

SUPPLEMENTARY NUTRIENTS FOR BEEF CATTLE ON NATIVE RANGE

by

SHANKUTE TESSEMA

B. Sc., Imperial Ethiopian College of Agriculture and
Mechanical Arts, Harrar, 1960

A MASTER'S REPORT

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Animal Husbandry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1963

Approved by:

E. F. Smith
Major Professor

LD
2668
R4
1953
T338
2.2

TABLE OF CONTENTS

INTRODUCTION 1

FACTORS AFFECTING THE NUTRITIVE VALUE OF RANGE FORAGE 2

 Stage of Maturity and Chemical Composition of the Plant Species 3

 Range Conditions and Management 9

 Intensity of Grazing 10

 Soil Influence 15

 Climatic Influence 17

 Fertilization 18

SUPPLEMENTAL FEEDING 22

 Energy 27

 Protein 33

 Minerals 43

 Vitamins 53

SUMMARY 60

ACKNOWLEDGMENT 67

LITERATURE CITED 68

INTRODUCTION

Pasture has a pre-eminent role to play in the nutrition of beef cattle in that it is the foundation of economical beef production. It commonly furnishes a more economical feed than any harvested crop.

Good pasture forage may be fully as rich in protein, on the dry basis as wheat bran, or wheat middlings or brewer dried grains. In vitamin content such forage is unexcelled. However, in two important respects the best of immature forage differs markedly from a high grade concentrate. This is the percentage of fiber, and consequently in the content of total digestible nutrients or net energy. For example (Morrison, 1956) corn grain has only two percent fiber, while young pasture forage will usually have 18 to 20 percent if dried to the same dry matter content. Because of the large difference in fiber, pasture forage furnishes considerably less total digestible nutrients on the dry basis than do high grade concentrates.

According to Reid et al. (1955) if a sufficient amount of herbage is available to satisfy the appetite for dry matter, in the usual grazing practice, an adequate amount of digestible protein and total digestible nutrients will be consumed by growing cattle.

If there is plenty of forage in a pasture, livestock tend to select the leaves and finer parts of the stem which are more tender and more nutritious and eat less of the coarser stemmy parts.

The exact extent to which pastures can meet the entire nutritive needs of beef animals is difficult to assess. It is dependent upon a multitude of factors, ranging from the composition and stage of growth of the pasture species being consumed; the stocking rate as well as climate and soil

influence on the plant species.

When wisely used, native grass provides ample summer and winter forage for cow herds and stocker cattle. While highly nutritious for a few months during the lush growing season, most species of native grass deteriorate in nutritive value after reaching maturity. The wintering period is the most critical time in the nutrition of range beef cattle. During the winter months, weathered range grass provides a source of energy for beef cattle, but may be decidedly deficient in protein, minerals (especially phosphorus) and carotene. Hence supplemental feeding becomes an important consideration.

According to Pinney et al. (1961) too low a plane of nutrition resulted in delayed growth and body development, retarded calving date, smaller and weaker calves at birth, poor milking heifers, and calves that wean off decidedly lighter than those from better wintered dams. Obviously then, supplemental feeding during the period when nutritive value of pasture forage is low may be of great economic significance in terms of growth, and reproductive performance of the female and net returns from the cow herd.

FACTORS AFFECTING THE NUTRITIVE VALUE OF RANGE FORAGE

The nutritive value of any forage is dependent upon its content of energy producing nutrients as well as its content of nutrients essential to the body, namely protein, minerals and vitamins. Precise information relating to the feeding value of range forages is notably lacking. This is a reflection of the complexity of plant analysis, as well as the difficulty of interpreting results in terms of actual feeding values.

The chemical analysis of consumed plant forage according to Cook and

Harris (1950) was in itself an incomplete measure of nutritive value, but it could be used as a guide, when interpreted with the results of digestibility trials that had been conducted with similar forages.

According to Oelberg (1956); Cook et al. (1953) and Cook and Harris (1956) the nutritive value of range forage was influenced in a major way by:

1. Stage of maturity and chemical composition of the plant species.
2. Range conditions and management which were essentially influenced by the interplay of grazing intensity, soil influence, climate and fertilization.

Stage of Maturity and Chemical Composition of the Plant Species

The stage of growth seems to be the most important factor affecting the chemical composition and digestibility of range forage. In general all forages are highly succulent in early growth, which markedly enhances their palatability. In addition their high protein content in relation to a low fiber content at this stage makes them highly nutritious as livestock forage.

Summarizing reports by Reid et al. (1955); Oelberg (1956); Patton and Giesker (1942); Kamstra et al. (1958), there were a number of differences in the nutritive value of forages caused by stages of maturity.

First of all young plants were much higher in protein, on the dry basis, than the same plants at later stages of growth. This protein content tended to decrease as the season advanced except in certain species which showed an increase in protein during the moist fall period.

As cited by Morrison (1956), investigations have shown that under such climatic conditions as those in the Northern part of the United States, the

best pasture grass contained before heading out 16 to 20 percent protein on the dry basis. The protein content in grasses decreased greatly when they headed out, largely because of the accumulation of carbohydrates. Also, after grass headed out, there was a much smaller proportion of leaves on the plants. Grass hay, cut at the usual stages of maturity generally had only six to nine percent of protein, on the dry basis, and the later it was cut, the lower the protein content. When grasses became mature, and especially when they were weathered by exposure, the protein fell to only three percent or less, on the dry basis. Stock, grazing on such grass therefore suffered from a deficiency of protein, unless they were fed a protein supplement.

Another difference between young plants and those that were more mature was that the young plants were soft and tender and had much less fiber and less lignin, on the dry basis than at later stages of growth. They were therefore more digestible than hay cut at the usual time.

Maynard (1937) reported that the trend in crude fiber content in regard to stage of maturity was normally the reverse of protein. As the percentage of crude fiber increased, digestibility usually decreased because crude fiber was resistant to decomposition and it often enveloped digestible nutrients rendering them unavailable.

In an experiment to determine seasonal changes in lignin and cellulose content, Patton and Glesker (1942) found that lignin increased with advancing season from about five percent in May to 18 percent in September with considerable species differences.

In a digestion trial of cellulose by rumen microorganisms, Kamstra et al. (1955) concluded that the poor feeding value of mature forage was due to the increase in lignin content of forages with increasing maturity.

Hale and Duncan (1940) found lignin varied in digestibility from 5.1 to 23.7 percent, but none of the digestion took place in the rumen.

Phillips et al. (1954) in a chemical composition study of some forages, reported that fiber did not increase continuously up to the seed stage but lignin usually did. With aging of tissue, lignification increased and the digestibility of the fiber decreased, but the evaluation of forage was usually made, not on the digestibility of the fiber but on its percentage. Since lignin showed a more regular increase in percentage as plants matured, and since it directly influenced digestibility, it could be considered a better criterion of quality than crude fiber. By likewise reasoning, the protein percentage could be accepted as a criterion of quality. One of the authors' objectives in the investigation was to determine, if possible, the proper time to cut forage for silage or for hay. They concluded that continuous lignification that took place during maturation necessitated as early cutting as possible for either silage or hay if quality alone was the desired object. At no point did lignification cease or slow down and wait for dry matter accumulation. Likewise there was no stage of development at which all grasses were usually high in fermentable carbohydrates and therefore most suitable for making silage. The proper time to cut was as early as possible.

All these workers agreed that lignin in forage plants was not only practically unavailable to the animal, but also had an adverse effect on the digestibility of other constituents as well.

The following table shows the chemical composition of prairie hay, processed from Morrison (1956), Appendix, Table 1, pp. 1016 and 1017.

Phosphorus content normally paralleled that of protein in regard to seasonal changes (Morrison, 1956). Young grasses on land well supplied with

Table 1. Nutritive value of prairie hay.*

Stage	D.P.%	T.D.N.%	Ca%	P%
Early cut	3.7	45.7	.31	.19
Cut in midseason	2.0	45.1	.33	.12
Mature	.9	43.7	.36	.08
Weathered	.1	40.1	.41	.03

* Morrison (1956), Appendix, Table 1, pp. 1016-1017.

phosphorus, had a good content of phosphorus, usually containing 0.25 percent or more of it, on the dry basis. The percentage of phosphorus decreased somewhat as the plants became older, but until they were nearly mature there was generally plenty for livestock. If the forage became mature and weathered, the phosphorus content fell greatly. Even where there was no deficiency in the soil, such forage would not supply enough to meet the requirement of animals pastured on it.

Calcium in contrast, generally increased as the season advanced (table on page 6). The fact that calcium content increased with maturity was explained on the basis of the increased amount of cellular material which was composed principally of this element (Oelberg, 1956).

All actively-growing green parts of plants have a very high vitamin A value because of their richness in carotene. Such forage is also rich in most of the B-complex vitamins, in vitamin E, in ascorbic acid and in certain unknown factors that are required. Vitamins are unstable in dry forage and quickly disintegrate as leaves and stems desiccate. Carotene content

decreases as the season advances.

Green plants contain little or no vitamin D. However this is generally of little importance for stock on pasture, because their vitamin D requirements are met through the effect of ultraviolet rays in sunlight upon their skin.

Savage and Heller (1947) reported on an investigation covering a six-year period during which forage plants on the United States Southern Plains Experimental Range were analyzed monthly for crude protein, calcium, phosphorus, fat, nitrogen-free-extract, crude fiber, ash, moisture and carotene. The relation of the nutrient constituents of the forage to the nutrition of yearling steers grazing on the range was measured by the weight gains of the steers and the blood content of calcium, phosphorus and carotene. The calcium content of all the range plants was in excess of the minimum requirement for cattle.

The plant phosphorus was in excess of the minimum requirement (0.13 percent) for seven months out of the year, and the monthly average plasma phosphorus varied from 4.33 mg/100 ml to 7.42 mg/100 ml. The blood phosphorus level was not increased by feeding bonemeal. The carotene in the blood reflected the carotene in the forage, which varied in the grass from 16 ug/g in January to 462 ug/g in April. The average weight gain of the steers was 356 pounds per year. Supplying bone meal with salt did not increase the gain.

Stanley (1938) reported on a range nutritional investigation in Arizona which included correlation of nutrient constituents of range grasses with the blood chemistry of cattle and growth and reproduction of the cattle. The results showed that the grasses had an average content of 6.37 percent crude protein, .227 percent calcium and 0.178 percent phosphorus. The blood plasma

of cattle on this range showed an average content of 5.37 mg phosphorus and 10.25 mg calcium per 100 ml. Mineral supplements did not increase these values, nor improve the weight gains or calf production.

Watkins and Knox (1945) reported the results of monthly determination of protein and phosphorus in two important range grasses in New Mexico during a period of eight years, and the monthly determination of phosphorus in the blood of cows on range from which the grass samples were taken. The eight-year monthly average phosphorus content of these grasses was below the calculated minimum requirement for cattle for all months except August, September and October. During the winter months, the average phosphorus percentage in forage varied from 0.039 to 0.058 percent, and the blood plasma phosphorus averaged 2.16 mg/100 ml. Supplementation of the phosphorus intake of the cattle by providing phosphorus in the salt increased the plasma phosphorus to 3.24 mg/100 ml, and increased the calf crop and the weaning weight of the calves. The conclusion was that the cows performance was satisfactory when the percentage of phosphorus in the feed was not lower than 0.095 percent in the winter months and the plasma phosphorus was not below three mg/100 ml during the same period.

Watkins and Knox (1950) reported on the relation of carotene content of range forage in southern New Mexico to the vitamin A requirement of breeding cows based on plant analysis and blood vitamin A determinations over a period of five years. The five-year average of carotene in the forage for each calendar month varied from 22 mg/kg to 163 mg/kg. The average vitamin A content of the blood plasma of the cows varied from 44 ug/100 ml to 60 ug/100 ml. These vitamin A levels were well above the accepted requirements.

All the above studies on chemical composition of forage as related to

nutrition of the animal indicated that the nutritive value of forages depended upon the stage of growth and time or season of the year. In general nutritive value decreased with maturity. Both lignin and crude fiber increased with maturity and were criteria of lowered quality. Protein and phosphorus decreased with maturity. Calcium in contrast, generally increased as the season advanced. Carotene content decreased with drying and advancing maturity. Supplemental feeding of nutrients at the time when the nutrients were adequate in the forages, neither increased the plasma level of the nutrients in the animals body nor did it improve growth and reproduction. Therefore supplemental feeding was considered necessary only at those times when forages were matured or weathered or level of element in the soil was deficient.

Range Conditions and Management

According to Marsh et al. (1959); Oelberg (1956); Cook et al. (1953); Cook and Harris (1950); Goebel and Cook (1960); range condition was influenced essentially by the interplay of grazing intensity, soil influence, climate and fertilization. These factors affected the productive capacity as well as the quality of the native forage growing on the range.

Misuse of the range changes the species composition of the vegetation. These changes generally result in a decrease in production and an increase in density of undesirable species.

Soil characteristics may also be modified by changes in range conditions. Trampling and other disturbances modify the surface structure of the soil. Likewise a change in species composition may affect soil structure by a change

in the abundance and depth of roots.

Investigators have found that any disturbance that interfered with the growing conditions of the plant community resulted in changes in the vegetation composition: Klemmenson (1956); Short and Woolfolk (1956); Stewart et al. (1940).

Other criteria most frequently used in describing condition of the range included floral composition, plant density, comparative vigor of forage species, total forage production, litter accumulation and soil stability (Parker, 1954).

