf. Inadequate nutrient intake prior to calving results in an extended postpartum anestrus period, poor conception rates and reduced milk production. Inadequate nutrient intake subsequent to calving simply compounds the problem.

Results of the cited research indicate that satisfactory growth of heifers can be obtained by feeding to permit gains of .25 to .35 kg per head daily during the first winter and losses of up to 10% of the fall body weight during the second and subsequent winters. However, when reproductive data are taken into account, it appears that permitting a loss of 10% of the fall weight the second winter may result in some delay in rebreeding for the second calf crop and possibly a small reduction in conception rates. For the first two to four calf crops, calves from cows wintered under these conditions may be smaller at birth and at weaning than calves from cows wintered with higher nutrient intakes. However, this effect, as with the other effects of undernutrition, tends to disappear with increasing cow age.

Under practical conditions, several factors have to be taken into consideration in the evaluation of wintering programs for replacement heifers and young cows. Under some conditions, savings in winter feed costs may more than offset the losses due to a small drop in conception rates and the production of smaller calves at weaning. Other factors, such as increased cow longevity, may provide further incentive for choosing a program of restricted winter feeding.

METHODS AND PROCEDURE

The objective of this experiment was to measure the effects of level of wintering nutrition and pasture treatment upon growth and reproduction of Hereford heifers from weaning to 4 1/2 years of age. Levels of certain blood constituents were determined at periodic intervals throughout the study as additional indicators of adequacy in intake for some major nutrients and for measures of general health of the animals. Data pertaining to weight and feed are reported in the English system, even though the metric system was used in the Review of Literature section. This was considered desirable in view of present common usage and the ease of application of results to practical farm and ranch conditions.

Three hundred native weanling Hereford heifers were purchased in October, 1965, from a South Dakota ranch for use in this experiment. The cattle arrived at the Norbeck Pasture Research Center on October 22 and were gate cut into six pens of 50 each. After arrival and until the experiment was started on November 11, they were fed a ration of 4 lb of alfalfa-brome hay, 2 lb of a 30% protein, corn-soybean meal supplement which furnished 10,000 IU of vitamin A and 350 mg of chlortetracycline per head daily and corn silage to appetite. All calves were vaccinated against brucellosis during this preliminary period.

Several of the heifers were affected with respiratory diseases shortly after arrival and were treated separately from the remainder of the group. Most of them had recovered by the time the experiment was started. The few which were being treated at that time were allotted on a weight basis and distributed uniformly among all the experimental treatment groups.

The experimental design utilized was a 2 x 3 factorial which included two levels of wintering with three pasture treatments. Each of the six treatments was replicated four times. The higher level of wintering nutrition (HW) was designed to result in winter gains of about 1.5 lb per head daily during the first drylot period, .5 lb per head daily up to calving time the second winter and to provide for maintenance of fall weights up to calving time the third and subsequent winters. The lower level of wintering nutrition (LW) was designed to result in gains of about .75 lb per head daily during the first winter, maintenance of fall weights up to calving time the second winter and a loss of about 10% of the fall body weight up to calving time the third and subsequent winters.

The three pasture treatments used with each of the levels of wintering nutrition were as follows:

1. Native prairie pasture only for a full pasture season (designated P1). The native pastures consisted of mixed prairie swards consisting of approximately 50% Kentucky bluegrass, Poa pratensis; 30% western wheatgrass, Agropyron smithii; 10% blue grama, Bouteloua gracilis; 5% green needlegrass, Stipa viridula, and 5% other species.
2. A short season pasture consisting of smooth bromegrass, Bromus inermis; intermediate wheatgrass, Agropyron intermedium, and Teton alfalfa, Medicago sativa, (P2).

3. A series of different pastures to provide a long grazing period (P3). The pastures and the order in which they were grazed were (a) crested wheatgrass, *Agropyron desertorum*; (b) a mixture of smooth bromegrass, intermediate wheatgrass and Teton alfalfa; (c) sudangrass, *Sorghum vulgare sudanense*, or switchgrass, *Panicum virgatum*; (d) regrazing of the bromegrass-intermediate wheatgrass-alfalfa pasture and (e) Russian wildrye, *Elymus junceus.*

The feeds used in the experiment, with the exception of free-choice mineral supplements and the protein supplement fed during the first 20 days after the calves were received, were raised on Pasture Research Center land and were of types common to the area. Hay fed included native prairie, alfalfa, bromegrass, crested wheatgrass and various combinations. Both corn, *Zea mays,* and sorghum, *Sorghum vulgare,* silages were fed. Oat grain, *Avena sativa,* was fed for a period of 5 days during the first wintering period to all calves following a blizzard which occurred in March, 1966, and for 35 days thereafter to the HW calves until they were turned on pasture. Trace-mineralized salt, dicalcium phosphate and ground limestone were offered free choice at all times. Feed consumption each winter was estimated on the basis of weights of randomly selected loads of each of the various feeds. Weights were obtained at approximately weekly intervals.

Representative samples were taken at approximately weekly intervals during each wintering phase from the feeds being fed at the time of sampling. The average composition of the feeds fed during each drylot phase, as determined by chemical analysis (A.O.A.C., 1960), is shown in table 1.

Two hundred forty of the heaviest calves from the initial 300 were assigned at random on the basis of stratified weights to experimental treatment with four replicates of 10 head in each of the six experimental groups. The six heaviest animals in each replicate were designated as "tester" animals for the pasture grazing studies, while the four lightest ones were designated "put and takes" to be removed from or added to a pasture to adjust grazing pressure. The remaining 60 head of heifers, the lightest animals from the group of 300, were assigned at random on the basis of stratified weights into two groups of reserve animals which were to be used to replace any females lost or culled during the course of the experiment. They were designated as replacements in the HW or LW groups and wintered accordingly.

During the first wintering period, the heifers were managed as six groups of 50 head each with three groups assigned to each level of wintering nutrition. They were wintered without an attempt to separate with respect to pasture treatment. They were separated on the basis of pasture treatment during the wintering phase of the two subsequent winters, 1966-67 and 1967-68. During the winter of 1968-69, the cattle were managed simply as two large groups separated according to level of wintering nutrition only. At calving in 1968 and 1969, cows were separated as they calved from the remainder of the groups. In 1968, cows with calves were fed a full feed of corn silage and limited amounts

TABLE 1. AVERAGE CHEMICAL ANALYSIS OF WINTERING FEEDS

Feed	Dry matter (%)	Crude protein (%)	Calcium (%)	Phosphorus (%)	Carotene (mg/lb)
	Drylot Phase, 1965-1966				
Alfalfa hay	87.0	14.4	1.38	.17	3.6
Alfalfa-crested wheatgrass hay	89.6	14.9	.84	.23	8.9
Native hay	89.4	6.3	.40	.14	12.7
Oat hay	90.3	8.0	.26	.22	8.0
Oat grain	92.8	12.1	.11	.37	.1
Corn-sorghum silage mix	34.7	2.7	.19	.05	.9
	Drylot Phase, 1966-1967				
Alfalfa-crested wheatgrass hay	83.0	12.4	.75	.16	8.5
Good quality native hay	87.7	7.8	.44	.17	18.4
Poor quality native hay	86.7	6.0	.40	.08	3.1
Corn silage	33.5	3.0	.13	.06	2.0
Sorghum silage	31.1	2.7	.14	.05	4.9
	Drylot Phase, 1967-1968				
Alfalfa-grass hay	89.3	8.6	.56	.18	8.5
Alfalfa-native hay mix (1/3 alfalfa)	89.6	6.6	.46	.13	6.2
Crested wheatgrass hay	90.8	6.8	.21	.18	9.1
Corn silage	38.4	2.9	.14	.07	.6
	Drylot Phase, 1968-1969				
Alfalfa-crested wheatgrass hay	86.7	13.5	.70	.22	5.0
Native hay	88.8	8.1	.25	.17	9.0
Slough hay	84.4	6.7	.26	.18	10.1
Corn silage	30.0	2.0	.07	.06	1.8

of alfalfa hay. In 1969, they were fed a full feed of alfalfa-crested wheatgrass hay until they were put on pasture.

During the first wintering period, all calves were fed about 6 lb of alfalfa-crested wheatgrass hay and 2 lb of native hay per head daily. Calves assigned to the higher level of wintering nutrition were fed mixed corn-sorghum silage to appetite, while those assigned to the lower level of wintering nutrition were restricted to 12 lb of the mixed silage per head daily. In subsequent wintering periods, HW females were given higher quality feeds and/or greater amounts of high quality feeds than were the cattle assigned to LW.

Following the first wintering phase, the cattle were separated into their assigned replicate groups and placed on pasture as the pastures became ready for grazing. Cattle were pastured in replicate groups of 10 head each with the exception of periods when some of the "put and take" animals were removed from the pasture to adjust grazing pressure. In later years, after some of the tame pastures had become better established, yearlings were pastured with the cows to obtain better utilization of some of the swards. All pastures were grazed in accordance with good management practices.

At the end of the pasture season for the cows in P2, which was generally about the last part of September or the first part of October, the cows in this group were brought into drylot, weighed, their calves weighed and the cows offered a ration of alfalfa-crested wheatgrass hay or crested wheatgrass hay until such time as the cows in the other treatment groups were removed from pasture. At that time, all cows and calves were weighed and within 1 to 3 days weaning took place. When cows in pasture treatments P1 and P3 were moved from pasture to drylot, all cows were sorted according to the management practice used that year and feeding of the drylot phase rations was begun.

While not on pasture, the cows were held in lots, one end of which was covered by a pole barn. The remainder of the lot was not covered and no portion of the lots was paved. Feeding was done in fence-line feed bunks at the end of the lot opposite the barn. During the 1968-69 wintering period and at other times late in the wintering period when the lots were excessively muddy, the cows were maintained in separate small pasture areas respective to level of wintering nutrition. Feeding was done on the ground.

Breeding during the first two breeding seasons was carried out by artificial insemination (AI) only. The breeding season during these 2 years was limited to about 6 weeks. In subsequent years, the 6-week AI period was followed by a 6-week period during which clean-up bulls were used. During the 1968 breeding season, heifers which had not calved previously were run with bulls during the entire breeding season.

Calving took place on pasture in 1967 but in succeeding years was conducted primarily during, but near the end of, the drylot phase. At birth, each calf was ear tagged and sex, weight, date of birth and dam number were recorded. Calf defects and problems associated with calving were also recorded. Additional data obtained on the calves included periodic weights from birth to weaning. Bull calves were left intact until after weaning.

Blood data, which included packed cell volume and hemoglobin concentration of the whole blood, calcium, inorganic phosphorus, vitamin A and carotene concentration of the plasma, were obtained as indicators of the nutritional adequacy of the various dietary treatments imposed. Blood samples were collected from all cows during the first 3 1/2 years of the experiment at periods planned to coincide roughly with the peak of the pasture season, late pasture season, beginning of the drylot phase immediately after P1 and P3 cows had been taken off pasture and near the end of the drylot phase before any of the cows had calved.

Blood obtained by jugular venipuncture was collected in heparinized tubes, labeled, placed in an insulated chest to cool or keep from freezing as the situation demanded and transported to the laboratory. Upon arrival, the packed cell volume and hemoglobin concentration of each sample were determined. Packed cell volume was determined by the microhematocrit method and hemoglobin by the method of Crosby et al. (1954). The plasma was then removed from each sample and frozen until such time as analyses for carotene, vitamin A, calcium and inorganic phosphorus could be undertaken. Vitamin A and carotene were determined by the method of Koehn and Sherman (1940), inorganic phosphorus by the method of Fiske and Subbarrow as described by Hawk et al. (1954) and calcium concentration was determined by atomic absorption spectroscopy in the presence of .5% lanthanum.

Individual cow weights were obtained at intervals throughout the experiment, although some periodic weights were not obtained while the cattle were on pasture. Weights were obtained on all cows at the beginning and end of the pasture season and whenever the cattle were moved to a different pasture. Calves were weighed at the time cows were weighed.

After the breeding season of 1968 and in subsequent years, cows were culled from the herd for having failed to bear a calf in 2 consecutive years. Cows were also culled when their physical condition was such that disposal was considered advisable or was imperative.

Weight data obtained from the cows and calves and blood data obtained from the cows were analyzed using the least squares analysis of variance for factorial design and Duncan's new multiple range test as described by Steel and Torrie (1960). Data pertaining to the incidence of calving problems, number of calves weaned and similar data were subjected to Chi-square tests.

RESULTS AND DISCUSSION

Growth

Data pertaining to body weights and body weight gains of the experimental animals during the different phases of each of the first 4 years of this trial are shown in tables 2, 3, 4 and 5. Data are shown separately for the drylot and pasture phases within each year. Within each phase, data are shown for each of the six pasture treatment groups and are combined to illustrate the effect of level of wintering nutrition and pasture treatments.

The data have not been broken down within the treatment groups to show the weights of lactating and dry cows. The emphasis in this study was on the growth of the cows rather than their production as such. Growth continues in the presence of lactation when adequate feed is available, and under these conditions reproduction has no great effect on growth rate. It was felt that, although some small improvement in accuracy might be obtained by separating the data accordingly, the overall treatment averages would likely be as representative of growth as would be the averages of smaller groups. Additionally, each of the treatment groups contained lactating cows and thus the effect of lactation would have been distributed over all treatment groups.

It will be noted there are some apparent discrepancies between the tabular weight data and the data cited in the discussion. Several substitutions were made during the course of this trial, each of which would have required revision of numerous data in order to obtain complete agreement. Very little, if any, improvement in the accuracy of the data would have resulted from such revision. Therefore, body weight and weight gain data have been corrected to only the earliest period in which a substitution was made.

First Year (November, 1965, to November, 1966)

Average body weight of the heifers at the initiation of the experiment was about 355 lb (table 2). During the first wintering phase, calves assigned to each level of wintering nutrition gained weight at about the same daily rate until late in the period. HW females would not consume appreciably more corn silage than the amount offered LW females. After oats grain was added to the HW ration, body weight gains of the HW females were appreciably greater than those of LW females.

Overall, HW cattle gained an average of 53 lb more weight per head than did LW cattle. Average daily gains were 1.08 and .82 lb per head daily for HW and LW cattle, respectively ($P < .01$). Even though the rate of weight gain of the HW females was greater late in the wintering period, their overall rate of weight gain was not as great as had been planned. This was due primarily to their inability to consume appreciably greater quantities of energy in the form of the ration provided.

Average daily weight gains for the first drylot phase for cattle assigned to the different pasture treatments were 1.00, .90 and .96 lb per head daily for those assigned to P1, P2 and P3, respectively. Average daily weight gains of P1 and P3 females were not significantly

TABLE 2. WEIGHTS AND WEIGHT GAINS, NOVEMBER, 1965, TO NOVEMBER, 1966 - FIRST YEAR[a]

Pasture treatment	H1	H2	H3	L1	L2	L3	Average H	Average L	Average P1	Average P2	Average P3
					Drylot Phase, 1965-1966						
Total days in phase	193	204	189	191	204	188	195	194	192	204	188
Initial wt, Nov., 1965, lb	360	353	351	353	358	354	355	355	356	356	352
Final wintering wt, lb	570	576	551	524	502	513	566[d]	513	547[b]	539[b,c]	532[c]
Total drylot gain, lb	210	223	200	171	144	159	211	158	190	183	180
Avg daily gain, lb	1.09	1.09	1.06	.90	.70	.85	1.08[d]	.82	1.00[d]	.90[e]	.96[d,e]
					Pasture Phase, 1966						
Days on pasture	164	105	167	165	105	168	145	146	164	105	167
Final pasture wt, lb	738	718	755	725	680	712	737	706	732	699	734
Total gain, lb	168	142	204	201	178	199	171	193	184	159	201
Avg daily gain on pasture, lb	1.02	1.35	1.22	1.22	1.69	1.18	1.20	1.36	1.12	1.52	1.20
Wt, Nov., 1966, lb	738	740	755	725	713	712	744[d]	717	732	726	734
Avg daily gain, pasture to Nov., lb	1.02	1.02	1.22	1.22	1.32	1.18	1.08	1.24[b]	1.11	1.17	1.20

[a] Statistical comparisons are made only between levels of wintering and between pasture treatments.

