DIGESTIBLE PROTEIN IN RANGE FORAGES AS AN INDEX TO NUTRIENT CONTENT AND ANIMAL RESPONSE

by
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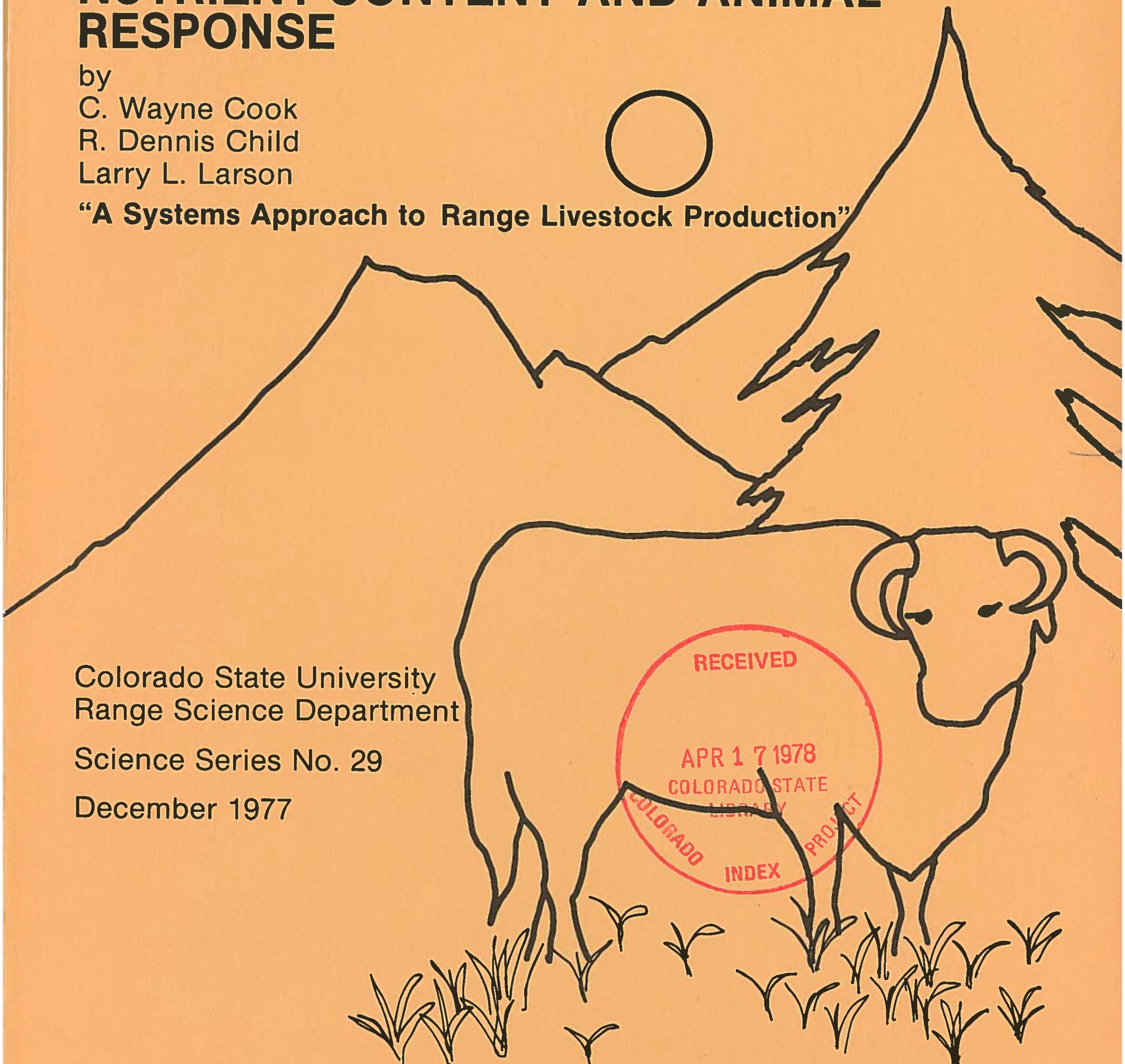
"A Systems Approach to Range Livestock Production"



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"DIGESTIBLE PROTEIN IN RANGE FORAGES AS AN INDEX TO NUTRIENT CONTENT AND ANIMAL RESPONSE,

A Report on NSF Contract No. RDI 75-17225,

"A Systems Approach to Range Livestock Production"

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HIGHLIGHTS

The application of a systems analysis approach to range livestock production required the quantification of as much of a total ranch system as possible. However, practical tradeoff points must be determined between the time and expense of quantification and the value of the information gained from the quantification procedure when dealing with complex systems such as ranching operations. Therefore, this study was undertaken to determine the minimum number of forage nutrients that would be required to evaluate a range livestock operation in a systems analysis framework.