Intensity of Grazing. Grazing intensity influenced the ultimate nutrient quality of forage according to Cook et al. (1953). Livestock normally consumed the leaves and more tender stems first and rejected the fibrous plant parts. This reduced the photosynthetic area of the plant and the root-shoot balance was disturbed. These Utah studies showed that available protein, phosphorus, cellulose and metabolizable energy in the forage decreased with heavier utilization while the lignin content increased. Digestibility of protein and cellulose was found to decrease 10 and 67 percent respectively in some cases as utilization increased.

It was noted by Cook et al. (1948) that the chemical analysis of "after-grazing plant samples" showed that continued heavy use of the range caused the nutritive content of the foraging sheep's diet to become less favorable as a balanced ration. This was the result of animals being forced to eat the more fibrous and less nutritious material. Animals normally preferred to consume largely leaves and tender stem tips and rejected the tougher and more fibrous parts of the plant. A sample of current year's growth of a shrub contained ten percent protein, whereas a similar sample after it had been

grazed contained only six percent. This was because the more nutritious portion had been removed by the grazing animal. Therefore if the area was grazed a second time, the available forage did not contain ten percent crude protein but contained only six percent.

Sarvis (1941) reported on a grazing intensity trial conducted since 1916 in North Dakota which indicated that a conservative rate of stocking with steers resulted in satisfactory gains per head, with the least detrimental effect on the vegetation. He stated several conclusions from these trials:

(a) gains per head were greatest under light stocking and smallest under the heaviest rate of stocking, (b) increased gains per head under light stocking were not enough to offset total gain in the more heavily stocked pastures, thus gains per acre increased with increased rates of stocking, (c) steer gains were highest during May, June and July, and tapered off during August and September, (d) weight losses often occurred during October, especially in the heaviest grazed pastures and (e) low growing species increased and taller-growing grasses decreased with increased intensity of grazing.

An economic analysis of returns from three intensities of grazing indicated that highest net returns were realized from the moderately grazed pasture.

Morrison (1956) stated that total yield of dry matter became less when grasses were cut at frequent intervals than when they were allowed to grow to the usual hay stage. This was because there was a smaller leaf surface exposed to the sunlight. Therefore production of carbohydrates through the action of sunlight on the chlorophyll of the leaves was decreased. The same result was produced by close grazing of the crop. Differing from the yield of dry matter, the total yield of protein during the season could be greater when the crop was cut frequently or grazed than when it was cut for hay.

The effect of increased degree of utilization upon nutritive value of forage is illustrated in two tables on the following pages, from Cook et al. (1953).

Table 2. Composition of two important desert forage plants and a mixed diet under two intensities of utilization.*

Forage species and degree of utilization in percent	Ether extract		Total protein		Lignin		Cellulose		Total ash		Calcium		Phosphorus		Other carbohydrates		Gross energy Cal/kg
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%		
Shadescale																	
0-20	2.4	8.7	11.3	17.5	25.4	2.24	0.09	34.8	3700								
21-50	2.6	8.1	13.5	14.2	26.4	2.73	0.07	35.2	3555								
Black Sage																	
0-30	10.3	8.5	15.6	25.6	6.1	0.57	0.16	33.9	5172								
31-50	8.4	7.8	18.2	23.7	8.2	0.60	0.12	33.7	4977								
Mixed Diet**																	
0-18	1.5	5.4	7.6	26.7	17.4	0.82	0.09	41.4	3733								
19-40	2.4	4.3	8.7	26.5	16.6	0.66	0.09	41.5	3498								

* Cook et al. (1953)

** Diet composed of 50 percent browse (black sage, shadescale and winter fat) and 50 percent grass (galleta grass, Indian rice grass and sand dropseed).

Table 3. Nutritive value of forage plants under two intensities of utilization.*

Forage species and degree of utilization in percent	Dry matter consumed	Percent digested						TLN	D.P.	D.E.
		D.M.	E.E.	T.P.	Cellulose	Other	Gross energy			
Shadescale										
0-20	3.5	47.8	44.6	61.4	37.7	61.3	37.7	35.7	5.3	1462
21-50	3.2	42.3	36.2	59.1	12.3	56.1	33.3	26.5	4.8	1210
Black sage										
0-30	2.9	41.1	63.5	54.5	35.9	58.2	43.6	48.3	4.6	2250
31-55	2.4	34.1	56.2	53.9	24.5	55.3	35.9	39.3	4.2	1770
Mixed diet										
0-18	3.6	52.0	33.0	40.6	48.8	63.0	48.5	42.4	2.2	1845
19-40	3.5	46.3	41.0	36.4	44.0	61.6	42.9	40.9	1.6	1530

* Cook et al. (1953)

The content of protein, phosphorus, cellulose and gross energy in forage decreased with heavier utilization whereas lignin increased.

In addition to the decreased content of desirable nutrients accompanying heavy utilization, the digestibility of these nutrients was materially decreased. As shown in Table 3, the digestibility of protein decreased as much as ten percent in some cases and the digestibility of cellulose as much as 67 percent as the degree of utilization increased. This decrease in digestibility with increased intensity of grazing resulted in even greater reduction of available protein and energy for animal use. The difference in some cases was sufficiently great to show that serious deficiencies could be present when the range was heavily used, whereas when moderately grazed the nutritional requirements would be more nearly satisfied.

It was also noted by these authors that in addition to the decreased content of the more desirable nutrients and the decreased digestibility of these nutrients with increased degree of utilization there was an indication that animals actually consumed less feed per day on heavier utilized areas compared to a more moderately used area (Table 3). This of course further added to the seriousness of the nutritional deficiencies already indicated, since the actual amount of the various constituents ingested was the only true measure of a balanced or an unbalanced ration.

In the same experiment, the authors further noted that the effect of heavy stocking was frequently reflected in livestock production long before actual changes in the range were evident. The reproductive efficiency of the animal could be materially reduced long before its general appearance suggested the addition of a supplement or a reduction in grazing intensity.

In summary, the reports of these various workers on grazing intensity

indicated that heavy utilization of the ranges over a long period of time reduced the yield of forage and in addition desirable plants were replaced by undesirable plants because of their high palatability.

As the degree of utilization increased, the content of the more desirable nutrients in the available forage decreased and in addition, the digestibility of these nutrients was decidedly lowered. Thus it was shown that through heavier utilization the animals were forced to consume the less nutritious portions of the plants and as a result the available nutrients frequently were not adequate to meet the demands of the grazing animals.

A high rate of return from capital investment in land and livestock is dependent upon high producing efficiency of the livestock grazing the lands which in turn, is dependent upon well managed ranges. Adjustments in stocking rate according to capacity of the range, rotation system or alternate grazing were shown to be necessary.

Soil Influence. The physical and chemical properties of soil exert almost unlimited influence upon the nutrient content of plants. Orr (1929) concluded that the mineral composition within a species was determined primarily by soil as shown by the response to fertilizers. It has long been known that plants grown on soils rich in certain nutrients usually were also rich in those nutrients.

Cook and Harris (1950) stated that the effect of soil differences upon nutritive composition of plants was difficult to determine because of the many interacting and interdependent factors involved. These included: soil acidity, soil moisture, structure, texture, organic matter content, soil organisms and chemical composition of the soil solution. Soil acidity, within certain limits was an important factor in rendering nutrients available

to plants. Phosphorus, calcium and potassium content of plants seemed to increase with increased soil acidity. The relationship of mineral and organic content of the soil was thought to influence acidity, and thereby, favor the absorption of certain constituents by plants. However, a change in acidity may have depressed the availability of some soil constituents involved. Increased soil moisture, to a limited degree, has been found to increase the mineral content of forage plants.

Koch et al. (1958) compared the nutritive value of forage from a limestone pasture and sandstone pasture. They used spayed heifers over a period of 18 months. Throughout the trial animals in each group received roughage grown either on sandstone or limestone soil. At the end of the overall study those cattle receiving forage grown on limestone soil had made an average total gain that was 53 pounds greater than that made by similar cattle receiving forage grown on sandstone soil. This extra gain made by the group consuming forage growth on limestone occurred during the two winter phase of the study. The addition of supplemental phosphorus did not result in any definite change in weight gain. Their data did not indicate the reason for the increased gain of the animals receiving limestone forage.

The same authors in 1959 conducted another trial to determine whether or not trace mineral supplementation was of any value when beef calves were grazing on native pasture growing on sandstone soil. They divided 24 steers calves into two groups. Cattle on one pasture had access to a mixture of plain salt and bone-meal, while those in the other pasture had access to a mixture of trace mineral salt and bone meal. They were put on the pasture on May 9, 1958 and at the end of the year there was no apparent difference in the animals in the two lots.

Various observations have shown that although plants do not absorb nutrients in the same proportions as they occur in the soil, their composition, to a large degree is influenced by the composition of the soil. The absorption of the nutrients depends upon a number of interacting and interdependent factors which require an optimum condition of soil pH, soil moisture, physical properties and content and ratio of the nutrients.

Oelberg (1956) stated that chemical properties of the soil may determine the nutrients that plants were able to absorb. For example, phosphorus was most available between pH 6 and pH 7. Phosphorus in soils of low pH reacted chemically with hydrous oxide of iron, aluminum and magnesium to form insoluble compounds which were unavailable to plants. At pH 7 and above, phosphorus again became insoluble as calcium phosphate.

Physical properties of soil such as texture and porosity affect the nutritive quality of forage more or less indirectly. Poorly aerated soils greatly limit or decrease the absorption of essential elements, especially phosphorus.

Climatic Influence. Climatic factors such as temperature, humidity, precipitation, light, intensity, and altitude may be dominant in controlling the nutritive value of plants (Oelberg, 1956). Although plants are dependent upon the soil for their mineral nutrients, climatic factors affect respiration, assimilation, photosynthesis and metabolism to the extent that the mineral and organic matter content of plants may be strongly modified by climate even though grown on the same soil.

Cook and Harris (1950) stated that intermittent periods of rain and sunshine greatly changed the chemical composition of forage, especially when plants had matured and partially dried. Exposure to rain resulted in a loss

of nutrients which was accounted for by leaching of soluble constituents. Calcium was not appreciably affected by leaching but phosphorus was decidedly lowered, which widened the calcium-phosphorus ratio. Nitrogen-free-extract and crude protein were likewise reduced by leaching.

Oklahoma studies by Daniel and Harper (1934) revealed a close relationship between precipitation and the calcium and phosphorus balance in Andropogon scoparius. Increased precipitation resulted in an increase in phosphorus and a decrease in calcium and vice versa.

Cook and Harris (1950) stated that drought might possibly lower both phosphorus and protein, whereas calcium and crude fiber probably increased. Rainfall in general, tended to increase nitrogen, phosphorus and ether extract (the soluble fat constituents).

Oelberg (1956) stated that "temperature seems to be the most important factor governing phenology." Increased intensity of sunlight has been shown to increase carbohydrate content and decrease protein content of plants when compared to plants grown in the shade. Low temperature tended to initiate the transformation of starches into plant sugars which were used in plant metabolism.

Altitude affected plant composition through the interrelation of factors such as light intensity, CO₂ concentration and precipitation. The nitrogen content of high altitude plants seemed to be higher than that of plants grown at lower elevation (Oelberg, 1956).

Fertilization. Crampton (1937) in a study of the nutritive value of fertilized versus unfertilized pasture herbage, found significant differences in nutritional worth between certain pure species of grasses as well as between mixed herbage. Properly fertilized pasture plants continued growth

over a longer period than those on infertile soil, and thus provided good feed for a longer time. Another important advantage was that pasture on well fertilized land was more palatable to stock than that grown on poor land.

Morrison (1956) stated that except where forage was deficient in phosphorus or in one of the trace minerals, the benefit from applying fertilizer to pasture or meadows was usually from an increase in yield, or from an increase in proportion of legume. The yield of forage on phosphorus-deficient soil would be increased by phosphate fertilization. While a liberal phosphorus fertilization would usually correct any phosphorus deficiency in the forage, a moderate application of phosphorus to such a soil could at first only increase the yield, without increasing the percentage of phosphorus in the crop.

Little et al. (1959) conducted an experiment to determine the response of irrigated tropical grasses (*Pennisetum purpureum*, *Panicum maximum*, *Digitaria decumbens*) to nitrogen fertilization. For two consecutive years, nitrogen at levels varying from 0 to 1,600 pounds per acre yearly was applied on an irrigated soil with conditions generally favoring maximum productivity. The results indicated that the yield of the first two species increased markedly with nitrogen rates up to 800 pounds of N per acre yearly. Protein content of all the grasses increased with nitrogen fertilization up to the 1,600 pound level at which it approached 12 percent with all species.

Dotzenko (1961) evaluated six grass species for forage yield, percentage total nitrogen content, and percentage nitrogen fertilization levels under irrigation. He applied elemental nitrogen (urea) at the rates of 0, 80, 160, 320, 640 pounds per acre annually for three years, on soils irrigated four times a year with approximately four inches of water per irrigation. Average

three-year data showed marked increase in forage yields from nitrogen fertilization. Yields ranged from a low of 1.30 tons per acre under the 0-nitrogen level to a maximum of 6.17 tons per acre under the 640-pound level, with some variation with species. The difference in total nitrogen level of the grasses was also highly significant; the level in forage increasing with increasing rates of nitrogen fertilization.

Norman (1962) presented a three year study of the effects of nitrogen and phosphate fertilizers carried out on native pasture. He used a factorial combination of three levels of nitrogen and three levels of phosphate fertilizers. Significant increase in total dry matter yield was obtained in the presence of both nutrients. The mean nitrogen content of the pasture increased substantially only when nitrogen was applied without phosphate. Mean phosphorus content increased with increasing level of applied phosphate and decreasing level of applied nitrogen. Total phosphorus yield increased with increasing level of applied phosphate but was little affected by the level of applied nitrogen.