[b,c] Means on same line not bearing same superscript are different ($P < .05$).

[d,e] Means on same line not bearing same superscript are different ($P < .01$).

different nor were average daily gains of P2 and P3 females. However, P1 females appeared to have gained faster ($P < .01$) than did P2 females during the first winter. Differences in date of pasture and the body weight changes which occurred as a result of handling and temporary changes in rations during the intervening period of time may have been responsible for this apparent difference.

Body weight gains made on pasture the first season were inversely related to body weight changes made during the preceding winter. HW females gained an average of 171 lb while on pasture, whereas the LW females gained 193 lb during the same period. Final pasture weights as the cattle in each of the pasture treatment groups were removed from pasture were taken over a period extending from September 16 to November 3 and were not treated statistically because of the range of time over which the weights were taken. All cattle were weighed in November at the time P1 and P3 cattle were removed from pasture. At that time, P2 heifers had been in drylot for 48 days. The difference between the average weights of cattle in the higher and lower levels of wintering groups was 27 lb at that time, or 4 lb less than the difference which existed when only the final pasture weights were considered. The difference of 27 lb was significant ($P < .01$). Cattle wintered on the lower level of wintering nutrition had not reached the same average weight at the end of the first pasture season as those in the HW group, even though they made greater weight gains on pasture than did heifers in the HW group.

Average daily gains made during the period from time on pasture to time of the November weight were 1.08 and 1.24 lb daily ($P<.05$) for HW and LW cattle, respectively. Several investigators have noted that body weight gains during a period of liberal nutrient intake tend to be inversely related to weight gains made during a previous period of more restricted nutrient intake (Winchester and Howe, 1955; Pinney *et al.*, 1960, 1963). The compensatory gains made by cattle in the studies cited, as in the present study, tended to reduce differences in body weight which existed at the end of the period of restricted nutrient intake.

Cattle assigned to P1, P2 and P3 gained 1.11, 1.17 and 1.20 lb per head daily, respectively, during the period from initial pasture date to November 3. The differences which existed between the daily gains of the cattle in the different pasture treatment groups during this period of about 165 days were not statistically significant.

Second Year (November, 1966, to November, 1967)

Data in table 3 show the body weights and weight gains made by the cattle during the second year of the experiment. During the winter of 1966-1967, the cattle were managed as six separate lots, each being composed of the cattle from one level of wintering-pasture treatment group.

Weights are shown as precalving weight as well as a final drylot weight. The precalving weights shown for cattle assigned to P1 and P3 are the weights of the cattle in those treatments immediately before they were placed on pasture May 9 and April 18, respectively, and are

TABLE 3. WEIGHTS AND WEIGHT GAINS, NOVEMBER, 1966, TO NOVEMBER, 1967 - SECOND YEAR[a]

Pasture treatment	H1	H2	H3	L1	L2	L3	Average H	Average L	Average P1	Average P2	Average P3
Drylot Phase, 1966-1967											
Total days in phase	187	251	167	186	251	167	202	201	186	251	167
Wt, April-May, 1967 (precalving), lb	875	892	890	777	802	786	886[d]	788	826	847	838
Total drylot gain, Nov. to April-May, lb	137	149	135	52	94	74	140	73	94	122	104
Avg daily gain, Nov. to April-May, lb	.73	.87	.81	.28	.50	.44	.80[d]	.41	.50[d]	.68[e]	.63[d,e]
Final drylot wt, lb	875	867	890	777	774	786	877[d]	779	826	820	838
Avg daily gain (drylot phase), lb	.73	.59	.81	.28	.37	.44	.71[b]	.36	.50	.48	.63
Pasture Phase, 1967											
Total days in phase	183	128	205	184	128	205	172	172	184	128	205
Final pasture wt, lb	956	974	1088	990	922	1035	1006	982	973	948	1061
Total gain, lb	81	107	202	213	156	250	130	206	147	132	226
Avg daily gain, lb	.44	.84	.99	1.16	1.22	1.22	.76	1.20	.80	1.03	1.10
Wt, Nov., 1967, lb	956	993	1088	990	927	1035	1012[b]	984	973[d]	960[d]	1062
Avg daily gain, pasture to Nov., 1967, lb	.44	.76	1.00	1.16	.94	1.22	.73	1.11	.80	.85	1.11

[a] Statistical comparisons are made only between levels of wintering and between pasture treatments.

[b,c] Means on same line not bearing same superscript are different ($P < .05$).

[d,e] Means on same line not bearing same superscript are different ($P < .01$).

also listed as the final drylot weights. The April-May weight shown for P2 cattle was taken on May 5, while that shown as the final drylot weight was taken on May 25 as the cattle were being put to pasture. Several calves had been dropped in the P2 lot by the time the cattle were put on pasture. Thus, the precalving weights are probably a better basis for comparison of cattle weights in the different treatment groups.

During the period from early November to the time the precalving weight was taken the following spring, HW cattle gained an average of 140 lb, while the LW cattle gained an average of 73 pounds. Average daily gains of .80 lb for the HW cattle were greater ($P < .01$) than the average daily gains of .41 lb per head daily made by the LW cattle. Weight gain in each group was in excess of planned wintering gain. The HW cattle were heavier ($P < .01$) than LW cattle both at the precalving weight and when the final drylot phase weights were taken. When average daily gains for the entire drylot phase were considered, HW cattle gained .35 lb per head daily more than did the LW cattle, a difference which was statistically significant ($P < .05$).

Within each level of wintering group, P2 cattle appeared to have gained the most weight during the period from November to the time of the precalving weights. This may be due to the difference in type of feed and amount of fill which existed at the time the November weights were taken (i.e., cattle coming off pasture had been grazing forage with a high moisture content, while those in drylot had been consuming dry hay). Some variation may have also resulted from differences in dates on which weights were taken. However, the difference in gain between P2 cattle and the other groups within each level of wintering group was relatively small. Even so, the average daily gain of P2 cattle from November to the time of the precalving weight was greater ($P<.01$) than that of P1 cattle.

The HW cattle averaged 98 lb heavier than the LW cattle at the time they were placed on pasture in 1967. The difference was significant ($P<.01$) and reflects the greater weight of the HW cattle at the beginning of the drylot phase as well as the greater body weight gains they made during the 1966-67 drylot phase.

During the pasture phase of 1967, the LW cattle again made greater body weight gains than did the HW cattle. However, HW cattle were 24 lb heavier than LW cattle on the basis of average final pasture weights and about 28 lb heavier when weights were taken in November. These were about the same differences which existed in average weights of the cattle in the two groups a year earlier at the same respective times.

Within each of the level of wintering nutrition groups, P3 cattle made the greatest body weight gains from the time they were placed on pasture to November. Within the LW group, L1 appeared to show more compensatory gains in relation to the comparable HW group than did L1 or L2 groups. However, H1 cattle had 18 calves as compared to four calves in the L1 group. Calf numbers were fairly well balanced between H2 and L2 and between H3 and L3 cattle.

When the data were averaged for the different pasture treatment groups, the effects of the series of pastures (P3) on weight gains become apparent. Cattle in P3 gained more weight during the pasture season than did cattle in either of the other two pasture treatment groups and were heavier ($P<.01$) than those cattle at the time the November weights were taken. P3 pastures had become better established during the second year of the study and thus afforded considerably better grazing.

Third Year (November, 1967, to November, 1968)

During the portion of the drylot phase from November, 1967, to the time the precalving weight was taken in March, 1968, HW cattle gained an average of 104 lb and LW cattle gained only 4 pounds (table 4). HW cattle at this time were about 127 lb heavier than LW cattle. Some weight loss was experienced by cattle in all lots from this time until the final drylot weights were taken immediately before the cattle in each of the respective lots were placed on pasture. This weight loss, and differences in amount of weight lost between groups within level of wintering nutrition treatments, was likely due in large part to differences in number of calves dropped before the cattle were placed on pasture.

P3 cattle were heavier than P1 or P2 cattle when the precalving weights were taken and at time they were placed on pasture. The advantage in weight gain from the previous pasture season had apparently carried through the winter.

TABLE 4. WEIGHTS AND WEIGHT GAINS, NOVEMBER, 1967, TO NOVEMBER, 1968 - THIRD YEAR[a]

Pasture treatment	H1	H2	H3	L1	L2	L3	Average H	Average L	Average P1	Average P2	Average P3
Drylot Phase, 1967-1968											
Total days in phase	186	235	155	186	235	158	192	193	186	235	156
Wt, March, 1968 (precalving), lb	1069	1110	1171	1010	929	1030	1116[d]	989	1039[d]	1020[d]	1100
Total gain, Nov. to precalving, lb	113	117	82	20	-3	-5	104	4	66	57	39
Avg daily gain, Nov. to precalving, lb	.80	.83	.59	.14	-.02	-.04	.73	.03	.47	.40	.28
Final drylot wt, lb	1034	1051	1172	952	906	1027	1086[d]	962	993[d]	978[d]	1100
Total gain, Nov. to pasture date, lb	78	58	84	-38	-26	-8	73	-24	20	16	38
Pasture Phase, 1968											
Total days in phase	191	134	221	191	134	218	182	181	191	134	220
Final pasture wt, lb	1127	1115	1137	1073	1058	1029	1126	1053	1100	1086	1083
Total gain, lb	92	91	-31	122	153	13	51	96	107	122	-9
Wt, Nov., 1968, lb	1127	1173	1137	1073	1090	1029	1146[d]	1064	1100[b,c]	1132[c]	1083[b]
Avg daily gain, pasture to Nov., lb	.49	.72	-.12	.64	1.06	.06	.36	.59	.56	.89	-.03

[a] Statistical comparisons are made only between levels of wintering and between pasture treatments.

[b,c] Means on the same line not bearing the same superscript are different ($P < .05$).

[d,e] Means on the same line not bearing the same superscript are different ($P < .01$).

Several of the cows from each pasture and wintering group were culled from the experimental herd in October, 1968, about 6 weeks after P2 cattle were removed from pasture and 3 weeks before P1 and P3 cattle were removed from pasture. All weight and weight gain data shown for the pasture phase of 1968 have been corrected for the removal of these animals, although such correction, as noted, gave rise to apparent discrepancies.

During the 1968 pasture season, HW and LW cattle gained an average of 51 and 96 lb, respectively. By November, the weight gains since March, 1968, amounted to 66 and 107 lb, respectively. But, as in previous years, the HW cattle were heavier ($P < .05$) than the LW cattle at the time the November weights were taken. At this time, a difference of 82 lb existed between the average weights of the cattle in these two groups as compared to a difference of only 28 lb which existed in November the previous year and 127 lb which existed in March, 1968.

Pasture treatment appeared to have a considerable effect on weight gains during the summer of 1968. Cows in P2 gained more weight during the pasture season than did cows in either of the other pasture treatment groups. However, the weight gains appear to be inversely related to the number of calves weaned by the cows in the different pasture groups. The number of calves weaned by cows in P1, P2 and P3 were 37, 26 and 44, respectively.

Fourth Year (November, 1968, to November, 1969)

Table 5 includes data obtained during the period from November, 1968, to November, 1969. Body weight gains made between November, 1968, and March, 1969, by the cows assigned to the different levels of wintering nutrition were different from planned weight changes. HW cows gained an average of about 53 lb, whereas the LW cows lost an average of only 49 pounds. Ideally, HW cows should have maintained their November weights and the LW cows should have lost an average of approximately 106 pounds. At the time precalving weights were taken, HW cattle weighed 173 lb more ($P<.01$) per head than did those assigned to the LW group.

When the precalving weights were taken in March, 1969, little difference existed between the average weights of cows assigned to the different pasture treatment groups. However, by the time the cattle were put to pasture, P3 cows were heavier ($P<.05$) than the cows in P1 and P2. This relationship was present in both level of wintering nutrition groups as well as in the average weight values. These observations are probably the direct result of prepasture calving occurring in P1 and especially in P2. Few calves had been dropped in P3 before the cows were put on pasture.

Total weight gains on pasture were greater for LW cows than for HW cows. However, as in previous years, HW cows were heavier ($P<.01$) than LW cows at the time the November weights were taken. No statistically significant differences existed between the weights of cows assigned to the different pasture treatment groups at the time the

TABLE 5. WEIGHTS AND WEIGHT GAINS, NOVEMBER, 1968, TO NOVEMBER, 1969 - FOURTH YEAR[a]

Pasture treatment	H1	H2	H3	L1	L2	L3	Average H	Average L	Average P1	Average P2	Average P3
Drylot Phase, 1968-1969											
Total days in phase	185	243	150	185	243	150	193	193	185	243	150
Wt, March, 1969 (precalving), lb	1186	1204	1201	1034	1031	1006	1197[b]	1024	1110	1118	1104
Total gain, Nov. to precalving wt, lb	54	33	70	-57	-67	-24	53	-49	-2	-17	23
Avg daily gain, Nov. to precalving wt, lb	.42	.26	.56	-.45	-.52	-.18	.41	-.39	-.01	-.13	.19
Final drylot wt, lb	1082	1058	1154	972	959	1003	1098[b]	978	1027[b]	1009[b]	1079
Total gain, Nov. to pasture date, lb	-50	-112	23	-120	-136	-29	-46	-95	-85	-124	-3
Pasture Phase, 1969											
Total days in phase	175	120	204	175	120	204	166	166	175	120	204
Final pasture wt, lb	1084	1180	1146	1037	1118	1105	1137	1087	1060	1149	1126
Total gain, lb	10	134	6	76	179	108	50	121	43	156	57
Wt, Nov., 1969, lb	1084	1140	1146	1037	1055	1105	1124[c]	1066	1060	1098	1126
Avg daily gain, pasture to Nov., lb	.06	.60	.04	.44	.75	.53	.23	.57	.25	.68	.28

[a] Statistical comparisons are made only between levels of wintering and between pasture treatments.

[b] Means on the same line not bearing the same superscript are different ($P < .01$).

[c] Means on the same line not bearing the same superscript are different ($P < .05$).

November weights were taken. The 66 lb difference which existed between P1 and P3 cows was of low statistical significance ($P < .10$).

Feed Consumption

The average amount of feed consumed per head by the cattle in each of the six treatment groups during each of the first four winters is shown in table 6. The average annual intake of the various feeds with average daily dry matter and calculated TDN intake are shown in table 7. Although several different feedstuffs may be listed for any one of the separate wintering phases, the rations at any one time generally consisted of only one or two kinds of hay plus corn or sorghum silage or a mixture of corn and sorghum silage. Some rations consisted entirely of hay. When the supply of one type of hay was exhausted, a different hay, but of comparable quality, was used in the rations.

The hay used during the various wintering phases included native prairie hay of several quality grades, alfalfa, bromegrass, crested wheatgrass, oat, intermediate wheatgrass and various combinations of these. Both corn and sorghum silage were used. Oat grain was fed only during the first winter as has been described.