Research has shown that the four nutrients considered most critical to range livestock production are protein, phosphorus, energy, and carotene (Vitamin A). The analysis of 14 independent factors determined that only a relatively few nutrients, such as digestible protein and digestible energy, were even moderately associated with animal gains on rangelands. Digestible protein alone was shown to be the best factor available to evaluate the nutrient quality of range forage. The digestible protein content of range forage responds, with a minimal amount of lag time, to periods of increased forage growth and the phenological advancement of plant growth.

The seasonal variation of forage nutrient quality on rangelands is closely related to plant species characteristics and the growth stage of the vegetation. Therefore, proper range management must be concerned with both the quantity and quality of forage available on rangelands.

The various phases of livestock production during the year involve physiological functions of the animal that require very different quantities of nutrients for optimum response. It is, therefore, important to know what forage types meet the nutrient requirements for various animal classes so that nutritional stresses can be avoided. It is more efficient to supply the nutritive needs of grazing livestock through a forage source than through a concentrate supplement. In most cases, yearlong nutrients for grazing livestock can be supplied by native range or seeded forage pasturage except when inclement weather conditions prevail.

INTRODUCTION

Numerous factors influence the nutrient content of a grazing animal's diet. The growth stage of a plant as well as differences among plant species can modify the nutrient content of the diet. In addition, an animal's consumption of various portions of a plant can be influenced by grazing intensity and season of use. However, in most rangeland situations the grazing animal's diet will be rather closely related to the nutrient content of the dominant forage plants, unless the range is in poor condition and the major forage species are relatively unpalatable. Thus, the chemical content of the current year's growth, of palatable plant species, can serve as an index to the nutrient content of range vegetation types and, hence, the grazing animal's diet.

Many chemical components of forage plants have been studied to predict the digestibility of dry matter or organic matter. However, the relationships derived from these studies were considered reliable only when they applied to a single species or species with similar growth characteristics. Animal response, on the other hand, has generally been associated with energy intake rather than protein, minerals, vitamins, or the relatively undigestible plant fiber material. Energy intake alone does not adequately represent the nutrient content of the diet since other critical nutrients can be seriously deficient when energy furnishing constitutents are adequate. Therefore, it has become common practice to balance rations with respect to all of the essential nutrients.

The development and application of a systems analysis approach to range livestock production required a simplified process of balancing diets in rangeland situations. Therefore, the present study was undertaken to determine if one or not more than two nutrients in range forage might adequately represent the nutritional aspects of most rangeland situations.

REVIEW OF LITERATURE

Scientific research has shown that the seasonal fluctuation of nutrient quality in range forage becomes a limiting factor in livestock production. Cook and Harris (1968a) noted that the four most important nutrients in range forage that may be limiting in range livestock production are protein, energy, phosphorus, and carotene (Vitamin A). In a summary of range nutrition research by Cook and Harris (1968b), it was suggested that animal response appeared to follow digestible protein content of the forage more closely than any other nutrient or combination of nutrients.

Nutrient supplements used to overcome the seasonal nutritional deficiencies of rangelands have shown a variety of animal responses. Scales (1972), in a study involving the supplementation of steers grazing native mixed grass range in Colorado, observed little response to energy supplements fed during the fall and winter. However, protein supplements used in the study were noted to increase live weight gain of steers. Meldrum et al. (1948), on Utah desert ranges, found that in the absence of sufficient protein, animal responses to supplemental energy was only slight. Clanton et al. (1966), on Nebraska sandhill range, and Lewis et al. (1964), in South Dakota, found that steers did not respond to energy supplements on grassland ranges during the winter grazing season. In addition, Clanton et al. (1966) and Cook and Harris (1968a) found that energy supplements (barley and corn) reduced the digestibility of protein in the forage while protein supplements (cottonseed meal and soybean meal) increased the digestibility of cellulose and protein in the diet. It was concluded from these studies that livestock gains were more responsive to a balanced protein diet than to a balanced energy diet because protein served both as an energy source and as a protein source.