According to the various workers above fertilization affected both composition and yield of forage, specially under irrigation or abundant soil moisture. Among nutrients required by animals, the application of phosphate and nitrogen fertilizers was considered more often largely because of their fluctuating status in the plant with seasonal variation.

Although most investigators have shown that fertilization on native pasture has increased level of both nitrogen and phosphorus in the plant the practical implication of these results is questionable. The increased level of the nutrients in the forage occurred during the growing season while any major impact on animal production comes through improvement of quality of dry

season pasture. While fertilization on deficient soil may be of practical importance, supplying nitrogen or phosphorus to the grazing animal by fertilizing the native pasture did not seem efficient.

Among the various factors that affect nutritive value, stage of maturity seemed to influence forage quality more than any other factor. Protein, nitrogen-free-extract, ether extract, carotene and phosphorus tended to decrease with advancing maturity, whereas crude fiber, lignin and calcium increased. Most studies indicated that environmental factors and soil moisture were more important in determining the nutrient content of range forage plants under various site conditions than the chemical content of the soil as determined by standard method. The physical and biological properties of the soil, aeration, texture and biotic influence were important in regulating physiological processes in plants. Chemical properties of soil, such as pH, available minerals and fertility, controlled to a certain extent the absorption of minerals by plants.

Heavy grazing had a detrimental effect on yield and composition. In order to realize the optimum gains on native range, moderate to light rate of stocking, varying the rate in order to leave about 50 percent of the annual production ungrazed, was recommended.

Climate affected forage value considerably, increased precipitation tended to increase the phosphorus content and decrease the calcium content of plants. Light intensity, temperature and carbon dioxide concentration limited forage value if they occurred in sub-optimum quantities. Sites indirectly affected the chemical content of plants and plant parts through soil and plant development, water run-off, intensity of shade, and other environmental factors.

SUPPLEMENTAL FEEDING

In the preceding section of this report it was shown from numerous studies that the weight gains of range cattle were greatest during May, June and July, and the rate of gain tapered off during August, September and October. All these studies were also in agreement that the seasonal variation in weight gain was mainly due to the decrease in nutritive value of the forage which was in turn closely related to stage of forage maturity. This occurred in all ranges, regardless of proper stocking rate for year-round grazing in normal rainfall areas, with good range conditions and good quality forage species.

Gains of a large proportion of range cattle are retarded during the fall and winter season and in many cases gains are completely interrupted or the animals are subjected to actual loss of weight. While interruption of weight gains may not be unfavorable in itself, too much weight loss can result in harmful effects.

Pinney et al. (1961) in 13 consecutive winters of supplemental feeding studies of low, moderate or high levels reported that:

...too low a plane of nutrition results in delayed growth and body development, retarded calving date, smaller and weaker calves at birth, poor milking heifers and calves that wean off decidedly lighter than those from better wintered dams.

Mann and Walton (1953) made a study on the effect of under feeding on the genital function in the bull. Regular weekly collections of semen were made during a five-week pre-experimental period of normal feeding, a 23-week experimental period of under feeding and a 25-week post experimental period of recovery.

Although the food intake was reduced to such an extent that the bulls

began to lose weight at the rate of 14.3 pounds per week, the volume and density of semen, and mobility and morphology of the spermatozoa were not significantly changed. In contrast to the testes, the secretory functions of the male accessory glands were markedly affected by under-feeding. The concentration of fructose and citric acid in semen decreased to about 30 and 60 percent respectively of the original levels. During the recovery period the values for fructose and citric acid gradually returned to normal.

This report did not show a decrease in reproductive ability of the bull, although it was obvious that through excessive weight loss the service power of the bull would be adversely affected.

Winchester et al. (1957) used identical twins and eight different rations to determine the effect of protein and energy restriction on beef cattle. Three of the eight rations provided for caloric maintenance, three for a pound of daily gain, and two for two pounds of gain each day while protein levels provided by different rations of like calorie value were different ranging from only 2.4 percent digestible protein to liberal amounts of protein.

During restriction, animals on 2.4 pounds of digestible protein and maintenance calories lost weight while those on the other rations made gains. When energy intake was held near maintenance, changes in body weight were positively correlated with level of protein intake.

These and numerous other studies have shown that supplemental feeding on pasture was beneficial, especially during such times as when the range has weathered and its nutritive value diminished. On the other hand, excessive and unwarranted supplemental feeding has produced unfavorable and uneconomical results.

Darlow et al. (1951) conducted an experiment on the value of supplements for fattening two- and three-year old steers on grass. They used five different ration combinations, all included blue stem grass and salt (free choice), the comparison being on the supplement fed with this basal ration.

Lot 1 -- No supplement

Lot 2 -- A mineral mixture (bone meal, ground limestone, salt)

Lot 3 -- 43 percent cottonseed cake

Lot 4 -- Ground shelled corn

Lot 5 -- No supplements to about July 1 and 43 percent cottonseed cake thereafter.

An energy feed (ground shelled corn) produced slightly less gain than a high protein feed (43 percent cottonseed cake), but the corn steers averaged enough higher in selling price to return a slightly greater profit. Feeding a concentrate throughout the grazing season gave slightly larger daily gains but the profit per steer and dressing percentage were slightly in favor of the steers which received cake only after July 1.

Referring again to Pinney et al. (1961), they have reported that limited amounts of supplemental winter feed (one pound of cottonseed meal per head daily) on dry, weathered native grass pastures resulted in nearly an eight percent increase in calf crop weaned and almost twice the number of cows surviving to 13 years of age when compared to high levels of supplemental winter feed (two and one-half pounds of cottonseed meal plus three pounds of oats per head daily). The cost of producing 100 pounds of calf was nearly twice as much for the high levels as compared to the low levels.

The very high level treatment demonstrated the effect of excessive feed levels in hastening maturity and in causing large stores of body fat.

Excessive feed levels could have had a depressing effect on growth of the fetus and milk production. With the tremendous cost of production involved in carrying females at the very high levels, this system was not recommended. A medium to high level appeared to be most desirable in terms of growth and development of the female and size of her calf at weaning.

Joubert (1954) gave a lengthy review of a four-year work on the influence of winter nutritional depression on the growth, reproduction and production of cattle. He used the paired method of feeding, each heifer maintained on grazing alone having a related counterpart of the same age which received supplementary feeding during the winter months. A summary of his results indicated that growth in body weight on the low plane of nutrition showed marked seasonal fluctuations. These usually reached a peak at the end of summer and then dropped fairly rapidly to the lowest level which was reached just prior to the first spring rains. Significant correlations between T.D.N. percentages of pasture samples collected at the time, and mean daily rates of gain, showed that seasonal fluctuation in live weight was closely allied to corresponding variations in the nutritive value of natural grazing. It was shown that the poor nutritional conditions prevailing during winter, significantly retarded developmental growth. The difference between high and low plane animals continued to be noticeable even after four years of investigation. In comparing the influence of early and late breeding on growth, it was found that the age of first calving had no permanent influence on the ultimate size of the animal.

The growth rates of calves suckling their dams were greatly influenced by the milking capacity of the cows. The low nutritional plane obviously resulted in a decreased milk flow which in turn, caused lower weaning weights

of the calves concerned.

Providing supplemental winter feed was one of the major costs of maintaining a calf and cow herd. The operator of such a herd needs information concerning the effect of using various supplements both for cows in the herd and for replacement heifers. The nutrient nearly always lacking in non-legume roughage, such as prairie hay and mature native grass is protein. It should be supplied in supplemental feed. Other nutrients most frequently lacking are certain vitamins and minerals. These are more deficient in mature range grass than in early cut prairie hay.

In this report supplements for range cattle are discussed in the following order: (1) Energy, (2) Protein, (3) Minerals and (4) Vitamins.

Range cattle for nutritional requirements, have been classified into three general categories: (1) breeding livestock, (2) yearlings and (3) calves (Kneise, 1957). The breeding herd included all producing cows, bulls, and replacement heifers after they had their first calf.

The nutrient requirements for breeding cows or for wintering young stock are much different from those for fattening cattle (Morrison, 1956). To enable fattening cattle to make rapid gains, they must receive rations rich in digestible nutrients or net energy. Beef cows may be wintered entirely on roughage, if it is of fairly good quality and if legume forage is fed to meet their limited need for protein. Normally beef cows need no concentrate during the pasture period. When calves or yearlings are being carried through the winter to be fattened later, they may likewise be fed entirely or chiefly on roughage, if it is of good quality.

Requirements of the cow herd are probably more exacting due to the fact that the cow must provide for the unborn calf as well as maintaining herself.

Proper nutrition of the replacement heifers will assure years of productivity. Replacement heifers should be wintered on a ration that will provide energy for continued growth and development as well as maintaining health. Proper supplementation of the wintering yearlings and steers during the winter will not only add economical pounds but will put a more vigorous, healthier calf on grass in the spring that will make a quicker, better conversion from grass.

Energy

A primary consideration in the feeding of the individual animal must be the adequacy of the energy supply. Blaxter (1956) stated:

Shortages of dietary energy are usually far more important causes of low productivity in farm livestock than are dietary deficiencies of vitamins, minerals, or amino acids. Furthermore, although deficiencies of most dietary essentials normally give rise to spectacular syndromes that can be easily recognized, shortages of dietary energy result in no obvious abnormality other than an insidious reduction in the animals production.

According to the same author the nutritive value of a food as a source of any nutrient was a measure of its ability to promote or sustain some group of metabolic activities in the animals body. Nutritive value was thus a biological measurement, not a physical or a chemical one. The fact that the nutritive value of food as a source of energy was stated to be a biological measurement means that the value obtained in any experiment reflects the intrinsic efficiency of the test animal. Thus the net energy value as determined calorimetrically with an adult steer was in effect, the net efficiency of the animal in converting unit weight of food to calories of body fat. From this it follows that if two animals differ in their intrinsic net efficiency of food utilization, then the one animal will provide a higher estimate of

the nutritive value of the food than the other.

It was apparent from these statements by Blaxter that energy requirements were different for various classes of beef cattle.

The following table from the National Research Council (1958) shows the digestible energy requirement per pound of feed for various classes of animals weighing the same (800 pounds).

Table 4. Digestible energy requirement per pound for various classes of animals weighing 800 pounds.*

Class of Stock	D.E. (therms/lb.)
Fattening calves finished as short yearlings	1.36
Fattening yearling cattle	1.30
Fattening two-year old cattle	1.24
Wintering yearling or calves	1.00
Wintering pregnant heifers	1.00
Wintering mature pregnant cows	1.00
Cows nursing calves	1.20
Bulls (growth and maintenance)	1.23

* National Research Council (1958)

Woodman in 1957 estimated a greater starch equivalent need by grazing dairy cows than by those fed in the barn on dry lot. This estimate was based on the assumption of greater activity by grazing animals in obtaining their forage.

Kroman et al. (1961) designed an experiment to study the requirements of steers grazing irrigated pasture. Various degrees of grazing intensity produced variation in energy gain and digestible energy intake. Included was a non-grazing control fed the same forage as silage in a small dry lot. A behavior study revealed that from 2.2 to 4.2 more hours were spent by steers

grazing forage than eating soilage. No difference however, was found in the maintenance requirement for digestible energy between steers fed soilage in a small dry lot and those grazing the pasture. Furthermore, comparisons between regression equations on digestible energy requirements of these pasture steers and steers fed in dry lot showed no significant difference. It was suggested by these data that the extra activity involved in grazing on irrigated pasture did not result in a measurable increase in digestible energy requirements.

Many difficulties are involved in obtaining information on differences in energy requirement of grazing animals and those in dry lot. Notable among these are the measurement of feed intake on pasture and the energy content of the weight gain. Therefore it is understandable that results are conflicting.

Numerous investigators (Nelson et al., 1954; Nelson et al., 1955; Reid et al., 1955; Pope et al., 1956; Darlow et al., 1951) were in agreement that mature native grasses and good quality hay, if consumed in sufficient quantity, provided adequate energy for wintering cattle.

It was reported in the National Research Council (1958) that feed intake was limited (1) by the bulk-handling capacity of the intestinal tract and (2) by the daily T.D.N. intake of cattle. Fattening cattle consume feeds in amounts equal to 2.5 to 3.0 percent of their live weight. Older cattle and more fleshy individuals consume less feed per unit of body weight than do younger animals carrying less condition.

Under such conditions then, it is apparent that small calves may not consume enough forage to meet their energy requirement and therefore energy supplementation may be warranted.

According to Kneise (1957) it was impossible to attain maximum growth

rates with calves under 450 pounds when hay, silage or native pasture with protein supplement was the ration. A calf this size simply did not have enough capacity to consume enough roughage to meet energy and growth requirements.

Duncan (1958) summarized a 16 year period experiment on the production of grass fed beef, at the Tennessee Experiment Station. In one experiment weanling beef steer calves were placed on a specific area of bluegrass, hop and white clover pasture in November and were kept on the pasture until they were sold as slaughter two-year-olds. The animals remained on the pasture throughout the year and received no feed in addition to that provided by the pasture. Excess spring and fall growth of the pasture were clipped and hay from the clippings was the only supplement feed provided during the winter. Steers in this experiment gained an average of 636 pounds from the time they were placed in the pasture as weanling calves until they were sold as slaughter two-year-olds. The permanent pasture produced an average of 136 pounds of beef per acre, and 2.48 acres were required per steer.

Kidder and Beardsley (1952) fed three supplements, (1) black strap molasses, (2) ground snapped corn and (3) cottonseed meal to three groups of steers on pasture for three spring seasons and compared these with steers on similar pasture without supplementary concentrates.