As a general policy, cattle assigned to the higher level of wintering were given high quality hay plus silage as a daily ration. Cattle assigned to the lower level of wintering nutrition were generally given a limited amount of the high quality hay and a greater

TABLE 6. AVERAGE FEED CONSUMED PER HEAD PER DRYLOT PERIOD, LB

Pasture treatment	H1	H2	H3	L1	L2	L3	Average H	Average L	Average P1	Average P2	Average P3
Drylot Phase, 1965-1966[a]											
Alfalfa hay	--	--	--	--	--	--	399	396	--	--	--
Alfalfa-crested wheatgrass hay	--	--	--	--	--	--	449	449	--	--	--
Native hay	--	--	--	--	--	--	241	239	--	--	--
Oat hay	--	--	--	--	--	--	168	168	--	--	--
Corn and sorghum silage	--	--	--	--	--	--	2336	2281	--	--	--
Oat grain	--	--	--	--	--	--	319	17	--	--	--
Drylot Phase, 1966-1967											
(Period from end of pasture, P2, to end of pasture, P1 and P3)											
Brome-intermediate wheatgrass-alfalfa hay	--	1499	--	--	1496	--	--	--	--	1498	--
(Remainder of drylot phase, Nov. 3, 1966, to pasture date, 1967)											
Alfalfa-crested wheatgrass hay	612	708	486	606	708	486	602	600	609	708	486
Brome-intermediate wheatgrass-alfalfa hay	532	532	532	532	532	532	532	532	532	532	532
Sorghum silage	5450	5452	5450	1850	1840	1850	5451	1847	3650	3646	3650
Corn silage	3700	3950	2650	1095	1110	795	3433	1000	2398	2530	1723
Native hay	--	182	--	1371	1589	1221	61	1394	687	886	611

TABLE 6 CONTINUED

Pasture treatment	H1	H2	H3	L1	L2	L3	Average H	Average L	Average P1	Average P2	Average P3
Drylot Phase, 1967-1968											
(Period from end of pasture, P2, to end of pasture, P1 and P3)											
Crested wheatgrass hay	--	1191	--	--	1183	--	--	--	--	1187	--
(Remainder of drylot phase, Nov. 9, 1967, to pasture date, 1968)											
Alfalfa hay	--	780	--	--	76	2	260	26	--	428	1
Alfalfa-crested wheatgrass hay	1374	656	1174	64	--	--	1068	416	719	328	587
Mixture, 1/3 alfalfa-2/3 native	--	--	--	4111	4310	3706	--	4042	2056	2155	1853
Corn silage	6884	7246	5769	398	477	13	6633	296	3641	3862	2891
Drylot Phase, 1968-1969											
(Period from end of pasture, P2, to end of pasture, P1 and P3)											
Crested wheatgrass hay	--	1551	--	--	1551	--	--	--	--	1551	--
(Remainder of drylot phase, Nov., 1968, to pasture date, 1969)											
Alfalfa-crested wheatgrass hay	1773	2081	957	1629	1900	928	1604	1486	1701	1991	943
Native hay	--	--	--	2321	2368	2086	--	2258	1161	1184	1043
Corn silage	9035	9222	8152	--	--	--	8803	--	4518	4611	4076

[a] Heifers were wintered as groups, high and low, without respect to pasture treatment. Values shown for feed consumed per head in each group are calculated from total heifer days and total feed consumed for each level of wintering group.

amount of poor-to-good quality native hay. Corn and/or sorghum silage were offered to the LW cows in limited quantities.

During the first drylot period, the calves were handled as six lots of 50 head each, divided only according to level of wintering nutrition. At the termination of the wintering phase, the cattle were segregated according to pasture treatment and held in these groups until they were placed on pasture. The period during which they were held prior to pasture as treatment groups ranged from 2 days for P3 cattle to 18 days for P2 cattle. Average feed consumption for the cattle in each of the pasture treatment groups was calculated as the sum of the average feed consumption of the cattle in each of the lots during the period prior to allotment for pasture and the average feed consumed per head during the interim period after the allotment procedure but prior to the cattle being placed on pasture.

Because all feed consumption figures are values obtained with only one lot of cattle and because in many cases different feeds were used, the feed consumption values were not treated statistically.

The primary difference which existed between the amounts of feed consumed by the LW heifers and the HW heifers during the winter of 1965-66 was the amount of oats grain consumed by the HW heifers. Originally, it had been planned to limit the amount of silage fed to the LW heifers and to obtain the additional gains desired in the HW heifers by allowing them to consume corn silage to appetite. However, some difficulty was encountered in getting the HW heifers to consume the desired quantities of corn silage and body weight gains were not as rapid as desired. In addition, a blizzard occurred during the early part of March, 1966. At that time, it became necessary to feed oats grain to the cattle in all lots since this was the only feed available. Subsequent to the blizzard, feeding oats grain was continued for the heifers in the HW lots in an effort to obtain greater rates of gain. Feeding 302 lb of oats in addition to the hay and corn silage resulted in an additional weight gain of 53 lb per head as compared to weight gains obtained with cattle fed no supplemental oat grain after the blizzard.

The data pertaining to subsequent drylot phases are broken down to show the amount of feed consumed by P2 cattle prior to removal from pasture of cattle in P1 and P3. P2 cattle were usually removed from pasture during the last part of September or the first part of October each year. From this time until the remainder of the cattle were removed from pasture, P2 cattle were fed a daily ration of from 30 to 35 lb of crested wheatgrass hay or alfalfa-bromegrass-intermediate wheatgrass hay. When the remainder of the cattle were brought off pasture, feeding of the normal wintering phase rations of silage and hay was begun.

During the drylot phase of 1966-67, the primary difference between rations fed the cows in the level of wintering nutrition groups was in the amounts of corn and sorghum silage and native hay. HW cows were offered about 5 lb of alfalfa and alfalfa-mixed hay with corn or sorghum silage fed to appetite. The LW cattle were offered 5 lb of alfalfa or alfalfa-intermediate bromegrass-crested wheatgrass hay, 12 lb of corn or sorghum silage and 5 to 6 lb of native grass hay. The cows in H2, unlike the cows in H1 and H3, were offered a limited amount of native hay, but this took place late in the drylot phase after cows in P1 and P3 were placed on pasture.

Overall, HW cows consumed an average of 782 lb more dry matter per head than did LW cows. The estimated average daily TDN intake for HW heifers was 12.5 lb per head, while the estimated average daily TDN intake for LW heifers was 9.0 pounds. This difference in TDN intake resulted in a difference of .4 lb per head in average daily weight gains during the period from November to the time the cattle were placed on pasture. On this basis, each pound of body weight gain would require about 17,500 kcal of digestible energy. This is considerably higher than the 9,080 kcal determined by Winchester and Hendricks (1953) to be required by a 454-kg steer for each pound of body weight gain and probably reflects differences in feed intake from calculated values as well as differences in TDN content of the various feedstuffs from the TDN values used to calculate TDN intakes. Very few calves had been dropped by the time the heifers went to pasture. The greater number, however, had been dropped in the HW group. This would decrease to a small extent the difference in average weights between the two groups and increase the amount of energy required per pound of weight gain.

Differences which existed in the feed consumption of the cattle in the different pasture treatment groups were due primarily to the differences in length of the drylot phase for each group and in part to the manner in which the different feeds were fed during the drylot phase as noted above. Cattle in P2 were in drylot for a considerably longer period of time than were the cows from either of the other two pasture treatment groups.

During the 1967-68 drylot phase, P2 cattle were fed a daily ration of about 30 lb of alfalfa-crested wheatgrass hay until P1 and P3 cattle were removed from pasture in November. When the other cattle were taken off pasture, feeding of the regular drylot phase rations began. HW cows were fed 5 to 6 lb of alfalfa-crested wheatgrass or alfalfa-mixed grass hay with about 28 to 30 lb of corn silage per head daily. LW cows were offered about 20 lb of a mixture consisting of one-third alfalfa and two-thirds native hay. These hays were either fed separately in the long form or chopped and fed as a mixture. These rations were fed to the cattle in the respective groups until the cows started to calve in the spring. Cows which calved prior to pasture were placed in a separate lot and fed a ration of about 50 lb of silage and all the alfalfa-crested wheatgrass hay they would consume. Differences in the average amount of feed consumed in the various lots within levels of wintering nutrition treatments were due in part to the number of cows fed the postcalving rations and in part to differences in pasture date between the different pasture treatment groups.

Total dry matter intake for HW cows was about 3700 lb, while total dry matter intake for LW cows was about 3776 pounds. However, average calculated TDN intakes per head were about 2504 lb and 1932 lb, respectively. This would be the equivalent of about 5.7 lb of TDN per pound of change in difference between weights of the cows in the two groups. This is about 11,440 kcal of DE per pound of weight change.

As in the previous drylot phase, cows assigned to P3 again required considerably less winter feed than did those assigned to either P1 or P2, and those in P1 consumed less than did those in P2. Calculated total dry matter and TDN intakes for cows in P1, P2 and P3 were 3868 lb, 2307 lb; 4064 lb, 2406 lb; 3284 lb and 1941 lb, respectively, during phases of 186, 196 and 156 days, respectively.

During the drylot phase of 1968-69, the cattle were handled in two groups separated on basis of level of wintering nutrition. HW cows were fed a ration of about 6 lb of alfalfa-crested wheatgrass hay with 50 to 55 lb of corn silage per head daily. LW cows were fed 6 lb of the same hay with 14 lb of native hay which varied in quality from poor to good. Cows which calved prior to pasture in the spring were placed in a separate lot and fed a full feed (about 35 lb per head daily) of alfalfa-crested wheatgrass hay.

Overall, HW cows consumed about 4036 lb of dry matter per head which contained a calculated level of 2659 lb TDN. LW cows consumed about 3298 lb of dry matter per head which furnished approximately 1793 lb of TDN. Cattle in P1, P2 and P3 consumed about 3866, 4166 and 2969 lb of dry matter per head, respectively, which furnished about 2344, 2520 and 1814 lb of TDN, respectively.

Table 7 shows in summary the average annual amounts of the various feeds consumed per head by cattle in each of the treatment

TABLE 7. AVERAGE ANNUAL FEED PER HEAD DURING DRYLOT PHASES[a]

Item / Treatment	H1 (lb)	H2 (lb)	H3 (lb)	L1 (lb)	L2 (lb)	L3 (lb)	H (lb)	L (lb)	P1 (lb)	P2 (lb)	P3 (lb)
Avg days per phase	188	198	167	188	197	167	184	184	188	198	167
Total hay	1387	1550	1101	2972	3184	2554	1346	2903	2180	2367	1828
Alfalfa	100	295	100	442	479	410	165	443	271	387	255
Alfalfa-crested wheatgrass	1052	974	766	687	764	466	931	639	870	869	616
Brome-intermediate wheatgrass-alfalfa	133	133	133	133	133	133	133	133	133	133	133
Native grass	60	106	60	1668	1766	1503	75	1646	864	936	782
Oat	42	42	42	42	42	42	42	42	42	42	42
Total silage	6851	7051	6089	1405	1427	1234	6663	1355	4128	4239	3661
Corn	4905	5104	4143	373	397	202	4717	324	2639	2750	2172
Sorghum	1362	1363	1362	462	460	462	1362	461	912	912	912
Corn-sorghum mixed	584	584	584	570	570	570	584	570	577	577	577
Total oat grain[b]	80	80	80	4	4	4	80	4	42	42	42
Avg dry matter/day	18.9	19.0	18.3	16.5	16.7	16.0	18.8	16.4	17.7	17.9	17.1
Avg TDN/day[c]	12.2	12.2	11.8	9.0	9.1	8.6	12.1	8.9	10.6	10.6	10.2

[a] Values do not include days P2 cattle spent in drylot before P1 and P3 cattle were removed from pasture at the end of the 1966, 1967 and 1968 pasture seasons nor the feed consumed during those periods. These lengths of the periods, the feed and the total amounts consumed per head by H2 and L2 females were 48 days, bromegrass-intermediate wheatgrass-alfalfa hay, 1496 lb, 1498 lb; 39 days, crested wheatgrass hay, 1183 lb, 1187 lb and 47 days, crested wheatgrass hay, 1551 lb and 1551 lb, respectively, for 1966, 1967 and 1968.

[b] Fed during first drylot phase only.

[c] Total digestible nutrient intake was calculated using N.R.C. (1970) TDN values as follows (moisture free basis): alfalfa hay, 57%; bromegrass hay, 44%; crested wheatgrass hay, 62%; native grass hay, 48%; oat hay, 61%; oat grain, 76%; corn silage, 70% and sorghum silage, 58%. Where mixtures of feed were used, TDN values were weighted proportionately.

groups during the first four drylot phases of this study. The figures shown do not include the amounts of roughage consumed by cattle in P2 during the periods between the time P2 cattle were removed from pasture and the time each fall when the other groups were taken off pasture.

Although HW cattle consumed only about 437 lb more dry matter per head per drylot phase than did LW cattle, the feed they consumed was of higher quality. HW cattle, as has been discussed, were generally fed alfalfa-mixed grass hay alone or in combination with corn or sorghum silage, while the LW cows were usually offered a limited amount of the alfalfa-mixed grass hay with a large portion of the ration consisting of native grass hay. As a consequence, HW cows consumed approximately 2331 lb more TDN over the period of the four drylot phases.

Within each of the level of wintering nutrition groups, cows in treatment P2 required the greatest amount of dry matter in the form of harvested feeds. Including the amount of feed consumed each year by these cows while P1 and P3 cows were on pasture near the end of the pasture season would increase the total amount of dry matter by 3702 and 3697 lb per head for cattle in H2 and L2, respectively, or 1232 and 1234 lb for each of the three phases.

Cattle in treatment P3 within each level of wintering consumed the least amount of harvested feed dry matter. They consumed about 1873 lb less harvested feed dry matter per head than did cows in P1 and about 2669 lb less than P2 cows, not including the 3700 lb fed to P2 cows prior to the time P3 cows were taken off pasture.

As shown in table 7, HW cows consumed about 3.2 lb more TDN per head daily than did LW cows. In terms of a single feedstuff containing about 50% TDN on an as fed basis, this would be about 6.4 lb less feed per head per day of drylot phase. Pasture treatment, on the other hand, had relatively little effect on the average daily TDN intake, except that cattle going to pasture later in the spring and coming off pasture earlier in the fall were fed a slightly greater amount of TDN per head daily. This was due largely to the greater number of cows fed lactation rations each spring. The considerably greater number of days spent by P2 cattle in drylot required a considerably greater total amount of harvested feed.

Blood Data

Data pertaining to blood constituents included packed cell volume (PCV) and hemoglobin (Hb) content of the whole blood as well as the concentration of calcium (Ca), inorganic phosphorus (P), carotene and vitamin A in the blood plasma. The mean squares of these blood components are shown in table 8. The least squares means of the components by season and by year are shown in tables 9 and 10, respectively. Tables 11 through 16 show the least squares means of the individual components by sampling date.

Packed Cell Volume

Table 11 shows the least squares means of the packed cell volume (PCV) by sampling date. Packed cell volumes ranged from a low of 36.0 to a high of 43.5% during the course of the study. All values

TABLE 8. MEAN SQUARES OF BLOOD COMPONENTS

Source	df	Hematocrit	Hemoglobin	Calcium	Inorganic phosphorus	Vitamin A	Carotene
Pasture (P)	2					4616.5**	5625.0*
Winter (W)	1	633.6*	115.3**	3.2*		5043.2*	4455.3*
Year (Y)	2	1265.2**	769.1**	35.8**	332.4**	49243.0**	15054.1**
Season (S)	3	1745.9**	349.6**	29.4**	165.2**	150524.7**	370161.1**
Y x S	6	307.8**	145.4**	21.2**	150.1**	59877.0**	34271.8**
Y x P	4	226.4**				1403.7**	2345.9**
S x P	6	397.8**	42.6**	2.82**		5095.1**	11774.1**
Y x S x P	12	70.6**	12.9**	1.64**	11.2**	1700.5**	2078.0**
Y x W	2	696.2**	123.1**		10.3*	2292.6**	2889.5**
S x W	3	69.2**	15.1**		1.8*	1749.2**	1152.3**
Y x S x W	6		2.69**	.44*		403.8**	337.1**
Y x S x P x W	12		2.61*		1.95*	114.3**	
Y x P x W	4			.85**			
S x P x W	6			.26*			

* $P < .05$.
** $P < .01$.

TABLE 9. LEAST SQUARES MEANS OF BLOOD COMPONENTS BY SEASON, MARCH, 1966, THROUGH NOVEMBER, 1968

Blood component	March	July	September	November
Hematocrit, %	40.4^{e}	38.0^{f}	41.5^{g}	41.3^{g}
Hemoglobin, g/100 ml	13.72^{e}	12.55^{f}	13.54^{g}	14.23^{h}
Calcium, mg/100 ml	10.01^{a}	9.83^{b}	10.24^{c}	10.26^{c}
Inorganic phosphorus, mg/100 ml	7.31^{e}	6.43^{f}	6.25^{g}	6.51^{f}
Vitamin A, µg/100 ml	36.7^{e}	68.4^{f}	58.2^{g}	42.3^{h}
Carotene, µg/100 ml	168^{e}	673^{f}	548^{g}	310^{h}

^{a,b,c,d} Values on the same line not bearing the same superscript are significantly different ($P < .05$).