DISCUSSION

Computer programs that lend themselves to ranch planning need to evaluate not only the quantity of forage needed to support animals but also the quality or nutrient content of forage. Such parameters are needed for each class and species of animal for each phase of livestock production through the entire year.

Protein and Energy as Related to Animal Response

Animal response is associated with a variety of forage nutrients. However, only a few of these nutrients have proven useful in the prediction of livestock gains.

Nutrient Evaluation

The analysis of 14 independent factors (X_i) determined that only a relatively few nutrients such as digestible protein and digestible energy were even moderately associated with animal gain (Table 1). The data in Table 1 was taken from spring, summer, and fall ranges for

Table 1. Predictive equations for average daily gain of range livestock during spring, summer, and fall for each class of animal.[1]

Animal class	Predictive formulae	R^2 values
Cows	$DG = -.22 + .24\ (DP)$	37
	$DG = 2.36 - 5.57e^{-.3(DP)}$	40
	$DG = .12 + 5.74\ (P)$	12
	$DG = .75 + .0018\ (DE)$	9
	$DG = 5.34 - 7.95e^{-.3(DP)} - .0023\ (DE)$	46
	$DG = -.02 + .33\ (DP) + 5.3\ (P) - .0016\ (DE)$	54
Calves	$DG = 1.13 + .1\ (DP)$	47
	$DG = 2.18 - 2.27e^{-.3(DP)}$	52
	$DG = 1.94 - .96\ (P)$	3
	$DG = .43 + .0012\ (DE)$	28
	$DG = 2.15 - 2.24e^{-.3(DP)} + .00002\ (DE)$	52
	$DG = 1.47 + .107\ (DP) - .88\ (P) - .0002\ (DE)$	50
Steers	$DG = .08 + .24\ (DP)$	58
	$DG = 2.13 - 7.24e^{-.5(DP)}$	77
	$DG = .054 + 7.16\ (P)$	50
	$DG = .28 + .001\ (DE)$	5
	$DG = 3.76 - 8.46e^{-.5(DP)} - .001\ (DE)$	83
	$DG = .37 + .2\ (DP) = 3.2\ (P) - .00065\ (DE)$	68
Ewes	$DG = -.28 + .06\ (DP)$	50
	$DG = .039 + .33\ (P)$	1
	$DG = -.51 + .0006\ (DE)$	19
	$DG = -.532 + .065\ (DP) + .93\ (P) + .00001\ (DE)$	59
Lambs	$DG = .48 + .01\ (DP)$	11
	$DG = .59 - .79e^{-.6(DP)}$	30
	$DG = .48 + .329\ (P)$	9
	$DG = .45 + .00009\ (DE)$	4
	$DG = .67 - .91e^{-.6(DP)} - .00007\ (DE)$	31
	$DG = .26 + .008\ (DP) + .52\ (P) + .0001\ (DE)$	28

[1]Daily gain in lbs (DG); digestible protein in % (DP); phosphorus in % (P); digestible energy in kcal/lb (DE).

cow-calf units, ewe-lamb pairs, and yearling steers. In all cases, it was found that digestible protein (DP) was related more closely to animal gain than digestible energy (DE). In most cases, the accounted variation in animal gain (Y) was increased only slightly when the influence of digestible energy was added to digestible protein as indicated by the magnitude of the R^2 values (Table 1).

The data in Table 1 was obtained from a path regression analysis. The nutrient content of the ingested forage varied markedly with the seasonal variation of the year. In general, the digestible protein content of the forage responded in a similar manner to the seasonal variation expressed by other nutrients, but not necessarily at the same rate. In addition, digestible protein content of the forage reflected increased forage growth following summer precipitation events and the decrease of nutrients associated with the phenological advancement of forage plants. In contrast, digestible energy, which was also moderately associated with animal gain, did not show a marked response to either precipitation events or the advanced growth stages of plants. The predictive formula illustrated in Figures 1 and 2 indicate that predicted gain followed actual gain more closely from the percentage of digestible protein in the diet than from digestible energy.