Under the conditions of these feeding trials the cattle obtained sufficient protein from the pasture grass to balance the limited carbohydrates fed in the first and second trial. They concluded that feeding concentrate supplements to steers on pasture was a remunerative practice under the following conditions: (1) When feed prices were not excessive, (2) When the cattle being fed were of such quality that they were capable of producing the higher

grades of beef and (3) When the cattle were so marketed that they bring the full value of the grade which they obtained. The records indicated that a reasonable return was obtained from fattening on grass without concentrate supplements.

Bohman et al. (1961) provided dietary supplements of phosphorus, energy (barley), protein (cottonseed meal, soybean meal and alfalfa) to part of 160 weanling calves. All cattle grazed the same range but were individually fed in portable pens.

During the winter, all supplements except phosphorus increased the rate of gain above the control animals (fed no supplemental feed). Cattle fed protein supplements grew significantly faster than those fed the barley supplement. The rate of gain was equal for the protein supplemented groups. During the summer, only phosphorus increased the rate of gain but for the entire year both phosphorus and winter protein supplements resulted in greater gains. It was apparent from these studies that energy supplementation from grain was necessary only on special occasions.

Several authors (Smith, 1952; Baker, 1952) were in agreement that if young cattle were to be grazed on summer pasture the following year, they could be fed so as to make only a moderate winter gain. If winter gains were large summer pasture gains were likely to be disappointing.

Nelson et al. (1960) divided 80 choice quality grade Hereford steer calves into eight lots of ten heads each and fed them the following winter rations:

Lot 1 and 2 -- Fed prairie hay ad lib, plus 1.25 lbs. of cottonseed pellets per head daily.

Lot 3 and 4 -- Same as lots 1 and 2, plus 3 lbs. of whole oats per

head daily.

Lot 5 and 6 -- Grazed dry native grass and fed 2 lbs. of cottonseed meal pellets daily during the winter.

Lot 7 and 8 -- Same as lots 5 and 6, plus 3 lbs. of whole oats per head daily.

The calves of all lots were allowed to graze native grass pasture during the summer.

The results indicated that adding oats to a winter ration of prairie hay and cottonseed meal pellets increased gains and produced fatter steers than rations without oats. The addition of three pounds of oats to the daily ration increased the gain an average of 38 pounds in the period (153 days) or 0.25 pounds per day. However, as yearlings, these steers gained an average of ten pounds less during the subsequent summer grazing period and consequently increased winter gains resulted in less economical gains.

In another test winter gains of calves were increased approximately 55 pounds by the addition of three pounds of oats per head daily. Without oats the daily gain of steer calves grazed dry range and feed two pounds of cottonseed meal pellets was 0.18 pounds. The addition of oats increased the daily gain to 0.62 pounds. Here again, subsequent summer gains as yearlings were inversely related to winter gains.

The feeding of prairie hay plus 1.25 pounds of cottonseed meal pellets resulted in the same gain as dry native grass range plus two pounds of cottonseed meal pellets and three pounds of oats.

Again, in another experiment, the same authors fed corn on grass to two-year-old steers to determine the effect of level of wintering and subsequent summer gains. Winter gains of steers were increased by adding three

pounds of corn to the ration. However, this practice reduced summer gains, as winter gains and subsequent summer gains were inversely related.

The steers grazed on native grass without supplemental corn did not gain as much as those fed corn on pasture. But the feeding of corn on pasture resulted in a large feed cost and the increased selling price of the steers was not equal to the increased cost.

In all the above studies the results seemed to indicate that energy was the most important limiting factor after protein needs were met. In all the systems of starting calves and managing them through the winter months and subsequent summer grazing season, high level of wintering was not profitable. Although the high feeding level increased gains, the gain was not economical. Summer gain on grass was inversely related to winter gain.

Protein

The protein content of the roughage will chiefly determine whether a protein supplement is required, and also, the amount advisable, if one is needed. Protein content of range forage indicates that protein supplement should be supplied to range cattle as early as late July in some years, and no later than September 1 in the best years.

In trials to determine the best time to feed protein supplement, Smith et al. (1950), fed four groups of steers soybean oil meal at different periods in late summer.

Lot 1 -- July 15 to September 29 -- 3 lbs. SBOM pellets per head
daily

Lot 2 -- August 10 to September 29 -- 3 lbs. SBOM per head daily

Lot 3 -- September 1 to September 29 -- 3 lbs. SBOM per head daily

Lot 4 -- No supplement.

The feeding of SBOM on bluestem pasture from July 15 to September 29 increased gains but relative costs of feed and cattle would determine the usefulness of the practice. The greatest benefit from feeding protein was in the month of September. This was understandable from the fact that the nutritive value of bluestem pasture usually begins to decline rapidly after mid summer.

Kidder and Beardsly (1952) reported a three year feeding trial on fattening steers to determine the necessity for protein supplements on a Florida pasture and to compare self-fed blackstrap molasses with a limited amount of ground corn.

A 20 acre pasture of Stenotaphrum secundatum was crossfenced into five lots with ten steers in each pasture. Blackstrap molasses was fed free choice to lots I and II. Two pounds of cottonseed pellets were fed per head daily to lots I and IV. Lot III was fed five pounds of ground corn per head daily and lot V received no supplement other than minerals.

By comparing the results on the basis of average daily gain the record indicated that 5.55 pounds of molasses with two pounds of cottonseed meal would produce about the same rate of gain as four to nine pounds of ground corn, when these supplements were fed to cattle on adequate pasture. Steers receiving two pounds of cottonseed meal daily gained equally as well as those consuming 5.4 pounds of molasses, but slightly less than those on the combination of the two supplements or on ground corn. As would be expected, those on pasture without supplement made the lowest average daily gain.

Smith (1953) reported that calves, yearlings, and older cattle may be satisfactorily wintered on bluestem pasture supplemented with protein.

Yearling steers gained an average of 39 pounds per head during the winter, and 310 pounds during the summer for a yearly gain of 349 pounds. Steer calves, wintered on dry bluestem pasture for three years, with protein supplements gained an average of 115 pounds during the winter, a yearly gain of 377 pounds.

The investigations above emphasize the need for supplemental protein for range cattle during the later part of the grazing season when the nutritive value of range forage, especially protein has decreased.

Marsh et al. (1959) reported satisfactory weights and reproductive record on cows grazed on range at stocking rates of 30.5 and 38.8 acres per cow with supplemental hay in winter under conditions of heavy snow or severe drought when the total soil nitrogen was 0.09 percent and the annual average crude protein in the forage was eight percent.

The National Research Council (1958) also reported that dry range forage containing less than eight percent crude protein was deficient in protein for all classes of cattle. Ross et al. (1950) stated that mature, dry, cured bluestem and associated long grasses contain as little as 2.46 percent crude protein. Since range forages weather and mature during fall and through winter, it is apparent that one of the main considerations in any cattle wintering program is the provision of adequate protein. The purchase of protein represents a great portion of the cost of wintering cattle on native grass. Therefore, in choosing the most satisfactory supplement, the value of certain protein feeds for wintering stocker cattle, especially as influenced by their mineral composition, becomes an important consideration.

Pope et al. (1956) in a three-year comparison of cottonseed meal versus soybean meal with and without mineral supplements showed that the steers

grazing on dry native grass and supplemented with an average of 2.17 pounds of cottonseed meal per head daily, lost seven pounds per head during the winter. Those of lot four, fed soybean on a protein equal basis, gained an average of 25 pounds. The steers were grazing "short" grass pasture in which buffalo and grama grasses were the predominant species.

In another Oklahoma work, Ross et al. (1950), in a comparison of soybean meal with cottonseed cake and a urea-cotton-seed cake pellet for wintering two-year-old steers on grass showed that a soybean cake ration, supplemented with bone meal when fed to two- and three-year-old steers grazing dry blue-stem grasses produced more winter gain than a soybean cake ration unsupplemented in each of four trials. Steers wintered on bluestem grasses and fed a soybean protein source made significantly greater gains than steers fed cottonseed meal as a source of protein.

Johnson et al. (1941) reported on the results of a nitrogen balance experiment with growing lambs, designed to compare the utilization of the nitrogen of urea, soybean oil meal and casien. They carried out digestion and metabolism experiments on sixteen growing lambs. The nitrogenous supplements were added to, or incorporated in, a basal ration containing approximately six percent of crude protein derived from red top hay and from corn.

From their results they observed that the addition of urea to the basal ration in amounts to produce the equivalent of 12 percent of crude protein on the dry basis induced a retention of nitrogen in growing lambs that could not be bettered by further urea addition, but could be improved by raising the true protein content of the ration. They also concluded that the nitrogen in the products formed in the rumen from urea was as well utilized in metabolism as the nitrogen of soybean meal and somewhat better utilized than the nitrogen

of casien.

Oklahoma workers, in their work with sheep and cattle, have shown that urea nitrogen was most efficiently utilized when supplied up to, but not much more than about 25 percent of the total nitrogen in a pelleted feed mixture for range feeding.

Urea should be combined with a carbohydrate feed when it is used to replace one of the common high-protein supplements such as cottonseed meal. Additional minerals, especially phosphorus, may be needed when as much as 25 to 50 percent of the protein in the supplement is provided by urea. This is because urea does neither provide energy nor does it contain minerals.

Gallup et al. (1953) reported that yearling heifers were successfully wintered on dry grass and a 25 percent urea pellet during three successive years. The pellet was fed at the average rate of two and one-half pounds per head per day.

In metabolism tests, the same authors report that low protein roughages such as non-legume hay and cottonseed hulls were not efficiently supplemented with urea alone. Much of the nitrogen in the urea was wasted unless some carbohydrate feed such as a cereal grain was added to the ration.

In another experiment the same Oklahoma workers compared urea with cottonseed meal as a supplement for wintering steers and heifers. For a period of 100 to 148 days, yearling Hereford heifers weighing 640 to 700 pounds were wintered on dry native grass and protein supplement. The heifers in one group were fed a supplement of cottonseed meal and in a corresponding group were fed the pelleted supplement with 25 percent of its nitrogen (crude protein) as urea. The results of these wintering trials showed that steers or heifers fed the 25 percent urea pellets wintered as well as those fed on

equal amounts of cottonseed meal.

In another test, ten pregnant beef cows were satisfactorily wintered on dry range grass and a daily supplement of three pounds of the 25 percent urea pellet. No difficulties were encountered with any of the cows.

While urea can be successfully used as a protein source, there are certain precautions that must be followed. A highly soluble and readily hydrolyzable protein in the ration tends to depress the utilization of urea nitrogen, as bacteria appear to prefer protein nitrogen. Utilization of urea decreases in low energy feeds because urea does not provide energy. Urea is also toxic in large amounts and can be used safely when it composes up to three percent of the concentrate ration or up to one percent of the total ration.

Numerous investigations have been done on the most desirable level of winter supplementation for beef cattle. At the Kansas Station, Smith et al. (1957) reported a three year summary of level of winter protein supplementation for steer calves both wintered and summer grazed on bluestem pasture.

Three ten-head lots of steers were used. All animals grazed together on a 190 acre pasture during the winter as well as summer. During winter, each morning they were gathered and divided into three feeding pens to receive their supplements.

Lot 12A -- 1 pound of soybean pellets per head daily.

Lot 12B -- 2 pounds of soybean pellets per head daily.

Lot 12C -- 1 pound of soybean pellets and 1 pound of corn per head daily.

Steers in lot 12A did not gain as much as those in 12B and 12C.

Apparently one pound of soybean pellets did not furnish sufficient protein

for steer calves wintered on dry bluestem pasture. Steers in lot 12C fed one pound of soybean pellets and one pound of corn per head daily gained about the same amount as those fed only one pound of soybean pellets.

The same authors (1957) reported a three year summary of steers on summer bluestem pasture supplemented with (1) two pounds of soybean pellets per head daily, (2) two pounds of ground corn per head daily and (3) no supplement, at the later part of the grazing season.

The gain was increased by feeding soybean pellets or corn. Most of the increase in gain came during September. The gain from feeding corn (141 pounds) increased the gain by 15 pounds which under the selling price at the time was too small to justify feeding corn. On the other hand the feeding of 141 pounds of soybean pellets produced 28 pounds of additional gain, which more than paid for the soybean pellets. The authors concluded that protein and not energy feeds were needed for late summer feeding on grass.

Again in 1958, Smith et al., fed the following supplements to four lots of steers which grazed on summer bluestem pasture.

Lot 1 -- 1.0 lb. of SBOM, 44 percent crude protein.

Lot 2 -- 2.9 lbs. of SBOM, 44 percent crude protein.

Lot 3 -- 1.3 lbs. of linseed meal, 34 percent crude protein.

Lot 4 -- 2.6 lbs. of linseed meal, 34 percent crude protein.

The results indicated that gain was increased with increasing level of concentrate feeding in both soybean and linseed meal group. The gain increase occurred in October with little benefit during August and September. It appeared that in most years no supplemental feed may be necessary in August, approximately one pound of protein concentrate would suffice in September, and two pounds per head daily in October.

Nelson et al. (1954) reported on the value of 20, 30, and 40 percent protein supplements for wintering heifer calves. For four years, they used different groups of weanling heifer calves. During the winter feeding period the heifers of lots 1, 2 and 3 were fed prairie hay, free choice, in small traps and an average of one pound per head per day of 20, 30, and 40 percent protein supplements respectively. The heifers of lots 4, 5, 6 and 7 were allowed to graze the dry native grass. Those of lot 4 were fed an average of two pounds per head per day of 20 percent protein supplement, and those of lot 5 were fed two pounds of 40 percent protein supplement. The heifers of lots 6 and 7 were fed an average of one pound per head per day of 20 and 40 percent protein supplements respectively.