^{e,f,g,h} Values on the same line not bearing the same superscript are significantly different ($P < .01$).

TABLE 10. LEAST SQUARES MEANS OF BLOOD COMPONENTS BY YEAR, 1966 THROUGH 1968

	Year		
Blood component	1966	1967	1968
Hematocrit, %	39.2^{a}	40.2^{b}	41.5^{c}
Hemoglobin, g/100 ml	12.50^{a}	13.79^{b}	14.24^{c}
Calcium, mg/100 ml	$10.04^{a,b}$	10.30^{a}	9.92^{b}
Inorganic phosphorus, mg/100 ml	7.22^{a}	6.58^{b}	6.04^{c}
Vitamin A, µg/100 ml	46.0^{a}	59.5	48.6^{a}
Carotene, µg/100 ml	379	440^{a}	454^{a}

^{a,b,c} Values on the same line not bearing the same superscript are significantly different ($P < .01$).

TABLE 11. LEAST SQUARES MEANS OF PACKED CELL VOLUMES, PERCENT[a]

Pasture treatment	H1	H2	H3	L1	L2	L3	Average H	Average L	Average P1	Average P2	Average P3
Sample date											
November, 1965	41.2	42.9	40.9	41.5	43.1	42.2	41.7	42.3	41.4	43.0	41.5
February, 1966	40.8	41.1	40.1	41.8	43.5	42.2	40.7	42.5[c]	41.3	42.3	41.2
April, 1966	39.6	40.3	39.5	38.4	39.2	38.8	39.8	38.8	39.0	39.8	39.2
July, 1966	37.3	38.3	36.8	36.0	36.6	36.8	37.5	36.5	36.6	37.4	36.8
September, 1966	40.4	41.3	40.9	39.8	40.3	39.6	40.9	39.9	40.1	40.8	40.2
November, 1966	41.0	40.4	40.5	38.8	40.8	39.5	40.6	39.7	39.9	40.6	40.0
March, 1967	41.4	40.9	40.0	38.6	40.6	40.3	40.8	39.8	40.0	40.8	40.2
June, 1967	38.1	39.1	38.0	37.1	37.6	37.6	38.4	37.4	37.6	38.4	37.8
September, 1967	41.3	42.3	41.8	40.8	41.3	40.5	41.8	40.9	41.0	41.8	41.2
November, 1967	41.2	41.9	41.7	40.5	41.3	40.3	41.6	40.7	40.9	41.6	41.0
March, 1968	41.9	43.0	41.3	40.7	41.1	41.6	42.1	41.1	41.3	42.0	41.4
July, 1968	39.5	40.2	39.6	38.5	39.3	38.6	39.8	38.8	39.0	39.8	39.1
September, 1968	43.3	43.3	42.8	41.5	42.9	42.2	43.1	42.2	42.4	43.1	42.5
November, 1968	42.7	43.0	43.1	41.7	42.8	41.5	42.9	42.0	42.2	42.9	42.3
March, 1969	38.5	40.0	38.7	36.3	39.5	37.4	39.1[b]	37.7	37.4[b]	39.8	38.0[b]

[a] Statistical comparisons are made only between levels of wintering and between pasture treatments.

[b] Means on the same line not bearing the same superscript are different ($P < .05$).

[c] Means on the same line not bearing the same superscript are different ($P < .01$).

appeared to be within ranges considered normal and indicative of healthy cattle (Bedrak et al., 1964). PCV was influenced by level of wintering nutrition ($P<.05$), year ($P<.01$), season ($P<.01$) and by various interactions as shown in table 8. Levels appeared to be lowest in the summer and highest during the fall. Overall, PCV appeared to increase as the age of the animals increased, but the effect was rather small.

Although levels of wintering nutrition appeared to be of significant influence ($P<.01$) at the time of the February, 1966, sample date, differences between treatment groups were small and the circumstance (a greater PCV in LW cattle) is the reverse of what would have been expected if any treatment effect could reasonably have been expected at that time. Other investigators have related low levels of protein and/or energy intake to a decrease in packed cell volume (Bedrak et al., 1964; Stufflebeam et al., 1969). However, little, if any, difference in feed intake or rate of gain existed at this time between cattle assigned to the different levels of wintering nutrition. Therefore, this apparent difference is likely due to chance or to sampling or analytical errors.

As indicated in table 8, PCV was influenced by level of wintering nutrition ($P<.05$) during the period from April, 1966, to November, 1968. Values observed during this period in HW cattle were higher ($P<.05$) than those observed in LW cattle. The difference, however, was generally on the order of only about one percentage unit. At the time of the final sampling date in March, 1969, PCV for HW cows was higher ($P < .05$) than for LW cows, but all values were within ranges considered normal.

Pasture treatment, with the exception of the apparent effect observed at the time of the March, 1969, sampling date, did not exert a significant influence on PCV.

As shown in table 8 and as illustrated further in tables 9 and 10, both season and year, or associated factors, influenced PCV. The highest values for any season were observed at the time of the September and November sampling dates. The values observed on these dates were significantly higher ($P < .01$) than at the time of the March or July sampling dates. Similarly, values observed in March were significantly higher ($P < .01$) than those observed in July.

These results are in disagreement with those of Stufflebeam et al. (1964) who reported that hematocrit values in Hereford cows were highest during the summer months and lowest in November and April. Others, however, have shown that PCV is generally depressed during periods of higher ambient temperatures (Shirley et al., 1968; Weldy et al., 1962). Nelson and Herbel (1967) reported the highest and lowest hematocrit readings occurred in the winter and summer, respectively.

Lactation has also been shown to depress hematocrit, with the lowest values being observed during the third and fourth months of the lactation period (Lane and Campbell, 1969). In that study, PCV was observed to increase during the last half of the gestation period.

Although lactation may have been of significant influence during the 1968 sampling year, it is doubtful that it was of very great influence during 1967 and it was of no effect in 1966. However, the data in table 11 indicate that the lowest average PCV observed during each of the respective years was at the time of the July sampling date. Thus, it must be concluded that season itself, or factors other than lactational status but which may be associated with season, were of significant influence on the observed PCVs.

Data shown in table 10 indicate that PCV differed significantly by year. PCV increased significantly ($P < .01$) in 1967 and again in 1968 over the average values observed in respective previous years. This appears to be an effect of increasing animal age. Gartner _et al_. (1966) reported that hematocrit values were higher in cattle ranging from 25 to 37 months of age than in cattle from 13 to 23 months of age. Others (Bhannasiri _et al_., 1961) have reported a decline in hematocrit as body weight increased from 500 to 800 lb in beef animals. Patterson _et al_. (1960) reported that age appeared to have no significant effect upon hematocrit. The animals used in their study, however, were all in excess of 30 months of age. Studies in which aged cows have been used (Shirley _et al_., 1968) indicate that hematocrit values of cows 9 years of age and older may be lower than that of cows 1 to 8 years of age.

Although PCV may have appeared to increase in response to increasing cow age in this study, it should be noted that the result is, in reality, the sum of the combined effects of increasing age of animals, differences from year to year in pasture and drylot conditions and differences in lactational status from year to year in addition to other factors, both animal and environmental, many of which may not have been identified.

A significant ($P<.01$) year x season interaction existed with respect to PCV. This is likely due primarily to the consistent manner in which PCV increased from year to year within the respective season during the 3-year period involved. Other signifcant interactions are noted in table 8.

Hemoglobin Concentration

The least squares means of the hemoglobin (Hb) concentration in blood of cattle from the various treatment groups are shown in table 12. Hb concentrations ranged from a low of 11.3 to a high of 15.2 g/100 ml of blood during the course of the study. As with PCV, all values appeared to be within ranges considered normal and indicative of adequate nutrient intake (Bhannasiri et al., 1961; Stufflebeam et al., 1969). Hb concentrations were influenced by level of wintering nutrition ($P<.01$), year ($P<.01$), season ($P<.01$) and by various interactions as shown in table 8. Levels appeared to be lowest in the summer and highest during the fall (table 9). Overall, Hb concentration appeared to increase as the age of the animals increased (table 10). Hb concentrations appeared to be closely related to PCV as would be expected in healthy cattle.

As was true with the PCV, Hb concentrations throughout the study, with the exception of the apparent difference observed at the time of

TABLE 12. LEAST SQUARES MEANS OF HEMOGLOBIN CONCENTRATION, G/100 ML[a]

Pasture treatment / Sample date	H1	H2	H3	L1	L2	L3	Average H	Average L	Average P1	Average P2	Average P3
November, 1965	11.8	12.0	11.6	11.7	12.1	12.0	11.8	12.0	11.8	12.0	11.8
February, 1966	12.3	12.4	12.2	12.4	12.8	12.5	12.3	12.6	12.3	12.6	12.4
April, 1966	13.0	13.0	12.7	12.5	12.6	12.4	12.9	12.5	12.7	12.8	12.6
July, 1966	11.7	12.0	11.5	11.4	11.3	11.3	11.7	11.4	11.6	11.6	11.4
September, 1966	1.26	12.8	12.8	12.5	12.5	12.0	12.7	12.3	12.6	12.6	12.4
November, 1966	13.6	13.4	13.2	12.9	13.2	13.0	13.4	13.0	13.2	13.3	13.1
March, 1967	14.5	14.0	14.1	13.6	14.2	13.6	14.2	13.8	14.0	14.1	13.9
June, 1967	13.1	13.3	12.7	12.6	12.6	12.7	13.0	12.6	12.9	12.9	12.7
September, 1967	13.8	14.2	14.0	13.9	13.7	13.4	14.0	13.6	13.8	13.9	13.7
November, 1967	14.7	14.8	14.6	14.4	14.4	14.2	14.7	14.3	14.5	14.6	14.4
March, 1968	14.9	14.9	14.1	14.0	14.2	14.5	14.6	14.2	14.5	14.5	14.3
July, 1968	13.4	13.6	13.5	13.2	13.2	12.8	13.5	13.1	13.3	13.4	13.2
September, 1968	14.4	14.5	14.4	14.1	14.2	13.9	14.5	14.1	14.3	14.4	14.1
November, 1968	15.1	15.1	15.2	14.8	15.0	14.4	15.1	14.8	15.0	15.1	14.8
March, 1969	13.0	13.6	13.3	12.4	13.7	12.8	13.3[b]	13.0	12.7	13.6	13.1

[a] Statistical comparisons are made only between levels of wintering and between pasture treatments.

[b] Means on the same line not bearing the same superscript are different ($P < .05$).

the February, 1966, sampling date, were higher ($P < .01$) in the blood of HW cattle than in the blood of LW cattle. A less significant difference ($P < .05$) was observed at the time of the March, 1969, sampling date. Relatively minor differences in nutrient intake during each drylot phase while a beef female is growing will apparently result in mathematically small but statistically significant differences in PCV and Hb concentrations.

Pasture treatment appeared to have no statistically significant effect upon Hb concentrations.

As would be expected from the results observed with PCV, Hb concentrations varied significantly according to both year and season. As indicated in table 9, the average Hb concentration at any given sampling date was different ($P < .01$) from the concentration observed at any other season. The lowest Hb concentration observed occurred during the summer at the time of the July sampling date concurrently with the lowest observed PCV, while the highest concentration was observed in November. In contrast to the results observed with PCV, however, Hb concentrations observed in September and November were significantly different ($P < .01$) from each other.

These results are not in agreement with those of Shirley et al. (1968) who reported that lowest hemoglobin concentrations in cows were observed in March and that concentrations increased throughout the summer to reach their highest values in December. However, cows in their study were maintained on pasture throughout the year and thus it would be expected that the lowest Hb values would be observed following a period of restricted nutrient intake and that increases in hemoglobin concentration would result from increased nutrient intake during the summer. Stufflebeam et al. (1964) also reported that highest Hb values were observed during the summer months with the lowest values occurring in November and April. The cows used in their study were fed mixed hay supplemented with protein and minerals during the winter and maintained on pasture during the summer. It was not reported whether the cows bore calves during the 13-month study. In other studies (Roussel et al., 1970), oxyhemoglobin concentrations in bulls appeared to be increased as a result of increased ambient temperatures.

In the present study, lowest Hb concentrations were observed in July, about 2 to 3 months after cows had calved. Lactation has been reported to depress hematocrit (Reynolds, 1953; Lane and Campbell, 1969) and hemoglobin concentrations (Patterson et al., 1960). Thus, it would appear that the apparent decrease in Hb concentration may have been influenced by both lactation and season. Season, or related factors other than lactation, appears to have been the factor of greater influence since the lowest Hb concentration was observed in July from year to year regardless of lactation status of the females.

Data in table 10 indicate that hemoglobin concentration appeared to increase significantly with increasing age of the cows. Again, it should be noted that this effect is probably not an age effect as such but rather the sum of the effects of several factors. Others have noted an increase in Hb concentration with increases in body weight from 500 to 800 lb (Bhannasiri et al., 1961), whereas Hb concentrations have been noted to decrease in cattle 10 years of age and older (Shirley *et al*., 1968).

The various interactions noted in table 8 indicate that Hb concentrations may have been influenced by many factors, but that the effects of year, level of wintering and season were factors of greatest importance.

Blood Plasma Calcium Concentrations

Of all the minerals found in the body, calcium and phosphorus are found in by far the greatest quantities. Stores of these minerals, unlike stores of many other nutrients, serve functions other than metabolism. Blood levels indicate the amount of these minerals available for metabolism but are not necessarily indicative of the status of bone stores. Milk flow and bone depletion alter calcium levels, but diet does not readily influence the concentration of calcium in the blood.

Least squares means of blood plasma calcium concentrations are shown in table 13. Concentrations ranged from a low of 9.21 mg to a high of 11.09 mg/100 ml of plasma during the study. Both these values were observed very early. All values during the study appeared to be within ranges considered adequate and normal (Palmer and Eckles, 1930; Stufflebeam *et al*., 1969). Calcium (Ca) concentrations were influenced by level of wintering nutrition ($P < .05$), year ($P < .01$), season ($P < .01$) and by various interactions as shown in table 8. Levels appeared to be lowest in the summer and highest during the

TABLE 13. LEAST SQUARES MEANS OF PLASMA CALCIUM CONCENTRATIONS, MG/100 ML[a]

Pasture treatment	H1	H2	H3	L1	L2	L3	Average H	Average L	Average P1	Average P2	Average P3
Sample date											
November, 1965	11.06	10.90	11.09	11.08	11.04	11.00	11.02	11.04	11.07	10.97	11.05
February, 1966	9.39	9.43	9.45	9.21	9.24	9.16	9.42[b]	9.20	9.30	9.33	9.30
April, 1966	9.99	9.97	10.04	9.93	9.95	9.92	10.00	9.93	9.96	9.96	9.98
July, 1966	9.76	9.85	9.84	9.79	9.70	9.76	9.82	9.75	9.78	9.78	9.80
September, 1966	10.22	10.18	10.28	10.15	10.19	10.14	10.23	10.16	10.18	10.18	10.21
November, 1966	10.25	10.18	10.31	10.16	10.24	10.15	10.25	10.18	10.20	10.21	10.23
March, 1967	10.25	10.18	10.35	10.19	10.26	10.14	10.26	10.20	10.22	10.22	10.24
June, 1967	10.15	10.05	10.03	9.92	10.02	10.09	10.08	10.01	10.04	10.04	10.06
September, 1967	10.36	10.54	10.56	10.53	10.35	10.38	10.49	10.42	10.44	10.44	10.47
November, 1967	10.50	10.44	10.58	10.43	10.49	10.40	10.51	10.44	10.46	10.46	10.49
March, 1968	9.78	9.84	10.01	9.89	9.83	9.71	9.88	9.81	9.84	9.83	9.86
July, 1968	9.69	9.66	9.74	9.62	9.65	9.62	9.70	9.63	9.66	9.66	9.68
September, 1968	10.13	10.09	10.10	10.00	10.05	10.08	10.11	10.04	10.06	10.08	10.10
November, 1968	10.12	10.11	10.14	10.05	10.06	10.07	10.12	10.06	10.08	10.08	10.10
March, 1969	9.71	9.56	9.83	9.15	9.39	9.24	9.70	9.26	9.43	9.48	9.53

[a] Statistical comparisons are made only between levels of wintering and between pasture treatments.