Average winter gains of calves were directly related to the protein content of the supplement. Heifers that had gained the least during the winter gained the most during the subsequent summer. The average yearly gains of the heifers wintered in traps and fed prairie hay increased with increases in the protein content of the supplement fed during the winter. The difference in yearly gains were very small when the 20 and 40 percent protein supplements were fed in equal amounts to heifers grazing the dry native grass during the winter.

Rowden et al. (1961) ran a three-year trial on the effect of level and source of supplemental protein to beef calves on native range. They divided 240 Herford steers into four groups to compare effects of different amounts of 20 percent and 40 percent protein supplements on weight gains made during the winter and the following summer. These two supplements were fed at the rate of one and two pounds per head daily during 165 day winter period.

The results of this experiment showed that the protein supplied by one

pound per head daily of a 20 percent protein supplement did not meet the supplemental protein needs of calves on winter range.

In a second experiment the same workers fed to the four groups on native range one pound of 40 percent protein supplement per head daily, two pounds of 20 percent protein supplement per head daily, four pounds of alfalfa hay per head daily, and a full feed of alfalfa. The results of this trial showed that two pounds of a 20 percent protein supplement, one pound of a 40 percent protein supplement and four pounds of alfalfa hay per head daily were of approximately equal value in producing the total gains (winter and summer) of cattle on range of the type used in these studies. The results also indicated, that supplementing this type of winter range with two pounds of a 40 percent protein supplement was not profitable.

In a third trial one group was fed one pound of 40 percent protein supplement per head daily. The other groups received four pounds of alfalfa hay per head daily. A full feed of alfalfa hay either on range or in the dry lot did not increase total gains enough (winter and summer) over either four pounds of alfalfa hay per head daily or one pound of a 40 percent protein supplement per head daily to repay the additional cost. This was not an economical way to winter calves that were to be grazed the following summer. These workers concluded that cost per unit of protein actually supplied was the major factor in selecting a protein supplement for calves on winter range.

Nelson et al. (1962) reported on supplemental winter feeding of fall-calving cows that were fed at different levels during the winter. In one lot cows were fed a low level supplement of 1.43 pounds of cottonseed meal. The high level was self fed a mixture which contained an average of 59 percent

ground milo, 20 percent cottonseed meal, and 21 percent salt. Prairie hay was the roughage during winter feeding season. During the summer all cattle grazed the native grass pasture.

The results indicated only a small difference in the winter losses of the two groups of cows (-158 and -144 pounds) although there was a considerable difference in intake of supplemental feed. There was a marked increase in weaning weights of the calves from the cows fed a high level when compared with those from low level of supplement.

The studies on the time of summer protein supplementation for growing animals indicated that the best time of supplementing was during the later part of the grazing season, starting with approximately one pound per head daily in September and increasing this amount to two pounds per head daily in October.

Winter gains of calves and yearlings were increased by adding two pounds of protein supplement or two to three pounds of grain (corn and oats) to a maintenance ration. Winter gains and subsequent summer gains were inversely related. Availability and cost and selling price seemed to be the important factors to consider in the kind and amount of protein to use.

Research reports on cows indicated decreased losses of weight and markedly increased weaning weights of calves from high level supplementation as compared to feeding a low level. But it was also indicated that females receiving one pound of cottonseed meal pellets per head daily survived longer in the herd, produced 6.5 percent greater calf crop, and returned 43 percent more net return than those fed 2.5 pounds cottonseed meal plus three pounds oats per head daily. These results showed that there was no necessity to feed the beef cow more than needed to maintain her in a thin, but strong, thrifty condition.

Other important considerations taken into account in choosing the most satisfactory supplement were the mineral and energy composition and toxicity of the supplement. From the review of the various studies above, soybean oil meal or pellet seemed to be superior over most other protein supplements.

Minerals

Mitchell (1947) classified the functions of minerals under four headings:

1. They contribute to the structure of the body. Calcium, magnesium and phosphorus are important constituents of bone. This is a growth requirement.

2. They aid in maintaining the status quo of the tissues already formed against the constant erosion of the life processes. This is the maintenance requirement.

3. They participate in the functional activities of the body, such as muscular activity....Reproduction, lactation and egg production will increase mineral requirements in proportion to the mineral content of the products formed.

4. As integral parts of the enzyme systems in the tissue, they aid materially in metabolizing the organic food nutrients making up the bulk of farm rations.

It was reported by Garret et al. (1960) that 13 mineral elements were essential to animals and must be present in their diet: calcium, chlorine, cobalt, copper, iodine, iron, magnesium, manganese, phosphorus, potassium, sodium, sulfur and zinc. Under certain conditions or in certain limited areas, livestock production has been greatly improved by addition of one or more of these essential elements to the animals diet.

Mitchell (1947) stated that among the mineral elements needed by the animal, phosphorus was foremost in importance. This would be particularly true with animals grazing on native forage, because as stated earlier in this report, the percentage of phosphorus in forages decreases somewhat as the

plants mature. Therefore it is important that livestockmen know definitely the conditions and areas under which one or more minerals is likely to be lacking so that expenditures for unnecessary feed supplements for specific situation can be avoided.

According to the National Research Council (1958) calcium deficiency in beef cattle was comparatively rare and mild and the symptoms were inconspicuous. Range forages of good quality possess enough calcium to meet the requirements for calcium.

The minerals, sodium and chlorine are supplied to cattle in the form of the common salt. According to the National Research Council (1958) the sodium and chlorine requirement for cattle was of the order of 1.5 grams of sodium and less than 5 grams of chlorine daily for young growing animals. The corresponding values for lactating cows were 11 and 15 grams.

Smith et al. (1951) studied the effect of withholding salt on the growth and condition of steers. On a ration composed largely of roughage, the steers allowed access to salt gained considerably more than those fed no salt.

The same results were obtained the next year on a wintering ration. They also observed that calves given free access to salt consumed slightly more feed and were much more efficient in converting their feed into pounds of beef.

The National Research Council also stated that magnesium deficiency of beef cattle had not been established. It seemed that since forages commonly fed to cattle contain much magnesium as well as potassium, these minerals were not normally thought of in supplemental feeding. Sulfur on the other hand was required in larger amounts (as part of amino acids, especially when urea makes a large part of the protein) than either potassium or magnesium. Many roughages contain enough manganese to more than meet the requirement by beef cattle.

The other elements, known as "trace elements" essential in nutrition and are required in trace amounts are: copper, iron, manganese, zinc, iodine and cobalt. Some of these elements are parts of the body machinery. Iron is part of the hemoglobin molecule, zinc is a constituent of the enzyme carbonic anhydrase and iodine is part of thyroxine. The metabolic trace elements are parts of the many enzyme systems that bring about the oxidation of nutritive material for the production of energy.

Reports on the value of these elements as supplements have been conflicting probably due to differences in mineral content of the soil upon which the feed was grown, management of animals and other environmental factors.

In beef cattle nutrition especially under range conditions, the minerals we concern ourselves mostly with are phosphorus, sodium, and chlorine. Although all the other minerals mentioned are of equal importance in animal nutrition in either structure or metabolism, these minerals are the ones that tend to become deficient or lacking with soil, weather and seasonal variation.

Black et al. in 1943 in a trial with various vegetation samples found that few of the samples contained more than 0.13 percent phosphorus but most of them contained more than 0.23 percent of calcium. The indication therefore was that cattle grazing on such forage would not get sufficient phosphorus to meet their requirements, but that calcium would be ample. Considerable differences existed in the composition of different species and in the same species in various localities and on different soils. The effect of rainfall was usually reflected in increased percentages of phosphorus in the months following the heaviest precipitation. These workers found that feeding supplements which supplied as much as 6.5 grams of phosphorus six days per week to dry cows grazing phosphorus-deficient vegetation prevented phosphorus deficiency.

Phosphorus supplements increased the number of calves and the weight of both cows and calves. In lactating cows, the feeding of 13.4 grams of phosphorus daily resulted in somewhat higher phosphorus content of the blood than 6.5 grams.

Reynolds et al. (1953) conducted an experiment to determine the most practical method of supplying phosphorus to range cattle and to determine the effect of application of different phosphates on the yield and chemical composition of pasture forage. Phosphorus was supplied to cattle by feeding bone meal in self feeders by adding disodium phosphate to a controlled water supply and by fertilizing pasture with triple superphosphate. For those receiving phosphorus in water 20 to 27.5 pounds of disodium phosphate, containing 8.74 percent of phosphorus, were added to 1,000 gallons of water. The solution supplied slightly more than one gram of phosphorus per gallon. For the group on pasture, the pasture was fertilized at the rate of 175 pounds of 58 percent triple superphosphate per acre.

Supplying phosphorus by all three methods gave good results and prevented phosphorus deficiency in normal seasons. Cows that were fed phosphorus supplements and cows on fertilized pasture produced larger calf crops and heavier calves at weaning time than cows that did not receive phosphorus supplements.

Marsh et al. (1959) reported satisfactory weights and reproductive record on cows grazed on range at stocking rates of 30.5 and 38.8 acres per cow with supplemental hay in winter under conditions of heavy snow or severe drought when available soil phosphorus was 2.5 p.p.m., when annual average forage phosphorus was 0.12 percent and when annual average blood phosphorus was 3.7 mg/100 ml.

Long et al. (1957) conducted two feeding trials with grade Hereford steers

to compare the effects of different percentages of supplemental phosphorus on feed consumption, weight gain and inorganic phosphorus in the plasma as measures of phosphorus nutrition. The steers were individually fed low phosphorus (0.07 and 0.09 percent) rations alone and supplemented with NaH_2PO_4 in amounts to provide from 0.11 to 0.19 percent total phosphorus.

Feed intake, weight gain and plasma phosphorus increased with increased amounts of supplemental phosphorus in the ration over the range of 0.07, 0.11, 0.15 and 0.19 percent total phosphorus.

Their results also indicated the equal availability of phosphorus from the three sources; bone meal, Curacao Island phosphate and dicalcium phosphate.

Drake et al. (1962) conducted a trial to study the effects of low to high levels of calcium and phosphorus supplementation for heifers grazing bluestem pasture. From their results these authors observed that the control heifers (those without dicalcium phosphate in ration) gained significantly more than the other three lots that received dicalcium phosphate at different levels. Their data indicate that dicalcium phosphate supplementation at low to high levels did not increase daily gains during a summer and winter period on bluestem pasture.

In another experiment at the Kansas Station, Richardson et al. (1961) examined phosphoric acid as a phosphorus supplement and compared phosphoric acid with steamed bone meal in wintering and fattening rations. They found that phosphoric acid was an acceptable source of supplemental phosphorus.

Wise et al. (1961) determined the availability of phosphorus in dicalcium phosphate, C.P.; deflorinated rock phosphate, Curacao Island phosphate; and soft phosphate with colloidal clay, considering such criteria as feed intake and efficiency, body weight gains, serum inorganic phosphorus, serum alkaline

phosphatase activity, bone growth and some ash; they found that the phosphorus in deflorinated rock phosphate tested was only slightly less available to the calf than that in chemically pure dicalcium phosphate. Availability of the phosphorus in Curacao Island phosphate appeared to closely approach that of deflorinated phosphate. Soft phosphate with colloidal clay was definitely the least satisfactory supplement used.

Much of research work done on mineral nutrition of range cattle emphasized the study of phosphorus. Phosphorus content seemed to vary specially with soil variation, plant species, climatic influence and stage of maturity. Animals did not get sufficient phosphorus when plants contained less than 0.13 percent phosphorus.

In a number of the studies above phosphorus supplements increased the number of calves and the weight gain of both cows and calves. There were a number of methods of supplying phosphorus, and among all the direct supplement of phosphorus as a mineral mix was more practical and efficient. Weight gain, feed intake and plasma phosphorus all increased with increased intake of phosphorus. In the above studies little variability was shown in the availability of phosphorus from the many different sources, although the chemically pure dicalcium phosphate seemed to be highly available.

In recent years various workers have reported on the value of trace minerals in rations. These studies have been done mostly in fattening rations and yet the results are inconclusive and sometimes conflicting. This is probably due to differences in mineral content of the soils upon which the feed was grown or management of animals and other environmental aspects.

Russel and Duncan (1956) reported that the cobalt content of pastures was correlated with that of the soil, particularly when the latter was low.

They suggested that the moisture relations of the soil, the availability of soil cobalt, the stage of pasture growth and the species of pasture plant, all play a part in determining the cobalt content of pasture. In general the cobalt content of pasture tended to increase in late autumn and winter when growth was retarded, and to be low in spring and summer when growth was at its maximum.

They further noted that the relation between soil cobalt and pasture was not constant. In general soils containing less than two p.p.m. of cobalt give pastures with insufficient cobalt for ruminant needs. And on such soils cobalt deficiency diseases appear.

In their review, the authors discussed a number of diseases that appeared on soils of widely different geological origin. The conditions in different parts of the world had one common feature and this was deficiency of cobalt in the soils and herbage of the affected areas.

The authors also stated that young calves between six and eighteen months of age were the most sensitive of all to cobalt deficiency. Severe cobalt deficiency developed in cattle when herbage contained 0.02 to 0.05 p.p.m. cobalt on the dry basis. Under such conditions a supplement of 0.05 mg. cobalt daily was found in western Australia to produce some improvement, while a supplement of 0.1 mg. daily produced optimum growth and health.

Morrison (1956) reported that supplemental cobalt given to deficient animals resulted in a marked improvement in appetite in three to seven days.

Underwood (1962) enumerated the various methods of supplying cobalt to grazing stock. He stated that the most economical and widely practiced means of ensuring continuous and adequate supplies of cobalt to grazing stock in deficient areas was through treatment or "topdressing" of the pastures with

fertilizers to which a proportion of cobalt salts or ones has been added. As little as four to five ounces of cobalt sulfate per acre applied annually or biennially or a single dressing of 20 ounces of cobalt sulfate which would last from three to six years would suffice on many deficient pastures.

Other methods mentioned were (1) cobalt-containing salt "licks," (2) oral dosing or drenching the animal with solutions of cobalt salts, (3) direct placement of cobalt salts into the abomasum or duodenum.

Morrison (1956) stated that although an animal could be poisoned by a considerable amount of a cobalt salt, no injury was produced by a ration that contains one hundred times the amount actually needed.

Many investigators are now in agreement that there actually is not a cobalt deficiency in animals, but a vitamin B₁₂ deficiency due to a lack of cobalt. Cobalt is an integral part of the vitamin B₁₂ molecule.

Indications from most research work were that except in areas where cobalt deficiencies were known to exist, or where symptoms strongly indicated such a deficiency, there was no advantage in adding cobalt to the ration of the beef animal.

Russel and Duncan (1956) stated that uncomplicated deficiency of copper was not of widespread occurrence, and consideration of diseases in which the animal's store of copper became depleted must involve discussion of the metabolic relations between this and other elements, most notably molybdenum. Underwood (1962) reported that pastures containing four to six p.p.m. on the dry basis, and similarly low in molybdenum, provided sufficient copper for the full requirements of cattle. On this basis the minimum copper requirement of cattle was placed at about four p.p.m. Pastures containing three to four p.p.m. copper or less and molybdenum concentrations usually below 1.5 p.p.m.

induced subnormal blood and liver copper levels and a whole range of copper deficiency signs.

Soils deficient in copper appeared to be less widespread than those deficient in cobalt. Investigations have shown that copper deficiency may appear in animals although the pasture forage had a normal amount of copper. This was usually caused by a high content of molybdenum in the pasture which interfered with copper metabolism. The trouble could be entirely corrected by supplying a copper supplement. The National Research Council (1958) stated that copper deficiency could be prevented by adding 0.25 to 0.5 percent copper sulfate to salt fed free choice.

Underwood (1962) gave three ways of supplying copper to the animal. He stated that the best way of supplying it to the grazing stock involved the application of copper containing fertilizers to the soil, which raised the copper content of the herbage to adequate levels and could also increase herbage yields. The amounts varied with the soil type and other conditions but in many areas five to seven pounds per acre of copper sulfate or its equivalent was usually sufficient for this purpose.

Underwood (1962) stated that the lack of iron was unlikely ever to be a serious problem with farm stock, other than with very young animals reared under confined conditions and dependent wholly on milk. He further noted the absence of an iron-deficiency problem in grazing stock due to the abundance of this element in most range grasses. Pasture grasses usually contained 100 to 200 p.p.m. iron on the dry basis. The National Research Council (1958) reported that iron requirements for beef cattle were unknown, but levels in the feed were believed to be ample.

The likelihood of zinc deficiency in beef cattle appeared remote since

most forages contained between 4.5 and 45 milligram per pound (National Research Council, 1958). Underwood (1962) stated that pasture plants and forages growing on normal soils usually contained 30 to 100 p.p.m. zinc on the dry basis. He also stated that minimum requirements of grazing cattle were not less than about 20 p.p.m. and were probably nearer 30 p.p.m.

Most pastures and fodder contained 50 to 150 p.p.m. manganese on the dry basis, which met the requirements of cattle (Underwood, 1962). It was reported in the National Research Council (1958) too, that since many forages contain 22.5 to 67.5 milligrams per pound of manganese on the dry basis, and since cattle requirements appeared to be met with as little as 2.7 to 4.5 milligrams per pound or air-dry ration, it seemed unlikely that most beef cattle rations required manganese supplementation.

Underwood (1962) reports that all land plants contained iodine in highly variable concentrations. The variation was a reflection of the species of plant, the soil type upon which the plant has grown, the fertilizer treatment received and to some extent, of the climatic and seasonal conditions. The average iodine content of roughages (hays and straws), calculated from a great number of analysis carried out in different parts of the world has been reported to lie within the range 300 to 500 mg/kg.

The National Research Council (1958) estimated iodine requirements of the cow (a 1000-pound dairy cow producing 40 pounds of milk daily) to be 400 to 800 micrograms of iodine per day. Therefore it seemed that iodine requirement of grazing cattle on normal pasture could be met without supplementation. On deficient areas the use of salt containing 0.01 percent stabilized potassium iodide (0.0076 percent iodine) would prevent symptoms of deficiency.

Underwood (1962) noted that it is difficult to ensure regular and

adequate intakes of supplementary iodine to grazing stock because iodized salt was subject to iodine loss under field conditions and also the consumption by grazing animal may be irregular and uncertain. He reported that although it was costly and time consuming, regular dosing or "drenching" was effective.

Research is scarce and inconclusive on the value of trace mineral supplementation to cattle under range conditions. Various investigators (Smith et al., 1955; Klosterman et al., 1953; Gossett and Riggs, 1956) have reported that supplemental trace minerals added to a roughage ration did not improve the performance of cattle. But their value from the standpoint of deficiency has been shown to be extremely important.

Many nutritional and metabolic disorders of economic importance have been shown to result from trace mineral deficiencies in grazing animals. These cases have generally been due to the animals eating forages that have grown on soils that were deficient in the minerals. Normally such soils were not widespread and most forages contained enough of these minerals to meet the animals requirement. Therefore, except in areas where trace mineral deficiencies were known to exist, or where symptoms strongly indicated such a deficiency, it seemed that there was no advantage in adding trace minerals to the ration of the grazing animal.

Vitamins

The information concerning the amounts of the different vitamins in various feeds was exceedingly limited. Furthermore, the amounts of a particular vitamin in various lots of a certain kind of feed seemed to vary

widely, depending on the quality of the feed, the stage of growth, and method of handling.

Morrison (1956) stated that all actively-growing green parts of plants had very high vitamin A values because of their richness in carotene. Such forages were also rich in most of the B-complex vitamins, in vitamin E, in ascorbic acid and in certain unknown factors that were required.

Many investigators (Crampton, 1956; Maynard and Loosli, 1956; Morrison, 1959; Snapp and Neumann, 1960) were in agreement that among the vitamins necessary for survival and continued health of animals, we need give no attention to the B-complex vitamins. This was because ruminants in general, through the action of rumen microorganism, synthesize a large supply of these water-soluble vitamins to meet the animals need. Vitamin A or its precursor, carotene, must sometimes be supplied in the ration when the content in forage was low due to low quality of the forage or its stage of growth. Therefore from the practical standpoint vitamin A was the most important vitamin required by beef cattle.

According to present knowledge the same authors were of the opinion that vitamin D was of little importance in range cattle because these animals synthesized the vitamin in their tissue by the action of ultraviolet rays from the sun. Research was very limited on the vitamin E requirement or supplementation to range cattle but here again the same authors seemed to agree that there was no deficiency of vitamin E in beef cattle kept under good practical condition because most range crops contain adequate amounts to satisfy the needs of cattle.

Vitamin A is formed within the body of the bovine from several plant caretenoids (particularly beta carotene). Many feeds (pasture, silage, yellow

corn, good quality hay) furnish carotene which is converted to vitamin A in the animals body.

Watkins and Knox (1950) stated that the blood carotene of cows on range when compared to existing statements of requirements seemed to indicate that a vitamin A deficiency might occur only in case of prolonged drouth or extremely abnormal conditions.

The authors give an approximate pattern of blood carotene, forage carotene and vitamin A in plasma. The average blood carotene for five years of study, for the months of January and February was approximately 165 micrograms, which was the lowest point of the year. This level was quite adequate when compared to the requirement for lactating cows which was 82 to 118 micrograms. The blood carotene level rose quite rapidly during the last of March and reached a peak during April and May, due to the presence of palatable annuals which appeared during spring seasons under favorable moisture conditions.

Marsh et al. (1959) reported satisfactory weights and reproductive record on cows grazed on range at stocking rates of 30.5 and 38.8 acres per cow with supplemental hay in winter under conditions of heavy snow or severe drought when annual average forage carotene was 70 micrograms per gram; blood carotene 265 micrograms per 100 ml. and blood vitamin A of 30 micrograms per 100 ml.

Oklahoma workers, Pope et al. (1961) chemically analyzed four species of native grass (big and little bluestem, Indian grass and switchgrass) over a twenty year period to examine carotene content. They found that the highest concentration of carotene in the plant occurred while rapid growth was being made. Then the content declined markedly as the grass matured, followed by extremely low carotene levels in October and November and essentially no carotene in the forage during mid-winter after weathering in the field.

The same authors conducted an experiment to compare vitamin A levels of steers in dry lot with those on pasture.

Table 5. Carotene and vitamin A values for cattle on pasture and in dry lot.*

	: Plasma (mcg/100 ml)		: Liver (mcg/gm)	
	: Carotene	: Vitamin A	: Carotene	: Vitamin A
Lot 1 Dry lot for 112 days (fattening ration)	117.6	22.9	2.27	27.97
Lot 2 Pasture for 112 days	523.0	25.4	10.57	69.96
Lot 3 Dry lot for 175 days	85.3	19.0	1.89	9.41
Lot 4 Pasture for 112 days and dry lot for 63 days	97.0	27.7	2.97	48.28

* Pope et al. (1961).

Their results in table showed that the cattle fed for 175 days in dry lot continued to show a decline in plasma and liver levels of vitamin A and carotene. When removed from good pasture in late August and finished in dry lot (lot 4), previously accumulated stores were sufficient to hold plasma and liver vitamin A at a high level.

Thus, it seems that body reserves of vitamin A are important in the need for a vitamin A supplement, especially during short periods of low intake. Temporary periods of deficiency may not cause any harm since cattle are able to store body reserves of carotene and vitamin A during periods of liberal intakes.

Embry and Korton (1961) stated that the reserve carotene may be sufficient for periods as long as four to six months. Time required for depletion on

rations deficient in vitamin A activity depended on the amount of body reserves. Calves became depleted more rapidly than adult cattle.

The vitamin A requirements of cattle are based on weight for the various types of production, maintenance, growth, fattening, reproduction and lactation. The intake of carotene required to furnish the needs depends on the digestibility of the carotene in the feeds and the efficiency of conversion of carotene to vitamin A. The concentration of carotene in the feeds depends on the type of feed, harvesting and storage methods and losses resulting during harvesting and storage.

Table 6. Carotene and vitamin A requirements of beef cattle.*

Type of production	: mg Carotene : per 100 lbs. : body weight	: I.U. Vitamin A : per 100 lbs. : body weight**
Growth and fattening (all rates of gain)	6	2,400
Production (pregnant cows and bulls in service)	6	2,400
Lactation (first 3 to 4 months)	9	3,600

* Embry and Korton (1961)

** 1 mg. carotene equals 400 I.U. vitamin A

Maynard and Loosli (1956) gave an estimated carotene content of feeds, in mg. per pound. Fresh green legumes and grasses contained 15 to 40. Legume hays contained 35 to 40 and non-legume hays contained 9 to 14. An examination of these values and the requirements shown in the table above show that a deficiency of vitamin A could not be a common occurrence unless cattle were on

low quality weathered ranges.

The high requirement during lactation is to provide the need for the calf, especially during the first three to four months. The calf is born with very little storage of vitamin A in its body. If it is unable to nurse and receive the colostrum at birth, colostrum substitutes with high levels of vitamin A should be given.

Oklahoma workers (Pope et al., 1961) reported that 300 mg. of carotene per head daily during lactation, while not sufficient to prevent some loss of liver vitamin A in the cow, may be more than necessary in order to maintain the beef cow and protect her suckling calf. It was necessary to consider the carotene requirement of the dam during early lactation because of low levels in the new born due to insufficient transport of vitamin A across the placental membrane.

The Oklahoma workers recommended a level of 30 mg. per cwt. daily in early lactation for cows entering lactation with low liver reserve. For those with greater vitamin A reserve 10 mg. of carotene per cwt. daily appeared adequate.

Smith et al. (1963) fed vitamin A supplement to Hereford steer calves on bluestem pasture and compared them with those that had no supplement but grazed the same pasture. Vitamin A supplement had no effect.

Oklahoma workers (Pope et al., 1961) state that steers fattened on pasture build about five times as much plasma carotene as those fattened in dry lot.

It was apparent therefore that vitamin A supplementation to cattle on range, especially of good high quality, unweathered forage, was fruitless. The effect of storage of carotene and vitamin A on lush pasture during the growing season was in most cases enough to carry animals, specially mature large animals, through the winter period when forage content was low. Vitamin

A supplementation in excess of the requirement gave no increased performance.

Oklahoma workers found that beef females could subsist for long periods (up to 43 months) on low-carotene rations before showing signs of severe deficiency. This long period of carotene deprivation did not affect conception, and abortions did not occur until the sixth to seventh month of the third pregnancy.

Liver reserves of vitamin A in the mature beef cow are poorly mobilized to protect the young suckling calf. Therefore it may be important to feed carotene rich feeds to dams during the first three to four months of lactation.

All green-leafed plants contain carotene and the amount present is positively correlated with the green color and the amount of leaves present. The content in plants decreases with advancing maturity. Roughage from mature forages with little green color and leaves are low sources. In this respect, carotene follows the same trend as phosphorus and protein.

Good pastures, legume or non-legume provide a liberal supply of carotene and a deficiency of vitamin A is not likely when cattle have access to green, growing pasture grasses. On the other hand, grasses which have dried up during late fall and winter or during drought will contain much less. Overgrazed and poorly managed pastures are much poorer sources of carotene than properly grazed and managed ones. These are important factors affecting the body reserves of vitamin A at onset of the winter feeding period and the need of winter supplementation.