[b] Means on the same line not bearing the same superscript are different ($P < .05$).

fall (table 9). Year of study had no consistent effect on blood calcium concentrations (table 10).

Blood plasma calcium concentrations were influenced by level of wintering. HW cows had higher Ca concentrations ($P < .05$) at the time of the February, 1966, sampling date and during the period from April, 1966, through November, 1968. Although a comparatively large difference existed between the plasma calcium concentrations of cattle assigned to the two levels of wintering at the time of the March, 1969, sampling date, this difference bore no statistical significance.

Pasture treatment had no significant influence on Ca concentration. With respect to seasons, highest plasma calcium concentrations were observed during late summer and fall ($P < .05$), whereas the lowest concentrations ($P < .05$) were observed during the summer at the time of the July sampling. Ca concentrations observed in March were lower ($P < .05$) than those observed in September and November but higher ($P < .05$) than those observed in July.

Others have noted seasonal effects upon the concentration of blood plasma calcium concentrations in cattle. Lane _et al_. (1968) reported that highest calcium concentrations in Guernsey cows were observed during the third quarter of the year (July to September), whereas the lowest concentrations were observed between April and June. In their studies, concentrations from October to December were equal to those observed during the second quarter of the year and those observed from January to March were nearly as high as the highest concentrations observed. Shirley _et al_. (1968) reported that plasma calcium levels in crossbred cows were higher in September than in March, although stage of lactation and/or pregnancy may have had some influence. Others, however, (Stufflebeam et al., 1964) have noted no seasonal effect on blood plasma calcium concentrations. Brody (1949) and Blincoe and Brody (1951) observed no significant effect of ambient temperatures on blood calcium in dairy cows. Data published by Lane et al. (1968) indicated that lactation appeared to influence blood plasma calcium concentrations. In their study, concentrations were lowest during the second month of lactation, rose to the highest point during the third month and gradually declined to the 12th month. In the present study, however, as is indicated in table 13, Ca concentrations appeared to decline during the early summer in all years, including the summer of 1966 when the heifers were first bred. Thus, even though lactation may have had some influence upon the plasma calcium concentration in later years, it must be concluded that under the conditions of this study the major portion of the effect was due to the effect of season or to factors other than lactation associated with season.

Plasma calcium concentrations also varied significantly from year to year. As indicated in table 10, concentrations were higher in 1967 than in 1968, but concentrations in 1966 were not significantly different ($P<.01$) from those observed in 1968. Others (Shirley et al., 1968) have concluded that as age increases in the bovine plasma calcium tends to decline. Their study covered a period of 17 years. Others, however, (Patterson et al., 1960; Van Landingham et al., 1935; Darlow et al., 1949) in studies of considerably shorter duration have not been able to detect an effect of age upon plasma calcium concentrations. Although the data concerning the effect of age upon blood plasma calcium concentrations appear to be inconclusive, it is quite likely that significant year to year variation may occur in blood plasma calcium due to differences in feed composition and to numerous other factors. However, as long as plasma calcium concentrations remain safely within normal ranges and adequate amounts of available calcium are consumed in the diet, such variation should not be harmful.

Blood Plasma Inorganic Phosphorus Concentrations

Least squares means of blood plasma inorganic phosphorus (P) concentrations are shown in table 14. P concentrations ranged from a low of 5.1 mg/100 ml of plasma to a high of 8.4 mg/100 milliliters. All values were within ranges considered normal (Stufflebeam et al., 1964). Plasma P concentrations were affected by year ($P < .01$), season ($P < .01$) and by a limited number of interactions as shown in table 8. Lowest P values were observed in September, while the highest values were observed in March. Plasma P values decreased as the age of the animals increased (table 10).

With the possible exception of the apparent difference observed at the time of the February, 1966, sampling date, level of wintering nutrition did not appear to have a significant influence upon the level of inorganic phosphorus in the blood plasma.

The apparent effect of pasture treatment observed at the initiation of the experiment is probably due to coincidence alone.

TABLE 14. LEAST SQUARES MEANS OF PLASMA INORGANIC PHOSPHORUS CONCENTRATIONS, MG/100 ML[a]

Pasture treatment							Average		Average		
Sample date	H1	H2	H3	L1	L2	L3	H	L	P1	P2	P3
November, 1965	7.84	8.09	7.59	7.37	7.70	7.67	7.84	7.58	7.60[b]	7.89	7.63[b]
February, 1966	8.01	8.10	7.87	8.40	8.54	8.29	7.99[b]	8.41	8.20	8.32	8.08
April, 1966	7.72	8.04	7.81	7.97	7.97	8.00	7.86	7.98	7.84	8.00	7.90
July, 1966	7.02	6.98	6.93	6.92	7.26	7.12	6.98	7.10	6.97	7.12	7.02
September, 1966	6.63	6.86	6.77	6.86	6.94	6.83	6.75	6.88	6.74	6.90	6.80
November, 1966	7.05	7.24	6.90	7.05	7.18	7.32	7.06	7.18	7.05	7.21	7.11
March, 1967	7.05	7.41	7.19	7.36	7.31	7.33	7.22	7.33	7.20	7.36	7.26
June, 1967	6.21	6.48	6.31	6.44	6.48	6.44	6.33	6.45	6.32	6.48	6.38
September, 1967	5.91	6.24	6.18	6.29	6.27	6.13	6.11	6.23	6.10	6.26	6.16
November, 1967	6.68	6.42	6.15	6.14	6.71	6.78	6.42	6.54	6.41	6.56	6.46
March, 1968	6.63	6.92	6.46	6.69	6.71	6.97	6.67	6.79	6.66	6.82	6.72
July, 1968	5.82	5.88	5.66	5.74	5.99	6.01	5.79	5.91	5.78	5.94	5.84
September, 1968	5.53	5.67	5.50	5.59	5.76	5.72	5.57	5.69	5.56	5.72	5.61
November, 1968	5.69	5.90	6.03	6.04	6.14	5.81	5.87	6.00	5.86	6.02	5.92
March, 1969	5.27	5.10	5.75	5.19	5.55	5.85	5.37	5.53	5.23	5.33	5.80

[a] Statistical comparisons are made only between levels of wintering nutrition and between pasture treatments.

[b] Means on the same line not bearing the same superscript are different ($P < .05$).

As indicated in table 10, plasma inorganic phosphorus concentrations were significantly different from year to year. Concentrations were lower ($P < .01$) in 1967 than in 1966 and lower ($P < .01$) in 1968 than in 1967. Although it is impossible to separate the effects of animal age, year of study and lactation effects under the conditions of this study, these results are in agreement with those of other investigators who have observed that plasma inorganic phosphorus values appear to decrease with increasing age in the bovine (Darlow et al., 1949; Palmer et al., 1930; Van Landingham et al., 1935). However, Shirley et al. (1968) noted that plasma inorganic phosphorus values appeared to increase during the period from 14 to 17 years of age in beef cows. Lactation also appears to cause a decrease in plasma inorganic phosphorus concentration (Eckles et al., 1932; Huffman et al., 1933). It is possible that the decrease in plasma inorganic phosphorus concentration observed under the conditions of this experiment may have been the result of both increased animal age and lactation effects.

Plasma inorganic phosphorus concentrations differed by season as is shown in table 9. Lowest concentrations ($P < .01$) were observed at the time of the September sampling date, whereas highest concentrations ($P < .01$) were observed at the time of the March sampling date. Concentrations observed at the time of the July and November dates were not statistically different from each other and were intermediate to values observed at the other sample dates. As indicated in table 14, plasma phosphorus concentrations were consistently lower in September of each year than at any other period within the year.

Thus, it must be concluded that season, or factors associated with season, rather than lactation or stage of pregnancy was likely the major factor influencing phosphorus concentrations.

Blood Plasma Carotene and Vitamin A Concentrations

Least squares means of blood plasma carotene and vitamin A concentrations are shown in tables 15 and 16, respectively. Vitamin A concentrations varied from a low of 22.9 µg/100 ml of plasma at the start of the study to a high of 79.3 µg/100 milliliters. Carotene varied from a low of 75 µg/100 ml of plasma to values in excess of 700 µg/100 milliliters. Pasture treatment, level of wintering nutrition, year and season all influenced carotene and vitamin A concentrations (table 8). Concentrations of these components were highest during the early summer and lowest near the end of the drylot phase (table 9). Carotene concentrations appeared to increase as the age of the animals increased, but year of study had no consistent influence on vitamin A concentrations (table 10). All plasma carotene and vitamin A concentrations observed during the course of this experiment were in excess of values considered minimal for the maintenance of health, growth and normal reproduction in the bovine (Eaton et al., 1961; Kohlmeier and Burroughs, 1964, 1970).

HW cows had higher blood plasma carotene and vitamin A concentrations than did LW cows ($P < .05$). These differences existed during both the drylot and pasture phases of the experiment, although the greatest difference usually existed only during the drylot phases.

TABLE 15. LEAST SQUARES MEANS OF PLASMA CAROTENE CONCENTRATION, µG/100 ML[a]

Pasture treatment	H1	H2	H3	L1	L2	L3	Average H	Average L	Average P1	Average P2	Average P3
Sample date											
November, 1965	153	152	155	148	159	149	153	152	150	156	152
February, 1966	154	156	156	171	171	164	155	168[b]	162	163	160
April, 1966	150	114	142	131	75	123	135	110	140	95	132
July, 1966	653	624	644	639	575	632	640	615	646	600	638
September, 1966	526	479	541	515	471	484	515	490	521	475	513
November, 1966	281	259	289	283	213	258	276	251	282	236	274
March, 1967	212	161	218	192	152	171	197	172	202	156	194
June, 1967	702	702	703	713	622	696	702	677	708	662	700
September, 1967	589	552	590	576	521	559	577	552	582	537	574
November, 1967	353	309	353	334	287	318	338	313	344	298	336
March, 1968	222	194	213	208	144	201	210	185	215	169	207
July, 1968	721	689	734	719	660	690	715	690	720	674	712
September, 1968	592	575	602	598	524	573	590	565	595	549	587
November, 1968	371	316	365	342	305	331	351	326	356	310	348
March, 1969	205	201	207	158	167	150	204[b]	159	181	184	178

[a] Statistical comparisons are made only between levels of wintering nutrition and between pasture treatments.

[b] Means on the same line not bearing the same superscript are different ($P < .01$).

TABLE 16. LEAST SQUARES MEANS OF PLASMA VITAMIN A CONCENTRATIONS, µG/100 ML[a]

Pasture treatment	H1	H2	H3	L1	L2	L3	Average		Average		
							H	L	P1	P2	P3
Sample date											
November, 1965	23.3	22.7	23.3	22.9	23.5	23.7	23.1	23.4	23.1	23.1	23.5
February, 1966	33.9	32.2	32.3	33.0	33.0	31.5	32.8	32.5	33.4	32.6	31.9
April, 1966	34.1	30.4	33.3	31.5	27.1	31.3	32.6	30.0	32.8	28.8	32.3
July, 1966	65.0	62.9	65.2	64.1	58.1	62.9	64.4	61.7	64.6	60.5	64.0
September, 1966	55.0	51.8	55.5	53.6	48.7	52.1	54.1	51.5	54.3	50.2	53.8
November, 1966	38.5	37.1	38.9	38.2	31.4	36.8	38.2	35.5	38.4	34.2	37.8
March, 1967	48.5	42.3	47.8	44.3	42.4	44.0	46.2	43.6	46.4	42.4	45.9
June, 1967	77.5	79.3	77.0	78.8	68.8	78.2	77.9	75.3	78.2	74.0	77.6
September, 1967	68.1	65.8	69.2	67.6	61.8	65.6	67.7	65.0	67.8	63.8	67.4
November, 1967	52.8	49.2	53.2	51.1	46.5	49.6	51.7	49.1	52.0	47.8	51.4
March, 1968	35.4	33.8	36.5	35.5	28.9	33.3	35.2	32.6	35.4	31.4	34.9
July, 1968	67.8	65.6	67.5	66.5	60.6	65.8	67.0	64.3	67.2	63.1	66.6
September, 1968	57.3	54.8	58.0	56.5	50.9	54.7	56.7	54.0	56.9	52.8	56.4
November, 1968	42.6	38.5	41.2	39.3	35.3	39.7	40.8	38.1	41.0	36.9	40.4
March, 1969	40.1	38.0	40.6	28.5	27.6	27.4	39.6[b]	27.8	34.3	32.8	34.0

[a] Statistical comparisons are made only between levels of wintering nutrition and between pasture treatments.

[b] Means on the same line not bearing the same superscript are different ($P < .01$).

Differences during the winter likely reflect differences in quality of roughages given the two groups of cows.

Pasture treatment had a significant influence on the concentration of vitamin A and carotene during the period from April, 1966, to November, 1968. Cattle in P2 were later going to pasture each year and were taken off pasture earlier each year than were cows from the other treatment groups. Consequently, they had lower plasma carotene ($P<.05$) and vitamin A ($P<.01$) concentrations than did cattle from the other pasture treatments.

Plasma carotene and vitamin A concentrations varied according to season ($P<.01$) and to year ($P<.01$). Plasma vitamin A concentrations were highest during the year of 1967. No significant difference existed between average concentrations observed during 1966 and those observed during 1968. On the other hand, plasma carotene concentrations were highest during 1968 and no significant difference existed between concentrations observed during 1967 and those observed during 1968. Average values observed for these constituents during any given season were different ($P<.01$) from values observed during any other season (table 9).

Significant year x season and year x pasture interactions existed for both carotene and vitamin A concentrations.

Others (Braun, 1945; Darlow <u>et al</u>., 1949) have also observed considerable yearly and seasonal variation in plasma carotene and vitamin A concentrations and that vitamin A concentrations appear to be subject to considerably less fluctuation than plasma carotene concentrations. Darlow et al. (1949) observed plasma carotene levels as high as 1200 µg/100 ml of plasma during the summer and lower than 75 µg/100 ml during the winter in individual cows. A similar range in carotene values was observed in individual cows during the course of this experiment. In contrast, vitamin A concentrations rarely exceeded 100 µg/100 ml of plasma in individual cows.

Reproductive Performance

The ultimate measure of effects of the various pasture and wintering nutrition treatments imposed on the cattle used in this experiment would be the reproductive performance of the cattle. Under practical conditions, it is primarily the number and weight of calves weaned that determine whether a given program is profitable. However, several conditions were present in this experiment which would not be encountered under practical conditions or which, if encountered, could be remedied to some extent by alterations in management.

First, the heifers used in this experiment were relatively small at the time they were obtained. Growth during the first winter was not rapid nor was a rapid rate of growth desired, since this was not the objective of the experiment. Consequently, the heifers were small at the time breeding began even though the first breeding season was delayed by about 1 1/2 months. It is apparent from the breeding performance that many of the heifers apparently did not demonstrate estrus during the first breeding season.

Secondly, the animals were maintained in replicate groups of 10 head each in order to obtain data necessary for other phases of the pasture study. This led to problems in heat detection because of the number of groups (24) involved and the time required for accurate observation of each group. In addition, a tremendous amount of effort and time was required for rounding up and inseminating the females detected. Under the conditions, it is likely that these factors were of major importance in determining the relatively poor breeding performance obtained the first 2 years and especially during the first year. However, all groups of cattle should have been affected to the same degree.

Breeding Performance

The data pertaining to the breeding performance of the experimental animals are shown in table 17.