SUMMARY

For beef cattle on native range an abundance of good quality grass played a vital role in economical beef production. While most pastures were highly nutritious during the growing stage and provided ample forage for the cow and calf herd, their nutritive value was affected by such factors as stage of maturity and chemical composition of the plant species as well as range conditions and management which were essentially influenced by the interplay of grazing intensity, soil influence, climate and fertilization.

Protein, nitrogen-free-extract, ether extract, carotene and phosphorus tended to decrease with advancing maturity, whereas crude fiber, lignin and calcium increased. Many investigators (Savage and Heller, 1947; Stanley, 1938; Watkins and Knox, 1945 and 1950) reported positive correlation of the various nutrients in the plant species consumed by the animal with that of the blood, plasma and tissue of the animal. Chemical and physical properties of the soil controlled to a certain extent the absorption of nutrients by the plants.

The effect of heavy utilization resulted in decreased forage, decreased nutrients in the forage and decreased digestibility. Cook et al. (1948), Sarvis (1941), and Cook et al. (1953), all indicated that in order to realize the optimum gains on native range, moderate to light rate of stocking, varying the rate in order to leave about 50 percent of the annual production ungrazed, was recommended.

Among the various factors that affect nutritive value, stage of maturity seemed to influence forage quality more than any other factor. Nutritive value of forages decreased as the season advanced and this occurred on all

ranges, regardless of proper stocking rate for year-round grazing in normal rainfall areas, with good range conditions and good quality forage species. Thus supplemental winter feed was one of the major costs of maintaining a calf and cow herd.

Protein was the nutrient most universally lacking in winter roughage. The requirement of the cow herd was probably more exacting due to the fact that the cow must provide for the calf as well as maintain herself. Most research workers indicated decreased losses of weight and markedly increased weaning weight of calves from proper supplementation as compared to low level supplementation. In this case a level of about 0.3 to 0.4 pounds of digestible protein supplied per head per day in addition to range forage seemed desirable from the standpoint of maintenance, calf crop and longevity. There was no necessity to feed the beef cow more than needed to maintain her in thin but strong thrifty condition.

On the effect of winter feed levels on the growth and productivity of the beef females, a 13 year summary of Oklahoma work (Pinney et al., 1961) indicated the danger of underfeeding and overfeeding. Underfeeding seemed to result in delayed skeletal growth, body weight, and late calving, with smaller calves at birth and weaning. Overfeeding seemed to result in more calving difficulty, depressed milk production, and a tremendous increase in feed cost. Medium to high level, where heifer calves were wintered to gain approximately 0.5 pound daily throughout the first wintering period and fed as to lose less than ten percent of their fall body weight each winter thereafter to maturity, appeared to be desirable from an economic standpoint and in terms of growth of the dam, weaning weight and number of offspring produced.

Studies by Smith et al. (1957) and (1958), Nelson et al. (1954) and

(1960), Pope et al. (1956) indicated increased gain by feeding protein supplement to calves, yearlings, two- and three-year-old steers and heifers. Supplementation and level depended upon the season of the year. During the lush growing season, it appeared that no supplement feeding may be necessary. When the season advanced and range forage matured, protein content decreased.

Studies on the time of protein supplementation for growing animals indicated that the best time to start supplementing was during the later part of the grazing season, starting with approximately 0.3 to 0.4 pound of digestible protein per head daily in September and increasing this amount to 0.6 to 0.8 pound of digestible protein per head daily in October.

Many investigators (Nelson et al., 1960; Smith, 1952; Baker, 1952; Nelson, 1954) have shown that a high level of wintering reduced gains in a subsequent summer grazing period. Therefore if young cattle were to be grazed on summer pasture the following year, they should be fed so as to make only a moderate winter gain. These authors have also shown that average winter gains of calves were directly related to the protein content of the supplement and recommended about 0.5 to 0.8 pound of digestible protein per head per day of a protein supplement.

A deficiency of energy, due to a simple lack of sufficient total feed, was a common deficiency, especially on overstocked ranges and during periods of prolonged drought. An energy deficiency was usually accompanied by deficiencies in all other nutrients but especially in protein. But many investigations (Nelson et al., 1954; Duncan, 1958; Reid et al., 1955; Pope et al., 1956) were in agreement that range grasses, if consumed in sufficient quantities, provided adequate energy for cattle needs. The studies on summer protein supplementation indicated that gain increases occurred mostly in

October. This indicated that protein and not energy feeds were needed for late summer feeding on grass.

Phosphorus deficiency was the most common mineral deficiency and was most likely to occur in growing cattle being wintered on all-roughage rations and in cows being wintered on mature weathered grass. In the early stages of phosphorus deficiency feed intake was decreased, gain was reduced, and milk production fell off with a consequent reduction in suckling calf gains. Efficiency of feed utilization was reduced and if the deficiency was prolonged, blood phosphorus level fell.

Definite information concerning the minimum phosphorus requirements of the various classes of beef cattle was very limited. The phosphorus content of various hays usually ranged from 0.10 percent or even less, up to 0.30 percent. Early in their growth, grasses and legumes had a much larger percentage of phosphorus on the dry basis than at the hay stage.

It was indicated by some authors that pastures that contained less than 0.13 percent phosphorus did not provide sufficient phosphorus to meet their requirements.

Feed intake, weight gain and plasma phosphorus were increased with increased amounts of supplemental phosphorus under deficient conditions. Whether a phosphorus supplement should be supplied to beef cows or young cattle on range depended mostly on the phosphorus content of the forage, which in turn depended upon the soil. The National Research Council (1958) recommended a level between 0.15 to 0.3 percent phosphorus in the total ration. Therefore when grass has matured and weathered and phosphorus content lowered, supplementation could be required.

Practical methods of supplementing phosphorus were discussed and among

them, direct supply or fertilization with phosphate fertilizers was found to be an efficient method. Fertilization not only increased the yield of crop, but also produced feeds of normal phosphorus content.

The National Research Council (1958) showed that various classes of beef cattle need no more than 0.2 to 0.3 percent calcium in their ration on the air-dry basis. Morrison (1959) showed that pasture grasses, matured and weathered contained 0.33 percent calcium while those of spring or autumn contained 1.2 percent. Therefore there seemed to be no deficiency of calcium unless the roughage was grown on soil very low in calcium.

The specific quantitative requirements for manganese, potassium and sulfur have not been determined. Experimental work in this area was limited, since the content of these minerals in the feedstuffs normally consumed by beef cattle were such that deficiencies do not normally occur.

Salt (sodium chloride) was essential to the growth and health of all kinds of livestock. Withholding salt from the ration decreased feed intake, decreased efficiency and decreased gain.

The content of trace minerals in feedstuffs was closely associated with their content in the soils from which they were grown.

Cobalt was required by rumen microflora to ensure adequate vitamin B₁₂ synthesis. The requirement expressed as content of the diet could be met by 0.10 p.p.m. cobalt in the feed, on air dry basis. Soils containing 2 p.p.m. of cobalt gave pastures insufficient cobalt for ruminant needs. Cobalt deficiencies in the ruminant could be prevented or overcome by treatment of the soil or pastures with cobalt containing fertilizers, or by direct administration of supplementary cobalt to the animal.

The minimum requirement of copper for beef cattle appeared to be about

four p.p.m. of the moisture free diet and pastures usually contained four to six p.p.m. on the dry basis, and if low in molybdenum, seemed to provide sufficient copper to meet their requirement.

The iron requirement of beef cattle was unknown, but since pasture grasses usually contained 100 to 200 p.p.m. of iron on the dry basis, iron deficiency was very unlikely other than with young animals reared under confined conditions and dependent wholly on milk.

Average content of iodine in plants lies within the range of 300 to 400 micrograms per kilogram. When daily requirement was estimated at 400 to 800 micrograms of iodine, the average content in pastures seemed to be adequate to meet the needs of range cattle.

The need for a trace mineral supplement was distinctly an area or individual problem. Several experiments have shown that there was no benefit from supplying trace minerals to a ration composed largely of roughage, which indicated that unless the soil was deficient in any one of the trace minerals, there was no need of supplementation.

It was reported that the cow could store sufficient vitamin A during the grazing season, provided grass was good, to run her system several months. However, the latter part of the gestation period, January, February and March could be critical as the cow would probably have used up this store. If the cow went into the winter with a low liver store of vitamin A, it was absolutely essential that her ration be supplemented with this vitamin for the production of a normal calf. It was unlikely that the cows themselves would show any symptoms of vitamin A deficiency, even if wintered on weathered roughage. However, cases of vitamin A deficiency were found among the calves dropped by cows which received no supplemental vitamin A. Several studies indicated that

calves dropped by cows from groups given vitamin A supplementation after depletion of vitamin A stores, showed a marked increase in vitamin A liver stores at three months of age, also higher vitamin A level in the blood, and consequently healthier calves. Vitamin A content of the milk from cows given extra vitamin A was higher.

Embry and Korton (1961) gave the requirement of carotene for growth and fattening, production and lactation as six mg. per 100 pounds body weight; six mg. per 100 pounds body weight and nine mg. per 100 pounds body weight, respectively. Morrison (1949) gave the following estimated carotene content of feeds in mg. per pound of feed; pasture grasses, summer, mature and weathered contained 40.3, 4.9, 2.2 respectively. A comparison between these values and those requirements given by Embry and Korton (1961) show that a deficiency of vitamin A should not be a common occurrence unless the cattle were on very low quality weathered forage.

ACKNOWLEDGMENT

The writer wishes to express his sincere appreciation to Dr. E. F. Smith, the major advisor, for his assistance and helpful suggestions in the preparation of this report. The writer also wishes to express thanks to members of the advisory committee and all the other professors for their help and guidance during course work.

LITERATURE CITED

- Black, W. H., L. H. Tash, J. M. Jones and R. J. Kelberg, 1943.
Effects of phosphorus supplements on cattle grazing on range deficient in this mineral. U.S.D.A. Tech. Bul. 856.
- Blaxter, K. L., 1956.
The nutritive value of feeds as source of energy. Review. J. Dairy Sci. 38:1396.
- Bohman, V. R., H. Melendy and M. H. Wader, 1961.
Influence of dietary supplements on growth of beef calves on semi-desert range. J. Animal Sci. 20:553.
- Cook, C. W., and L. E. Harris, 1950.
The nutritive value of range forage as affected by vegetation, type, site and stage of maturity. Utah Agr. Ex. Sta. Bull. 344.
- _____, 1950.
The nutritive content of grazing sheep's diet on summer and winter ranges of Utah. Utah Agr. Ex. Sta. Bull. 342.
- Cook, C. W., L. A. Stoddart, and L. E. Harris, 1953.
Effect of grazing intensity upon the nutritive value of range forage. J. Range Mgmt. 6(1):51-54.
- _____, 1948.
Measuring the nutritive content of a foraging sheep's diet under range conditions. J. Animal Sci. 7:170-180.
- Crampton, E. W., 1937.
The effect of fertilization on the nutritive value of pasture herbage. Am. Soc. An. Prod. Proceedings. 1934-36. Page 69.
- Daniel, H. A., and H. J. Harper, 1934.
The relation between total calcium and phosphorus in mature prairie grass and available plant food in the soil. J. Am. Soc. Agr. 26(12):986.
- Darlow, A. E., W. D. Campbell, V. G. Heller, J. C. Hillier, R. N. MacVicar, O. B. Ross, D. F. Stephens and R. Taylor, 1951.
Value of supplements for fattening two- and three-year-old steers on grass. Okla. Ag. Ex. Sta. Bull. No. B-372.
- Dotzenko, A. D., 1961.
Effect of different nitrogen levels on the yield, total nitrogen content, and nitrogen recovery of six grasses grown under irrigation. Agron. J. 53:131-133.

- Drake, C. L., E. F. Smith, D. Richardson, and D. L. Follis, 1962.
The effect of feeding different levels of dicalcium phosphate to heifers on bluestem pasture. Kan. Agr. Ext. Sta. Cir. 447.
- Duncan, H. R., 1958.
Production of grass fed beef. Ten. Ag. Ex. Sta. Bull. 282:1-24.
- Embry, L. B., and L. J. Korton, 1961.
Vitamin A in beef cattle feeding. S. D. Agr. Ex. An. Husbandry Pamph. 3:1-10.
- Gallup, W. D., L. S. Pope, and C. K. Whitehair, 1953.
Urea in rations for cattle and sheep. Okla. Agr. Ex. Sta. Bull. No. 409.
- Garret, W. N., G. P. Lofgreen, and J. H. Meyer, 1960.
Addition of minerals to a beef cattle ration. Cal. Ag. Ex. Sta. Bull. 14:7-8.
- Goebel, C. J., and W. Cook, 1960.
Effect of range condition on plant vigor, production and nutritive value of forage. J. of Range Mgmt. 13(6):307.
- Gosset, J. W., and J. K. Riggs, 1956.
The effect of feeding dehydrated alfalfa leaf meal and trace minerals to growing beef calves fed poor quality prairie hay. J. Animal Sci. 15:840.
- Hale, E. B., C. W. Duncan, and C. F. Huffman, 1940.
Rumen digestion in the bovine with some observation on digestibility of alfalfa hay. J. Dairy Sci. 23:953-967.
- Johnson, C. B., T. S. Hamilton, H. H. Mitchel, and W. B. Robinson, 1941.
The relative efficiency of urea as a protein substitute in the ration of ruminants. U. An. Sci. 1:236.
- Joubert, D. M., 1954.
Influence of winter nutritional depression on the growth reproduction and production of cattle. J. Ag. Sci. 44:5-66.
- Kidder, R. W., and D. W. Beardsly, 1952.
Protein and carbohydrate supplements for fattening steers on Everglades pasture. Fla. Ag. Ex. Sta. Bull. 493:1-16.
- Klemmenson, J. O., 1956.
Interrelation of vegetation, soils and range conditions induced by grazing. J. Range Mgmt. 9:134-138.
- Klosterman, E. W., L. E. Kunkle, O. G. Bently, and W. Burroughs, 1953.
Supplements to poor quality hay for fattening cattle. Ohio Agr. Ex. Sta. Res. Bull. 732.