When the heifers were put on pasture at the end of the 1965-66 drylot phase, the overall average weight was about 540 lb (table 2) which may have been lighter than desirable for optimum reproductive performance. Clanton and Zimmerman (1970) recommend that heifers retained for replacement purposes should weigh 550 to 600 lb when grazing begins about the first of May. Wiltbank et al. (1959) reported that puberty occurred in Hereford heifers at an average age of 434 days and an average weight of 562 pounds. However, Wiltbank et al. (1966) later demonstrated that several factors including sire, dam and rate of gain from birth to weaning and from weaning to puberty can have a significant influence on age and weight at puberty. Average age and

TABLE 17. BREEDING PERFORMANCE BY YEAR[a]

Pasture treatment	H1	H2	H3	L1	L2	L3	Total H	Total L	Total P1	Total P2	Total P3
Item											
					Reproductive Cycle, 1966-1967						
No. in group at time of breeding	40	40	40	40	39	40	120	119	80	79	80
Total AI	31	20	30	15	21	26	81[c]	62	46	41	56
Conceptions	19	11	15	4	12	11	45[b]	27	23	23	26
Conception rate, percent of females inseminated	61.3	55.0	50.0	26.7	57.1	42.3	55.6	43.5	50.0	56.1	46.4
Conception rate, percent of total in group	47.5	27.5	37.5	10.0	30.8	27.5	37.5	22.7	28.8	29.1	32.5
Services per conception	2.1	2.1	2.5	4.8	2.2	2.8	2.2	2.9	2.5	2.2	2.7
					Reproductive Cycle, 1967-1968						
No. in group at time of breeding	40	39	40	40	39	39	119	118	80	78	79
Total AI	29	33	33	32	29	37	95	98	61	62	70
Conceptions	14	17	19	23	14	25	50	62	37	31	44
Conception rate, percent of females inseminated	48.3	51.5	57.6	71.9	48.3	67.6	52.6	63.3	60.7	50.0	62.9
Conception rate, percent of total in group	35.0	43.6	47.5	57.5	35.9	64.1	42.0	52.5	46.2	39.7	55.7
Services per conception	2.4	3.2	2.7	2.0	2.7	2.1	2.8	2.2	2.2	3.0	2.3

TABLE 17 CONTINUED

Pasture treatment Item	H1	H2	H3	L1	L2	L3	Total H	Total L	Total P1	Total P2	Total P3
				Reproductive Cycle, 1968-1969							
No. in group at time of breeding	40	40	38	38	40	40	118	118	78	80	78
Total AI	28	20	24	16	19	19	72[b]	54	44	39	43
Conceptions, AI	14	12	12	6	7	10	38[b]	23	20	19	22
Conception rate, percent of females inseminated	50.0	60.0	50.0	37.5	36.8	52.6	52.8	42.6	45.5	48.7	51.2
Conception rate, AI, percent of total in group	35.0	30.0	31.6	15.8	17.5	25.0	32.2	19.5	25.6	23.8	28.2
Services per conception	3.6	2.7	2.6	3.3	4.6	2.8	3.0	3.5	3.5	3.4	2.7
No. apparently conceiving to natural service	21	26	20	22	23	19	67	64	43	49	39
Conception rate, percent females exposed to natural service	80.8	92.9	76.9	68.8	69.7	63.3	83.8	67.4	74.1	80.3	69.6
Total conceptions, AI plus natural service	35	38	32	28	30	29	105[c]	87	63	68	61
Overall conception rate, AI plus natural service, percent of total exposed	87.5	95.0	84.2	73.7	75.0	72.5	89.0	73.7	80.8	85.0	78.2

[a] Statistical comparisons are made only between levels of wintering nutrition and between pasture treatments.

[b] Means on same line bearing different superscripts are different ($P<.05$).

[c] Means on same line bearing different superscripts are different ($P<.01$).

weight at puberty of Hereford heifers in that study were 457 days and 592 lb, respectively. Clanton et al. (1964) reported that only 36% of heifers fed restricted protein and energy intakes had demonstrated estrus by 15 months of age. Although the average weights indicated that many of the heifers in each treatment group in the present study should have already established regular estrual cycles, few of them were apparently cycling in June when the regular breeding season would have begun. The breeding season was delayed about 1 1/2 months in order to allow more of the heifers to begin cycling; but, even though this delay was allowed, only 59% of the total 240 heifers were inseminated.

Among the six individual treatment groups during the first breeding season, the greatest number of inseminations and conceptions occurred in the H1 group, while the smallest number of inseminations and conceptions occurred in the L1 group. No large difference occurred between groups of heifers assigned to different levels of wintering nutrition within any of the other pasture treatment groups. On the basis of initial and final pasture weights (table 2) and the relationship of body weight, age and puberty (Wiltbank et al., 1966; Clanton and Zimmerman, 1970), the largest difference between total artificial inseminations and between conception rates would have been expected to occur in P2 between H2 and L2 heifers where initial body weights differed by 74 lb at the beginning of pasture. However, such was not the case and factors not indicated by animal weight alone apparently resulted in the comparatively poor reproductive performance of the L1 heifers.

On the basis of the limited data available, the effect of level of wintering nutrition on breeding performance appeared to be considerable the first year. The number of HW heifers inseminated (81) was greater ($P<.01$) than the number (62) of LW heifers inseminated and more of the HW heifers conceived ($P<.05$). Although all conception rates were low, the conception rates, stated as a percentage of the heifers which were inseminated from each of the levels of wintering groups and as a percentage of the total number in each group, indicate that treatment effects were likely responsible for the comparatively low conception rate observed in the LW group.

The number of inseminations per conception was inversely related to the number of conceptions. Even though a considerable numerical difference existed between services per conception for HW and LW females (2.2 vs 2.9), no statistical significance was obtained by the difference. As can be seen, much of the difference between these averages resulted from the 4.8 services per conception observed in L1 heifers.

When the effects of pasture treatment were examined, there was no statistically significant effect on the number of heifers which were inseminated, which conceived or upon the number of services per conception. Although numerically fewer P2 heifers were inseminated, they tended to conceive more readily and with fewer services per conception.

The breeding season of 1967 was started on June 26. During the breeding season of 1967, more of the cows were inseminated than during the breeding season of the previous year. Overall, about 80% of the total number of females were inseminated as compared to 59% inseminated the previous year. Much of this improvement was due to the greater number of LW females inseminated.

Among the six treatment groups, only small differences could be noted in the total number of females inseminated. The greatest number of inseminations (37) occurred in L3 and the least (29) occurred in H1 and L2. The numbers of conceptions and the conception rates were improved over the previous year, especially in the LW pasture groups. Within each level of wintering nutrition group, pasture groups with relatively high conception rates the first year had relatively low conception rates the second year. Part of this effect may have been due to the advancement of the breeding season.

The same effect was demonstrated between levels of wintering nutrition groups. During this reproductive cycle, 62 of the LW females conceived as compared to 50 of the HW females. Conception rate of the HW females was 52.6%, or about the same as in the previous year; but the conception rate of LW females, based on the number of cows inseminated, improved to 63.3% or about 18% greater than the rate observed previously.

Conception rates obtained during this reproductive cycle appeared to be inversely related to conception rates obtained the previous year. It has been noted by several investigators that under some conditions lactation stresses in first calf heifers may reduce conception rates at the time of the second breeding (Carrol and Hoerlin, 1966; Dunn *et al.*, 1969). Calf condition, an indicator of milk production, has been shown to be negatively correlated with pregnancy rate (Warnick et al., 1967). Level of wintering nutrition of the cow during the period before she drops her first calf, or subsequent calves, and nutrition during the period following birth also have considerable influence on the ease with which she conceives (Dunn et al., 1969). These factors in combination with the advanced breeding season likely exerted considerable influence on conception rates.

Again, as in the previous year, pasture treatment appeared to have no statistically significant effect on AI rates or conception rates. Differences, although important from an economical standpoint, only approached statistical significance.

During the 1968 pasture season, the cattle were reallotted, within wintering level-pasture treatment groups as closely as possible, to separate the heifers which had never calved into replicate 4 within each of the six treatment groups. Artificial insemination was conducted on three of the four sorted replicates for a 6-week period beginning June 19, following which a clean-up bull was used for a period of about 6 weeks. Cattle in replicate 4 were run with a bull for the entire breeding season.

About one-half of the total number of cows in each group conceived to natural service. Apparent conception rates for natural service as determined from AI records and calf birth dates were excellent and total conception rates were good in all groups, although not as high as had been desired. Fewer cows were artificially inseminated during this breeding season than during the previous breeding season due to the smaller number of cows which were actually subjected to the AI program during this period.

Among the six treatment groups, the number of cows artificially inseminated in each group was, with minor differences, similar to the number inseminated the first year. However, AI conception rates tended to be lower. Services per conception increased considerably as compared to the first year. The number of cows conceiving to AI was smaller than the first year due in part to the smaller number of cows inseminated and in part to the especially low conception rate of the artificially inseminated LW cows. The conception rate of HW cows, as a percentage of the cows inseminated, remained at a level comparable with the values obtained during the first 2 years. Overall, the number of cows apparently conceiving to AI in the HW group in 1968 (38) was greater ($P<.05$) than that in the LW group (23).

About equal numbers of cows from each of the wintering treatment groups apparently conceived to service by the clean-up bulls (67 vs 64), but the apparent conception rate to natural service of the LW cows was about 16% less than that of the HW cows.

Overall, more HW cows conceived ($P<.01$) than did LW cows. The conception rate, including both AI and natural service, of the HW cows was about 15.3% greater than that of LW cows.

Among the different pasture treatment groups, little difference existed in number of cows artificially inseminated, in cows conceiving to AI or in AI conception rates. However, cows in P3 required fewer services per conception. Differences in total numbers of conceptions and in overall conception rates were not significant.

A cumulative summary of the breeding performance obtained on all treatment groups for the first three reproductive periods is shown in table 18. Among the results shown for the six treatment groups, the overall breeding performance for groups L1 and L2 appears to be relatively poor. As a consequence, a greater number of the HW cows were inseminated than of the LW cows ($P<.05$). However, even though more of the HW cows conceived to AI (133 as compared to 112 LW cows), the difference was not statistically significant. Also, there appeared to be little difference due to level of wintering nutrition when comparisons were made on the basis of conception rates of cows inseminated, services required per conception or total AI conception rates stated as a percentage of the total number of cows in the herd during the breeding season. The overall conception rate, including both artificial and natural service conceptions, was numerically greater for HW cows than for LW cows, but the difference bore only a low level of statistical significance ($P<.10$).

In comparing the overall effects of the three pasture treatments, it can be seen that the greatest number of cows artificially inseminated were in P3 (92) and the least in P2 (73). The AI conception rate was not greatly different between the three treatments, but cows in P3 tended to have the highest conception rate on the basis of cows inseminated as well as on the basis of total number of cows exposed.

TABLE 18. OVERALL BREEDING AND CONCEPTION DATA, 1966 TO 1969[a]

Pasture treatment	H1	H2	H3	L1	L2	L3	Total H	Total L	Total P1	Total P2	Total P3
Item											
No. in group at time of breeding	120	119	118	118	118	119	357	355	238	237	237
Total AI	88	73	87	63	69	82	248[b]	214	151	142	169
Conceptions, AI	47	40	46	33	33	46	133	112	80	73	92
Conception rate, percent of females inseminated	53.4	54.8	52.9	52.4	47.8	56.1	53.6	52.3	53.0	51.4	54.4
Conception rate, AI, percent of total in group	39.2	33.6	39.0	28.0	28.0	38.7	37.2	31.6	33.6	30.8	38.8
Services per conception	2.6	2.8	2.6	2.6	2.9	2.4	2.6	2.6	2.6	2.8	2.5
No. exposed to natural service	26	28	26	32	33	30	80	95	58	61	56
No. apparently conceiving to natural service	21	26	20	22	23	19	67	64	43	49	39
Conception rate, percent of females exposed to natural service	80.8	92.9	76.9	68.8	69.7	63.3	83.8	67.4	74.1	80.3	69.6
Total conceptions, AI plus natural service	68	66	66	55	56	65	200	176	123	122	131
Overall conception rate, AI plus natural service, percent of total exposed	56.7	55.5	55.9	46.6	47.5	54.6	56.0	49.6	51.7	51.5	55.3

[a] Statistical comparisons are made only between levels of wintering nutrition and between pasture treatments.

[b] Means on the same line bearing different superscripts are different (P<.05).

Number of services required per conception was inversely related to the conception rates observed.

The number of cows apparently conceiving to natural service in each of the treatment groups was inversely related to the number of conceptions obtained with artificial insemination. Cows in P2 appeared to conceive more readily to natural service than did cows in the other treatment groups, and the lowest natural service conception rate was obtained in P3. However, the highest total number of conceptions and the highest overall conception rate were obtained in P3. Groups P1 and P2 had a total of 123 and 122 conceptions, respectively, with overall conception rates of 51.7 and 51.5%, respectively. Nevertheless, all conception rates were low and no significant differences existed between pasture treatment groups in AI conceptions or overall number of conceptions.

Calving Performance

Calving data for each of the first 3 years of the study are shown in table 19.

As a result of the problems encountered in breeding during the first year, only 72 calves were born, 67 of which lived to 72 hours of age or more. HW females weaned 41 calves in comparison to only 26 calves weaned by LW cows ($P < .05$). The smallest number of calves was born in L1 and the largest number in H1.

Only about 4 days difference existed between the average birth dates of calves from HW and LW cows. Assuming that level of wintering had no effect on length of the gestation period, it appears that the

TABLE 19. CALVING AND WEANING DATA BY YEAR, 1966 TO 1969[a]

Pasture treatment	H1	H2	H3	L1	L2	L3	Total H	Total L	Total P1	Total P2	Total P3
Item											
					Reproductive Cycle, 1966-1967						
Total calves living, 72 hr postpartum	18	11	12	4	12	10	41	26	22	23	22
Calves weaned											
Males	8	6	6	3	5	5	20	13	11	11	11
Females	10	5	6	1	7	5	21	13	11	12	11
Total	18	11	12	4	12	10	41[b]	26	22	23	22
Percent calf crop weaned (total no. calves x 100 ÷ total cows in lot at breeding)	45.0	27.5	30.0	10.0	30.8	25.0	34.2	21.8	27.5	29.1	27.5
Avg birth date of calves weaned	May 21	May 21	May 24	May 28	May 26	May 26	May 22	May 26	May 24	May 23	May 25
Avg birth weight of calves weaned, lb	69.2	70.4	75.4	63.2	63.8	70.6	71.3	66.3	68.1	67.0	73.2
Avg age of calves at weaning, days	170.7	170.9	168.0	164.5	166.4	166.4	170.0	166.1	169.5	168.5	167.3
					Reproductive Cycle, 1967-1968						
Total calves living, 72 hr postpartum	14	15	19	23	13	25	48	61	37	28	44
Calves weaned											
Males	8	11	11	15	4	14	30	33	23	15	25
Females	6	3	8	8	8	11	17	27	14	11	19
Total	14	14	19	23	12	25	47	60	37	26	44
Percent calf crop weaned (total no. calves x 100 ÷ total cows in lot at breeding)	35.0	35.9	47.5	57.5	30.8	64.1	39.5	50.8	46.2	33.3	55.7
Avg birth date of calves weaned	Apr. 24	Apr. 28	May 9	May 1	Apr. 28	May 4	May 1	May 2	Apr. 28	Apr. 28	May 6
Avg birth weight of calves weaned, lb	73.7	76.3	80.7	70.6	66.7	73.6	77.3	71.1	71.8[b]	71.8[b]	76.7
Avg age of calves at weaning, days	209.7	205.6	194.0	201.9	205.7	199.2	202.1	201.5	204.9	205.6	197.0

TABLE 19 CONTINUED

Pasture treatment	H1	H2	H3	L1	L2	L3	Total		Total		
							H	L	P1	P2	P3
Item											
					Reproductive Cycle, 1968-1969						
Total calves living, 72 hr postpartum	35[d]	34	32	28	29	29	101[b]	86	63	63	61
Calves weaned											
Males	14	16	17	14	14	20	47	48	28	30	37
Females	21	18	15	11	14	8	54	33	32	32	23
Total	35	34	32	25	28	28	101[c]	81	60	62	60
Percent calf crop weaned (total no. calves x 100 ÷ total cows in lot at breeding)	87.5	85.0	84.2	65.8	70.0	70.0	85.6	68.6	76.9	77.5	76.9
Avg birth date of calves weaned	May 7	May 3	May 3	May 7	May 15	May 15	May 4	May 13	May 7	May 8	May 9
Avg birth weight of calves weaned, lb	70.6	71.5	77.2	71.8	69.4	79.1	73.0	73.5	71.1	70.5	78.1
Avg age of calves at weaning, days	189.7	187.4	187.1	190.7	175.2	174.9	188.1	179.9	190.1	181.9	181.4

[a] Statistical comparisons are made only between level of wintering nutrition and between pasture treatments.
[b] Means on the same line bearing different superscripts are different ($P < .05$).
[c] Means on the same line bearing different superscripts are different ($P < .01$).
[d] Includes one set of twins.

main effect of a decreased level of wintering nutrition the first winter was to delay puberty.