- Kamstra, L. D., A. L. Moxon, and O. G. Bently, 1958.
The effect of stage of maturity and lignification on the digestion of cellulose in forage plants by rumen microorganisms in vitro. *J. An. Sci.* 17:199.
- Kneise, Marvin, 1957.
Supplemental feeding of range livestock and its effect on ranch operations. *J. of Range Mgmt.* 10(6):259.
- Koch, B. A., E. F. Smith, D. Richardson, and R. F. Cox, 1958.
Nutritive values of forages as affected by soil and climatic differences; limestone pasture U.S. Sandstone pasture. *Kan. Agri. Ex. Sta. Circular* 358.
- _____, 1959.
Nutritive value of forages as affected by soil and climatic differences; value of trace minerals for calves on sandstone pasture. *Kan. Agri. Ex. Sta. Circular* 371.
- Kroman, R. P., J. H. Meyer, and J. L. Hull, 1961.
Energy requirements of grazing steers. *J. Animal Sci.* 20:450.
- Little, S., Jose Vicente, and Fernando Abruna, 1959.
Yield and protein content of irrigated napier grass, guinea grass and pangolagrass as affected by nitrogen fertilization. *Agron. J.* 51:111-113.
- Long, T. A., A. D. Tillman, A. B. Nelson, W. Gallup, and B. Davis, 1957.
Availability of phosphorus in mineral supplements for beef cattle. *J. Animal Sci.* 16:444-450.
- Mann, T., and A. Walton, 1953.
Effect of underfeeding on the genital functions of a bull. *J. Ag. Sci.* 43:343.
- Marsh, H., K. F. Swingle, R. R. Woodwar, G. F. Payne, E. E. Frohm, L. H. Johnson, and J. C. Hide, 1959.
Nutrition of cattle on eastern Montana range as related to weather, soil and forage. *Montana Agri. Ex. Sta. Bul. No.* 549.
- Maynard, L. A., 1937.
Interpretations of variations in plant composition in relation to feeding value. *J. Am. Soc. Ag.* 29(3):504-511.
- Maynard, L. A., and J. K. Loosli, 1956.
Animal nutrition (4th ed.). New York: McGraw-Hill Co., Inc.
- Mitchell, H. H., 1947.
The mineral requirement of farm animals. *J. Animal Sci.* 6:365.
- Morrison, F. B., 1956.
Feeds and feeding (22nd ed.). Ithaca, N. Y.: Morrison Publishing Co.

- National Research Council, 1953.
Nutritional requirements of domestic animals. No. 4. Nutrient requirements of beef cattle. Pub. 579.
- Nelson, A. B., G. Bratcher, and O. B. Ross, 1960.
Effect of level of wintering on the production of two- and three-year-old steers. Okla. Agr. Ex. Sta. Bull. B-571.
- Nelson, A. B., R. D. Furr, and G. R. Waller, 1962.
Level of wintering fall-calving beef cows. Okla. Agri. Ex. Sta. Feeding and Breeding Tests Progress Report. Page 71.
- Nelson, A. B., R. W. MacVicar, W. D. Campbell, and O. B. Ross, 1955.
Supplements of different protein and vitamins, mineral contents for wintering bred yearlings. Okla. Agr. Ex. Sta. Bull. B-460.
- Nelson, A. B., O. B. Ross, A. B. Darlow, W. D. Campbell, and R. W. MacVicar, 1954.
Studies on winter rations for commercial beef cows. Okla. Agr. Ex. Sta. Bull. B-418.
- Nelson, A. B., R. Totusek, L. S. Pope, W. D. Gallup, and R. W. MacVicar, 1960.
Feeding trace minerals to beef cattle in Oklahoma. Okla. Agr. Ex. Sta. Bull. B-470.
- Norman, M. J. T., 1962.
Response of native pasture to nitrogen and phosphate fertilizer at Katherine, N. T. Australian J. of Exp. Agri. and Animal Husbandry. 2(4):27.
- Oelberg, K., 1956.
Factors affecting the nutritive value of range forage. J. Range Mgmt. 9:220-225.
- Orr, J. B., 1929.
Mineral in pasture and their relation to animal nutrition. H. K. Lewis and Co. London.
- Patton, A. R., and L. Giesker, 1942.
Seasonal changes in the lignin and cellulose content of some Montana grasses. J. Animal Sci. 1:22.
- Parker, K. W., 1954.
Application of ecology in the determination of range condition and trend. J. Range Mgmt. 7:14-23.
- Phillips, T. G., J. T. Sullivan, M. G. Loughin, and V. G. Sprague, 1954.
Chemical composition of some forage grasses, changes with plant maturity. Ag. J. 46:361-369.

- Pinney, D., L. S. Pope, K. Urban, and D. Stephens, 1961.
Winter feeding studies with beef heifers. Okla. Agr. Ex. Sta. Misc.
Pub. MP-64.
- Pope, L. S., F. H. Baker, and R. W. MacVicar, 1961.
Vitamin A studies with beef cattle. A summary of experimental studies
conducted at O.S.U. 1946-1959. Okla. Ag. Ex. Sta. Bull. B-578.
- Pope, L. S., D. Stephens, R. D. Humphry, R. MacVicar, and O. B. Ross, 1956.
Wintering and fattening steers on native grass. Okla. Agr. Ex. Sta. Bull.
No. B-474.
- Reynolds, E. B., J. M. Jones, J. H. Jones, J. F. Fudge, and R. J. Kleberg,
Jr., 1953.
Methods of supplying phosphorus to range cattle in south Texas. Tex.
Ag. Ex. Sta. Bull. 773.
- Reid, J. T., K. L. Turk, W. A. Hardeson, C. M. Martin, and P. G. Woolfolk,
1955.
The adequacy of some pasture as the sole source of nutrients for growing
cattle. J. Dairy Sci. 38:20-26.
- Richardson, D. F., H. Baker, E. F. Smith, and R. F. Cox, 1961.
Phosphoric acid as phosphorus source for beef cattle. J. Animal Sci.
20:522-525.
- Ross, O. B., R. W. MacVicar, and D. F. Stephens, 1950.
Supplements for two- and three-year-old calves. Okla. Agr. Ex. Sta.
Bull. B-359.
- Rowden, W. W., J. E. Ingalls, K. E. Gregory, and R. M. Koch, 1961.
Protein supplements for beef cattle on winter range. Nebraska Agr. Ex.
Sta. Circular 108:1-7.
- Russel, F. C., and D. L. Duncan, 1956.
Minerals in Pasture: deficiencies and excess in relation to animal health
(2nd ed.). Commonwealth Bureau of Animal Nutrition. Technical Communi-
cation No. 15.
- Servis, J. T., 1941.
Grazing investigation on the northern Great Plains. N. Dak. Agr. Ex.
Sta. Bull. 308.
- Savage, D. A., and V. G. Heller, 1947.
Nutritional qualities of range forage plants in relation to grazing with
beef cattle on the Southern Plains Experimental Range. U.S.D.A.
Tech. Bull. 943.
- Short, L. R., and E. J. Woolfol, 1956.
Plant vigor as a criterion of range condition. J. Range Mgmt. 9:66-69

- Smith, E. F., 1953.
Bluestem pasture in summer and winter for making beef. J. of Range Mgmt. 6:347-349.
- Smith, E. F., F. N. Baker, R. F. Cox, and G. L. Walker, 1956.
Trace minerals in calf wintering ration, and a yearling fattening ration. Kan. Agr. Ex. Sta. Circular 335.
- Smith, E. F., F. W. Boren, D. Richardson, and J. E. Kramer, 1963.
The value of dicalcium phosphate, vitamin A and grinding sorghum grain for calves fed prairie hay. Kan. Ag. Ex. Sta. Bull. 460.
- Smith E. F., and R. F. Cox, 1950.
Effect of feeding a protein supplement during the latter part of the grazing season to two-year-old steers on bluestem pasture. Kans. Agr. Ex. Sta. Circular 373:41.
-
- _____, 1952.
The value of trace minerals in a wintering and fattening ration. Self-feeding grain in dry lot vs. self-feeding grain on bluestem pasture. Kans. Ag. Ex. Sta. Circular 283.
- Smith, E. F., B. A. Koch, R. F. Cox, and G. L. Walker, 1957.
Level of winter protein supplementation for steer calves both wintered and summer grazed on bluestem pasture. Kans. Ag. Ex. Sta. Circular 349:27.
- Smith, E. F., D. B. Parish, and A. J. Clawson, 1951.
Factors influencing the salt requirement of beef cattle. The effect of withholding salt on the growth and condition of steers, Kans. Agri. Ex. Sta. Circular 273.
- Snapp, R. R., and A. L. Neumann, 1960.
Beef Cattle (5th ed.). New York and London: John Wiley and Sons, Inc.
- Stanley, E. B., 1938.
Nutritional studies with cattle on a grassland type range in Arizona. Arizona Agr. Ex. Sta. Tech. Bull. 79.
- Stewart, G., W. P. Cottam, and S. S. Hutchings, 1940.
Influence of unrestricted grazing on northern salt-desert plant association in western Utah. J. Ag. Res. 60:289-316.
- Underwood, E. J., 1962.
Trace elements in human and animal nutrition (2nd ed.). New York and London: Academic Press.
- Watkins, W. E., and J. H. Knox, 1945.
The monthly protein and phosphorus contents of two important range grasses in southern New Mexico. J. Animal Sci. 4:297-305.

Watkins, W. E., and J. H. Knox, 1950.

The relation of carotene content of range forage to the vitamin A requirement of breeding cows. *J. Animal Science*. 9:23-29.

Winchester, C. F., R. L. Hiner, and V. C. Seaborough, 1957.

Some effects on beef cattle of protein and energy restriction. *J. Animal Sci.* 16:426.

Wise, M. B., R. A. Wentworth, and S. E. Smith, 1961.

Availability of the phosphorus in various sources for calves. *J. Animal Sci.* 20:329.

Wooman, R. E., 1957.

Rations for livestock. Ministry Agr. Fisheries and Food (England), Bull. 48.

SUPPLEMENTARY NUTRIENTS FOR BEEF CATTLE ON NATIVE RANGE

by

SHANKUTE TESOEMA

B. Sc., Imperial Ethiopian College of Agriculture and
Mechanical Arts, Harrar, 1960

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Husbandry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1963

Regardless of stocking rate, range condition or soil composition the nutritive value of range forages usually decreased with advancing maturity. Protein, nitrogen-free-extract, ether extract, carotene and phosphorus tended to decrease with advancing maturity whereas crude fiber, lignin and calcium increased.

Good quality range grass, if consumed in sufficient quantity provided adequate energy during both winter and summer, for most purposes. While feeding energy supplements on grass increased the weight gain, such supplementation was largely an economic problem.

Soils containing less than 0.09 percent available nitrogen and forage containing an annual average content of not less than eight percent protein gave satisfactory weights and reproductive performance. Average winter gain, up to a point, was directly related to protein supplementation. For young cattle a moderate level of protein supplied during the latter part of the growing season, starting with approximately 0.3 to 0.4 of a pound of digestible protein per head daily in September and increasing this amount to 0.6 to 0.8 of a pound of digestible protein in October, improved performance.

Monthly average phosphorus content of most grasses was below the calculated minimum requirement for cattle for most months except when the plants were actively growing. During the winter the average phosphorus percentage in forages varied from .039 to .058. Satisfactory results occurred when soils contained 2.5 p.p.m. of available phosphorus and when blood contained 3.7 mg. of phosphorus per 100 ml. of blood. Increasing low phosphorus rations (less than .09 percent) up to 0.19 percent total phosphorus increased feed intake, weight gain, calf crop, weight of calves and plasma phosphorus. The daily requirement for sodium and chlorine ranged from 1.5 grams to 11 grams of

sodium and five grams to 15 grams of chlorine for young and adult cattle respectively. Free-choice feeding of salt was recommended. Supplemental feeding of trace minerals was an area problem. Soil containing less than two p.p.m. of cobalt produced forage with insufficient cobalt for ruminant needs. Severe cobalt deficiency developed in cattle when herbage contained 0.02 to 0.05 p.p.m. cobalt on the dry basis. Supplements of 0.05 to one milligram of cobalt daily gave improved and optimum growth. Soils and forages deficient in copper occurred infrequently. Most pastures contained four to six p.p.m. copper; 100 to 200 p.p.m. iron; 30 to 100 p.p.m. zinc; 300 to 500 p.p.m. of iodine and 50 to 150 p.p.m. manganese on the dry basis. Since these values were well above the requirements, deficiencies rarely occurred.

Carotene content in forage varied from 16 ug/gram (matured, weathered range forage) to 4622 ug/gram (actively growing range plants) depending upon species and locale. Carotene in the blood reflected carotene in the forage. Satisfactory performance was obtained when annual average values of carotene were 70 ug/gram in forage, 265 ug/100 ml. in blood or when blood vitamin A was 30 ug/100 ml. Mature animals, even when wintered on weathered low quality roughage did not show a vitamin A deficiency, because they stored large amounts accumulated during periods when the forage contained much carotene. However calves produced by cows deficient in vitamin A were apt to show symptoms of deficiency.