The average birth weights of calves from cows assigned to the different levels of wintering nutrition were not statistically different, even though a numerical difference of about 5 lb existed between the average birth weights. Considerable range in calf birth weights was noted among the six treatment groups. Weights varied from 63.2 lb in L1 to 75.4 lb in H3. These differences probably reflected differences in dam weight as much as differences in nutritional treatment, although certainly dam weight differences were the result of differences in nutrition.

In 1968, as a result of the better breeding performance obtained in 1967, LW pasture group cows gave birth to greater numbers of calves than did HW pasture group cows. As an exception, however, only 13 calves were born in the L2 group as compared to 15 calves born to H2 cows. LW cows gave birth to 62 calves, 61 of which lived to 72 hours of age or more, whereas 48 of 50 calves born survived to 72 hours in the HW group.

HW calves in 1968 were about 6.2 lb heavier at birth than were LW calves. Sex ratio of the calves may have had a minor influence. However, this difference appeared to be more the result of differences in cow development than to level of wintering nutrition. Had calf birth weight been affected by level of wintering nutrition to this extent, there would likely have been a considerable number of weak calves and greater incidence of death among the smaller calves.

Among the pasture groups, the largest number of calves (44) was born to P3 cows and the smallest (31, of which 28 survived to 72 hours) was born in P2. There is no clearly apparent reason for the small number of calves born to P2 cows. However, other data such as comparative cow weights (table 3), calf growth during 1967 (table 21) and the 1967 breeding performance data (table 17) indicate that the P2 series of pastures may not have been supplying optimum levels of nutrition at the time of breeding.

Calves born to P3 cows in 1968 were heavier ($P<.05$) than P1 or P2 calves. Again, this is likely due primarily to differences in cow size.

In 1969, all groups had greater numbers of calves than in previous years. This was the first calf crop subsequent to the use of clean-up bulls. Cows in the HW pasture treatments tended to have greater numbers of calves than did cows in LW groups. Overall, 105 calves were born to HW cows and 101 were weaned. LW cows gave birth to 87 calves, 86 lived for 72 hours or longer, and 81 of these were weaned. It appears that this may have been the first year in which the effects of level of wintering nutrition were clearly expressed. Birth weights were not affected by level of wintering nutrition.

Pasture treatment had no significant influence on the numbers of calves weaned. The apparent difference in birth weights due to pasture treatment bore only a low level of statistical significance. The apparent advantage in birth weights for P3 calves may have been due to the higher ratio of bull calves to heifers born in that group since precalving cow weights were very similar at that time (table 5).

Overall birth and weaning data are shown in table 20. The total numbers of calves born in the different treatment groups ranged from 54 in L2 to 67 in H1. Overall, from 200 conceptions in the HW treatment, 190 calves were born and lived to 72 hours of age and 189 were weaned. From 176 conceptions in the LW group, 173 calves lived to 72 hours of age and 167 were weaned.

HW calves were born about 4 days earlier on the average than were LW calves and tended to be heavier at birth (73.7 vs 71.5 lb). This was probably due primarily to differences in cow size.

Pasture treatment did not have a statistically significant effect on any of the parameters shown in table 20. However, P3 cows gave birth to more calves which tended to be heavier at birth than calves from other groups. The largest advantage in numbers of calves occurred in 1968 for the P3 cows. Birth weights of P3 calves tended to be greater than birth weights of other calves each of the 3 years of calving, but the greatest advantage occurred in 1969.

Preweaning Performance of Calves

The preweaning performance of calves is shown in table 21. Average actual or observed total body weight gain and average observed daily weight gain are shown. Total and average observed weaning weights are shown and are adjusted for age effects and for age-and-sex effects within year.

A considerable range existed between the preweaning performance of calves from the six treatment groups in 1967. The slowest growing

TABLE 20. OVERALL BIRTH AND WEANING DATA, 1966 TO 1969

Pasture treatment / Item							Total		Total		
	H1	H2	H3	L1	L2	L3	H	L	P1	P2	P3
Total calves living, 72 hr postpartum	67	60	63	55	54	64	190	173	122	114	127
Calves weaned											
Males	30	33	34	32	23	39	97	94	62	56	73
Females	37	26	29	20	29	24	92	73	57	55	53
Total	67	59	63	52	52	63	189	167	119	111	126
Percent calf crop weaned (total no. calves x 100 ÷ total cows in breeding herd)	55.8	49.6	53.4	44.1	44.1	52.9	52.9	47.0	50.0	46.8	53.2
Avg birth date of calves weaned	May 8	May 5	May 9	May 6	May 13	May 12	May 7	May 11	May 7	May 9	May 11
Avg birth weight of calves weaned, lb	70.9	72.4	77.9	70.6	67.5	75.6	73.7	71.5	70.7	70.1	76.8
Avg age of calves at weaning, days	188.8	188.6	185.5	193.6	180.2	183.2	187.6	185.5	190.9	184.7	184.4

TABLE 21. PREWEANING PERFORMANCE OF CALVES, 1966 TO 1969[a]

Pasture treatment / Item	H1	H2	H3	L1	L2	L3	Total H	Total L	Total P1	Total P2	Total P3
					Reproductive Cycle, 1966-1967						
No. calves weaned	18	11	12	4	12	10	41	26	22	23	22
Avg gain, birth to weaning, lb	259.4	256.5	310.8	259.5	215.8	265.9	273.7	241.7	259.4	235.2	290.4
Avg daily gain, birth to weaning, lb	1.52	1.50	1.85	1.58	1.30	1.60	1.61	1.46	1.53[b]	1.40[c]	1.74[d]
Total weaning weight, lb											
Actual	5,915	3,595	4,635	1,290	3,355	3,365	14,145	8,010	7,205	6,950	8,000
205-day age adjusted	6,852	4,160	5,473	1,538	3,930	3,987	16,485	9,455	8,390	8,090	9,460
205-day age and sex adjusted	6,939	4,207	5,537	1,547	3,982	4,032	16,683	9,561	8,486	8,189	9,569
Avg weaning weight, lb											
Actual	328.6	326.8	386.2	322.5	279.6	336.5	345.0	308.1	327.5[b]	302.2[c]	363.6[d]
205-day age adjusted	380.7	378.2	456.1	384.5	327.5	398.7	402.1	363.7	381.4[b]	351.7[c]	430.0[d]
205-day age and sex adjusted	385.5	382.5	461.4	386.8	331.8	403.2	406.9	367.7	385.7	356.0	435.0
					Reproductive Cycle, 1967-1968						
No. calves weaned	14	14	19	23	12	25	47	60	37	26	44
Avg gain, birth to weaning, lb	313.9	348.7	301.5	279.5	314.7	282.7	319.2	287.9	292.5	333.0	290.8
Avg daily gain, birth to weaning, lb	1.50	1.70	1.55	1.38	1.53	1.42	1.58[b]	1.43	1.43	1.62	1.48
Total weaning weight, lb											
Actual	5,427	5,950	7,262	8,052	4,576	8,908	18,639	21,536	13,479	10,526	16,170
205-day age adjusted	5,431	5,965	7,587	8,161	4,549	9,091	18,893	21,801	13,502	10,514	16,678
205-day age and sex adjusted	5,484	6,045	7,791	8,355	4,475	9,350	19,320	22,450	13,839	10,790	17,141
Avg weaning weight, lb											
Actual	387.6	425.0	382.2	350.1	381.3	356.3	396.6[b]	358.9	364.3[b]	404.8	367.5[b]
205-day age adjusted	381.5	426.1	399.3	354.8	379.1	363.6	402.0[b]	363.4	364.9	404.4	379.0
205-day age and sex adjusted	391.7	431.8	410.1	363.3	395.4	374.0	411.1	374.2	374.0	415.0	389.6

TABLE 21 CONTINUED

Pasture treatment / Item	H1	H2	H3	L1	L2	L3	Total H	Total L	Total P1	Total P2	Total P3
					Reproductive Cycle, 1968-1969						
No. calves weaned	35	34	32	25	28	28	101	81	60	62	60
Avg gain, birth to weaning, lb	267.6	280.3	300.0	263.0	241.9	261.6	282.1	255.2	265.7	263.0	282.0
Avg daily gain, birth to weaning, lb	1.41	1.50	1.60	1.38	1.38	1.50	1.50	1.42	1.40	1.45	1.55
Total weaning weight, lb											
Actual	11,835	11,960	12,070	8,370	8,715	9,540	35,865	26,625	20,205	20,675	21,610
205-day age adjusted	12,625	12,834	12,943	8,886	9,870	10,767	38,402	29,523	21,511	22,704	23,710
205-day age and sex adjusted	12,993	13,170	13,228	9,082	10,111	10,923	39,391	30,116	22,075	23,281	24,151
Avg weaning weight, lb											
Actual	338.1	351.8	377.2	334.8	311.2	340.7	355.1	328.7	336.8	333.5	360.2
205-day age adjusted	360.7	377.5	404.5	355.4	352.5	384.5	380.2	364.5	358.5[b]	366.2[b]	395.2
205-day age and sex adjusted	371.2	387.4	421.5	365.1	362.3	385.8	398.9	372.0	373.1	380.7	403.7

[a] Statistical comparisons are made only between levels of wintering nutrition and between pasture treatments.

[b,c,d] Means on same line bearing different superscripts are different ($P < .05$).

calves were those in L2 (1.30 lb/head/day), while H3 calves grew the most rapidly (1.85 lb/head/day).

Overall, HW calves tended to gain more rapidly than LW calves (1.61 vs 1.46 lb/head/day). This effect was likely due to differences in dam size (and/or condition) and subsequent milk production, calf birth weight and calf birth date. All of these factors can be related directly or indirectly to the level of wintering nutrition of the dam.

Pasture treatment influenced preweaning average daily gain and weaning weight. P3 calves gained significantly faster ($P < .05$) than P1 calves and P1 calves grew more rapidly ($P < .05$) than P2 calves. Weaning weights were also different from each other ($P < .05$). Because precalving dam body weights were similar between groups, as were calf birth weights, it must be concluded that the effects of different summer pastures played a major role in these results. This observation is also supported by the November, 1967, cow weights of 973, 960 and 1,061 lb for P1, P2 and P3 cows, respectively.

In 1968, considerable range in performance again existed among calves from the various treatment groups. However, the range was only 69 lb in average preweaning body weight gain (279.5 to 348.7 lb) as compared to a range of 95 lb the first year. Average actual weaning weights ranged from 350.1 lb for L1 calves to 425.0 lb for H2 calves.

Level of wintering nutrition appeared to influence preweaning average daily weight gain. HW calves again gained weight faster than LW calves ($P < .05$). As a consequence of slightly greater birth weights and faster average daily weight gains, HW calves were heavier at weaning than LW calves ($P<.05$). These results may again be related to average dam weight (or condition and/or size) brought about by differences in wintering nutrition during previous periods.

Pasture treatment did not have a significant effect on average daily weight gain of the calves. However, P2 calves were heavier ($P<.05$) at weaning time than calves from P1 or P3. Calves in P1 and P3 gained at similar rates and only small differences existed in weaning weights. However, P2 calves gained at a faster rate, resulting in a heavier weaning weight.

Performance of calves born in 1969 was more uniform than in the previous 2 years. The range of body weight gains of calves from the six treatment groups was only 58 pounds. The least total gain was made by L2 calves (242 lb) and the most (300 lb) was made by H3 calves. L2 calves averaged 69.4 lb at birth with an average birth date of May 15, while H2 calves averaged 71.5 lb at birth with an average birth date of May 3. H2 calves gained faster than L2 calves, probably in part as a result of being slightly older and more able to utilize pasture and in part as a result of better cow condition.

Differences in level of wintering nutrition resulted in less difference in average daily weight gain and total weight gain of calves in 1969 than in previous years. As the cows matured, their reproductive performance appeared to be less affected by seasonal variation in nutrition.

Pasture treatment had no significant effect on average daily weight gain of calves, but P3 205-day age adjusted calf weights were greater ($P < .05$) than corresponding weights for P1 and P2 calves. The longer pasture season with better quality grazing apparently resulted in higher milk production by P3 cows throughout the season and/or in grazing of which the calves could make better use.

Overall preweaning calf performance is shown in table 22. Weaning weights have been adjusted over all years to obtain the age and sex adjusted weights. Decreasing the level of wintering nutrition of beef females resulted in a decrease of .11 lb per head per day gain in calves. This effect tended to be least severe when used in combination with native grass pasture. When native grass was used, the depression associated with the lower level of wintering nutrition amounted to only .07 lb per head daily, while a depression of about .15 lb per head daily was experienced with the other pasture treatments. It is interesting to note that the HW calves in the tame pasture treatments (P2 and P3) had preweaning rates of gain equal to or greater than those of calves in the native pasture treatment all 3 years of the study. Gains of LW calves on tame pasture were not consistently nor appreciably better than gains of P1 calves during this period and in 1967 L2 calf gains were .28 lb per head daily less than the gains of calves in the native pasture treatment (P1).

The actual weaning weights were higher for HW calves than for LW calves, although only a low level of statistical significance was associated with the difference. The greater weaning weight was the result of slightly greater average birth weights and greater preweaning body weight gains. The greatest advantage in preweaning rate of gain

TABLE 22. OVERALL SUMMARY OF PREWEANING CALF PERFORMANCE, 1966 TO 1969[a]

Pasture treatment / Item	H1	H2	H3	L1	L2	L3	Total H	Total L	Total P1	Total P2	Total P3
Total calves weaned	67	59	63	52	52	63	189	167	119	111	126
Avg gain, birth to weaning, lb.	275.0	292.1	302.5	270.0	252.7	270.7	289.5	264.9	272.8	273.6	286.6
Avg daily gain, birth to weaning, lb	1.46	1.55	1.63	1.39	1.40	1.48	1.54	1.43	1.43	1.48	1.55
Total weaning weight, lb											
Actual	23,177	21,505	23,967	17,712	16,646	21,813	68,649	56,171	40,889	38,151	45,780
205-day age adjusted	24,908	22,959	26,003	18,585	18,349	23,845	73,780	60,779	43,403	41,308	49,848
205-day age and sex adjusted	25,416	23,422	26,556	18,984	18,838	24,305	75,394	62,127	44,400	42,260	50,861
Avg weaning weight, lb											
Actual	345.9	364.5	380.4	340.6	320.1	346.2	363.2	336.4	343.6	343.7	363.3
205-day age adjusted	371.8	389.1	412.7	357.4	352.9	378.5	390.4[b]	363.9	364.7	372.1	395.6[b]
205-day age and sex adjusted	379.3	397.0	421.5	365.1	362.3	385.8	398.9[b]	372.0	373.1	380.7	403.7[b]
Total weight of calf weaned per cow in breeding herd, lb											
Actual	193.1	180.7	203.1	150.1	141.1	183.3	192.3	158.2	171.8	161.0	193.2
205-day age adjusted	207.6	192.9	220.4	157.5	155.5	200.4	206.7	171.2	182.4	174.3	210.3
205-day age and sex adjusted	211.8	196.8	225.0	160.9	159.6	204.2	211.2	175.0	186.6	178.3	214.6

[a] Statistical comparisons are made only between levels of wintering nutrition and between pasture treatments.
[b] Means on the same line bearing different superscripts are different ($P < .05$).

occurred in 1967 and 1968 and was .15 lb per head daily each year. In 1969, the difference was .08 pound. Age and age-and-sex corrected weaning weights were greater ($P<.05$) for HW calves. On the basis of the age-and-sex corrected weaning weights, HW calves were 26.9 lb heavier than LW calves. In addition to weaning calves at heavier weights, HW cows weaned more calves than did LW cows. Overall, HW cows weaned 12,478 lb more actual calf weight than did LW cows during the course of this study.

Pasture treatment had no statistically significant influence on overall preweaning rate of weight gain or on the actual average weaning weight of calves. However, the greatest average daily weight gains (1.55 lb/head), the greatest number of calves weaned (126), the greatest weaning weights (363 lb) and the greatest total calf weaning weight were obtained with the long pasture series (P3). P3 calves also had the greatest 205-day age-and-sex adjusted weaning weights ($P<.05$). The smallest daily and total weight gains were obtained with native grass (P1). P2 calves gained slightly faster on the average than did P1 calves; but, due to the larger number of P1 calves, P1 cows weaned a greater total calf weight than did P2 cows.

Incidence of Difficulties Associated with Reproduction

Table 23 contains data pertaining to the incidence of difficulties associated with reproduction. As can be seen, there appears to be little relationship between treatment and the occurrence of any given difficulty. In general, however, more difficulties

TABLE 23. INCIDENCE OF DIFFICULTIES ASSOCIATED WITH REPRODUCTION

Pasture treatment							Total		Total		
Item	H1	H2	H3	L1	L2	L3	H	L	P1	P2	P3
Total births overall	68	66	66	55	56	65	200	176	123	122	131
Abortions	1	3	--	--	1	--	4	1	1	4	--
Stillbirths	--	1	2	--	1	1	3	2	--	2	3
Calves dying at birth	--	2	1	--	--	1	3	1	--	2	2
Births requiring assistance (including prolapses and retained placentas)	14	14	11	11	8	9	39	28	25	22	20
Prolapses at calving	2	1	2	2	4	2	5	8	4	5	4
Retained placentas	3	2	--	3	2	2	5	7	6	4	2
Total incidence of problems	15	20	14	11	10	11	49	32	26	30	25
Percent incidence of problems, total births	22.1	30.3	21.2	20.0	17.9	16.9	24.5	18.2	21.1	24.6	19.1

appeared to be encountered with HW cattle than with the LW cattle. The greatest number of problems encountered in either of the wintering levels of nutrition groups occurred at calving. Many of these problems can be related to the first calving of heifers, especially at 2 years of age. Since more of the HW heifers than of the LW heifers were calved first at 2 years of age, it would be expected that the incidence of calving problems would be greater with the HW heifers.

Cows Lost or Removed from Experiment

Table 24 lists the number of cows lost or removed from each of the experimental groups and the reason for which the cows were lost or culled. Culling was not undertaken on a herd basis until the fall of 1968. At that time, females which were open and had not calved the previous year were culled.

Overall, 18 HW and 33 LW females were removed or lost from the experiment through November, 1969. The primary cause for removal was failure to breed. More LW cows than HW cows were removed for this reason ($P < .05$). Treatments L3 and especially L2 appeared to be the source of much of the difference between wintering groups.

TABLE 24. COWS LOST AND REASONS FOR LOSSES THROUGH NOVEMBER, 1969

Pasture treatment	H1	H2	H3	L1	L2	L3	Total H	Total L	Total P1	Total P2	Total P3
Open	2	2	4	3	9	6[a]	8	18[b]	5	11	10
Uterine prolapse	3	1	2	4	2	2	6	8	7	3	4
Lumpy jaw	-	1	-	3	-	1	1	4	3	1	1
Death related to calving	1	-	1	-	1	-	2	1	1	1	1
Broken hip	-	-	-	-	1	-	-	1	-	1	-
Undetermined	-	1	-	-	-	1	1	1	-	1	1
Total, all causes	6	5	7	10	13	10	18	33[b]	16	18	17

[a] Includes one cow with infantile reproductive tract.
[b] Significantly greater ($P < .05$) than observed with high level of wintering.

SUMMARY AND CONCLUSIONS

Two hundred forty weanling Hereford heifer calves were used in an experiment utilizing a 2 x 3 factorial design with four replicates per treatment to determine the effects of levels of wintering nutrition and pasture treatment on growth, development and reproductive efficiency of beef females from weaning to 4 1/2 years of age. Two levels of wintering nutrition were used. The higher level (HW) was designed to result in winter gains of about 1.5 lb per head daily during the first drylot period, .5 lb per head daily up to calving time the second winter and to provide for maintenance of fall body weights up to calving time the third and subsequent winters. The lower level (LW) was designed to result in gains of about .75 lb per head daily during the first winter, maintenance of fall weights up to calving time the second winter and a loss of about 10% of the fall body weight up to calving time the third and subsequent winters. The three pasture treatments used with each level of wintering nutrition were as follows: P1, native grass only for the full pasture season; P2, a short season pasture consisting of a mixture of smooth bromegrass, intermediate wheatgrass and Teton alfalfa and P3, a series of different pastures designed to provide a long grazing period. The pastures, in order of grazing, were (a) crested wheatgrass, (b) a mixture of smooth bromegrass, intermediate wheatgrass and Teton alfalfa, (c) sudangrass or switchgrass, (d) regrazing of the bromegrass-intermediate wheatgrass-alfalfa pasture and (e) Russian wildrye.

The cattle were maintained in drylot on harvested feeds when not on pasture. The different levels of wintering nutrition were achieved by feeding different amounts and combinations of roughages produced on the Research Center. Hays utilized included native prairie grass, alfalfa, smooth bromegrass, crested wheatgrass and various combinations. Corn silage and sorghum silage were utilized. A small amount of oats grain was fed during the latter part of the first wintering period. Trace-mineralized salt, dicalcium phosphate and ground limestone were offered free choice at all times.

Breeding was conducted by means of artificial insemination during the study and was followed by the use of clean-up bulls in 1968.

Criteria of performance of the cattle in this experiment included the growth and reproductive performance of the cows and growth of their calves. Blood samples were obtained at intervals from all cows during the first 3 years of the study. Hematocrit and concentration of hemoglobin in whole blood and the concentration of calcium, inorganic phosphorus, carotene and vitamin A in the blood plasma were used as indicators of the adequacy of the various nutritional treatments.

All of the heifers used in this trial were lighter in weight than desirable at the initiation of the trial. The average weight at that time was 355 pounds. Weight gains of HW heifers the first winter were not as great as anticipated. Both HW and LW heifers were relatively light in weight when placed on pasture the following spring. Weights at that time were 566 lb and 513 lb, respectively. Subsequently, HW heifers generally gained less weight on pasture than did LW heifers but gained more weight or lost less weight than LW heifers during the wintering phases. LW females were consistently lighter in weight than HW heifers during the remainder of the trial. At the termination of this study in November, 1969, HW females weighed an average of 1,124 lb as compared to 1,066 lb for LW females.

Overall, the growth patterns of the heifers used in this experiment appeared to be satisfactory. However, had larger heifers been obtained initially, it is likely that fewer problems would have been encountered in the breeding program.

Values determined for all blood constituents were significantly influenced by level of wintering nutrition, year and season, except that level of wintering nutrition exerted no significant influence on inorganic phosphorus content of the blood. Carotene and vitamin A concentrations were significantly influenced by pasture treatment. However, levels of all constituents were in excess of levels considered adequate for growth, reproduction and lactation.

Difficulties were encountered with the breeding program during the first year. Due to the relatively slow development of the heifers, the breeding season was delayed. Even then, only 72 of the entire 240 heifers conceived, 45 HW heifers and 27 LW heifers. In subsequent years, conception rates improved. However, it was not until the breeding season of 1968 that even the HW heifers had acceptable conception rates. Overall, the conception rates for HW and LW females were 56.0 and 49.6%.

Calves born to LW females were dropped about 4 days later than HW calves on the average, weighed about 2.2 lb less at birth and gained about 1.43 lb per head daily up to weaning time as compared to an average daily gain of about 1.54 lb for HW calves. HW calves had an average age-and-sex adjusted weaning weight of 398.9 lb as compared to 372.0 lb for LW calves.

One of the costly problems associated with relatively small replacement heifers is failure to rebreed for their second calf. Successful rebreeding appears to require that a good sized heifer (400 to 425 lb at weaning) be fed to reach at least 600 lb body weight by the end of her first winter and that nutrient intake be sufficient to provide for around .5 to .75 lb of weight gain per head per day during the second winter up to calving time. Under these conditions, it is also highly important to insure that fully adequate rations are provided prior to and after the birth of the first calf.

Another factor which imposed itself on this experiment, but which was not discussed at length, was the blizzard which was experienced in the Norbeck area in March, 1966. It would be difficult to determine the effects stresses imposed by that storm may have had on the breeding performance of the heifers. The stresses no doubt reduced weight gains and resulted in the heifers being lighter in weight at the first breeding season.

Overall breeding performance was probably not sufficiently great to obtain a highly sensitive measure of the effects of the treatments imposed in this portion of the experiment. Breeding performance during the 1968-1969 cycle is probably more typical of what could be expected under normal South Dakota conditions with the treatments imposed, although the difference in conception rates between HW and LW cattle would likely decrease as the cows aged. All told, it may be estimated from these data that the ultimate difference between cow herds, including all age groups in the herd, managed under the HW and LW systems would be an average of approximately 8% in weaning rates and a different of about 15 to 20 lb in the average weaning weight of calves. This combination would result in about 43 to 48 lb less calf weaned per cow exposed to breeding if the normal (HW) weaning rates averaged between 85 and 100% and calves were weaned at about 400 lb live weight. The data from the present study indicate that the HW level of production would require roughly an additional 3 lb of TDN per head daily during a drylot period of about 188 days (with native grass). This amount of additional TDN would be about 564 lb per year, or the equivalent of 2,014 lb of corn silage (40% dry matter) or about 1,100 lb of excellent native hay.

The projections in table 25 indicate something of the economics of the theorized situation above. If steer calves average $34 per hundredweight, heifers $30 per hundredweight and cull cows $17 per hundredweight at market, the decrease in income as a result of changing from the HW to the LW system, assuming a decrease of 8% in weaning rates and a decrease of 20 lb in average weaning weights, would be only $10.62 per cow exposed to breeding. The manager presently using the LW management system under the theorized conditions would have about an

TABLE 25. PROJECTED ANALYSIS WITH 8% DECREASE IN WEANING RATE AND 12 LB AND 20 LB DECREASES IN WEANING WEIGHT OF CALVES DUE TO LEVEL OF WINTERING NUTRITION OF DAM

Level of wintering	HW	LW	
		Calves 12 lb light	Calves 20 lb light
Total calves weaned per 100 females exposed	88	80	80
No. heifers used for replacements	12	20	20
No. calves sold per year			
Steers	44	40	40
Heifers	32	20	20
Avg sale weight, lb			
Steers	410	398	390
Heifers	390	378	370
Total calf weight sold per year, lb			
Steers	18,040	15,920	15,600
Heifers	12,480	7,560	7,400
Total cows culled per year	12	20	20
Total cow weight culled per year at 1,000 lb per head	12,000	20,000	20,000

additional $10.62 with which to pay for the additional 2,014 lb of corn silage allowed under the HW system. If steer calf prices were $50 per hundredweight, heifer prices $45 per hundredweight and cull cows were priced at $22 per hundredweight, the difference in income would amount to $17.42 per head exposed to breeding. It should be noted that labor and materials costs appear to be rising regularly. Higher levels of production would reduce nonfeed costs per pound of weaning weight, but total feed costs would be increased under these conditions.

Pasture treatments, consisting of various pasture systems, were the other major variable in this study. There appeared to be no difference in the growth rate of the heifers managed under the various pasture systems until the 1967 pasture phase. Precalving body weights in April for P1, P2 and P3 heifers were 826, 847 and 838 lb, respectively. In November, 1967, the corresponding weights were 973, 960 and 1,061 lb, respectively. Thereafter, with the exception of the weight taken in November, 1968, P3 females were heavier than females in the other pasture treatment groups at each weigh date. P2 cattle tended to be lighter in weight than P1 or P3 cattle at the end of both the 1966 and 1967 pasture seasons. The reason for this is not immediately apparent, although it obviously had to be related to either the pasture and/or to the short drylot period experienced by P2 cows prior to the time that P1 and P3 cattle were taken off pasture each year.

Pasture treatment did not appear to have an appreciable influence upon breeding performance until the 1967-68 breeding year.

The factor(s) responsible for P2 cattle being lighter in weight in November, 1967, also apparently caused P2 conception rates to be adversely affected. The conception rates, as a percent of cows exposed, of P1, P2 and P3 females for the 1967 breeding season were 46.2, 39.7 and 55.7%, respectively. Conception rate of P2 cattle during the other 2 years was equal to or better than the conception rates obtained by cattle in the other pasture treatment groups. Overall conception rates for P1, P2 and P3 females were 51.7, 51.5 and 55.3%.

Calves born to P1, P2 and P3 cows weighed about 70.7, 70.1 and 76.8 lb at birth, respectively, gained 1.43, 1.48 and 1.55 lb per head daily up to weaning time and their respective average age-and-sex adjusted weaning weights were 373.1, 380.7 and 403.7 pounds.

An overall comparison of the results of the pasture test on the basis of other than the growth and reproduction of the females used in the study is beyond the intent of this paper. However, economic factors guide much of what science does not. Therefore, a rather simple and incomplete work-up of a comparison of the results of the three pasture treatments is presented in table 26.

Based on the values shown and using the data from the present study as the basis for the projection, it appears that the P3 system, as compared to P1, would result in about 6% improvement in weaning rates with about 20 lb heavier calves at weaning. The result would be that the herd operator would increase his return per cow by about $6.67 (using $34 for steer calves, $30 for heifers and $17 per

TABLE 26. ECONOMIC COMPARISON OF PASTURE SYSTEMS

Pasture system	P1	P2	P3
Calves weaned per 100 cows exposed	85	79	90
Heifers used for replacements	15	21	10
Calves sold per year			
Steers	43	40	45
Heifers	27	18	35
Avg sale weight, lb			
Steers	360	360	380
Heifers	340	340	360
Total calf weight sold per year, lb			
Steers	15,480	14,400	17,100
Heifers	9,180	6,120	12,600
Value of calf weight sold per year, $			
Steers, 34 cents per lb	5,263	4,896	5,814
Heifers, 30 cents per lb	2,754	1,836	3,720
Cows culled per year	15	21	10
Cull cow weight at 1,000 lb per head, lb	15,000	21,000	10,000
Pounds TDN used per day in drylot	10.5	11.4	10.2
Avg no. days, drylot	189	231	167
Total TDN needed per head, lb	1984	2633	1703
Difference in TDN from P1	--	649	-281
Equivalent weight of corn silage, 40% dry matter	--	2318	-1004
Acres required to produce amount of corn silage, allowing 15% loss in storage, at 16 tons per acre	--	.085	-.037

hundredweight for cull cows) and would save the equivalent of about .037 acre of corn ground which had previously been harvested and fed as corn silage. On the other hand, this saving must be balanced against the cost of establishing a series of pastures to be used in place of the native pastures utilized in P1. If the series of pastures is sufficiently productive that fewer acres can be utilized for pasture and the remainder placed under cultivation or used to produce higher quality hay crops for sale, then the returns from these enterprises must also be considered. Overall, P3 had many important benefits, especially in combination with the higher level of wintering nutrition. However, it may not be economically justifiable. Similar considerations must be given to the short season pasture treatment.

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