Digestible protein appears to be the best single factor available to evaluate the nutrient quality of range forage. In most cases, when the requirements of digestible protein are met by range forage for either gestation, lactation, or growth the requirements for energy, phosphorus, and Vitamin A are also met. Exceptions to this statement are: (1) on summer ranges, when the grasses are in the head producing state, protein, energy, and Vitamin A may be adequate for late lactation but the

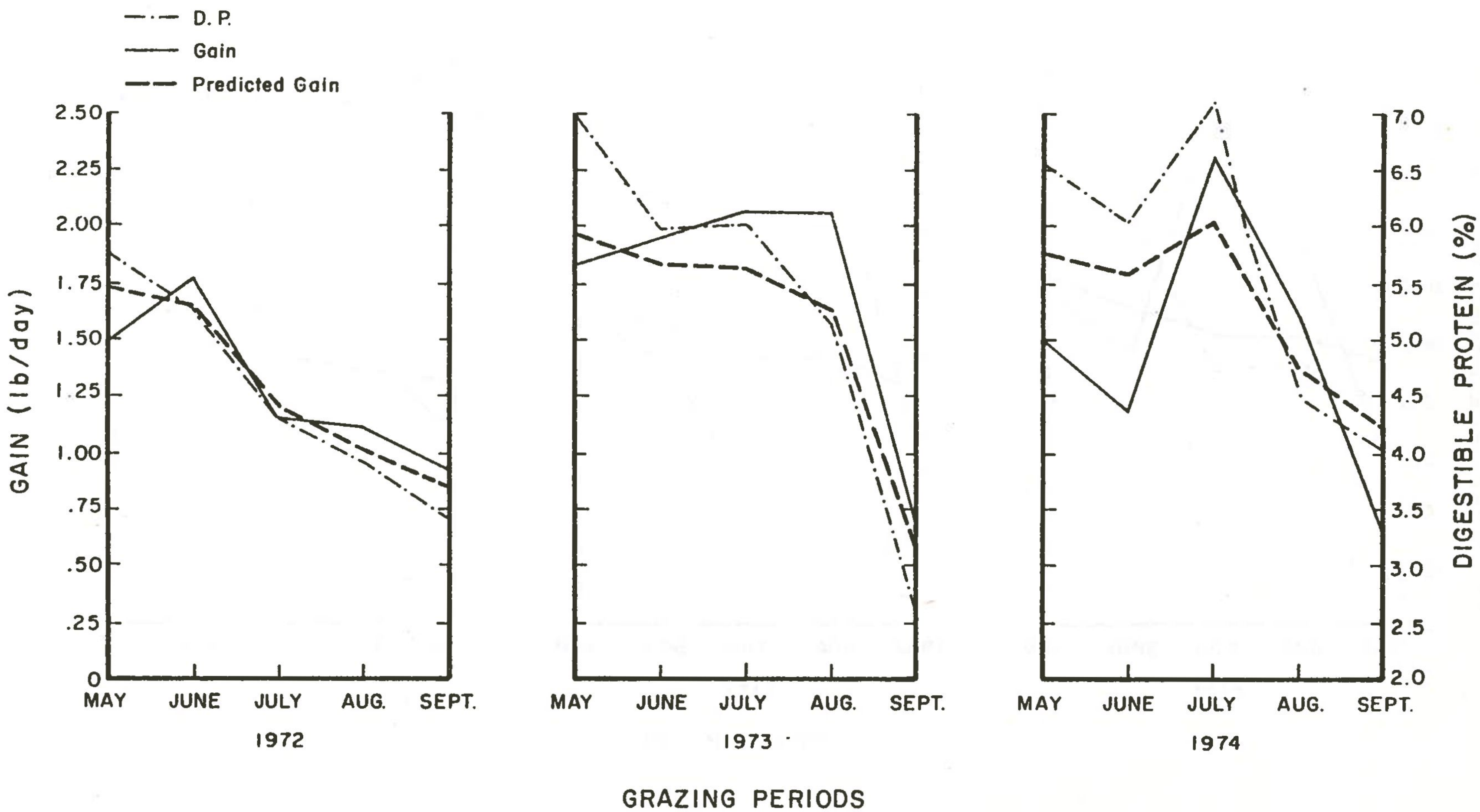

Figure 1. Average daily gain for steers on native range in eastern Colorado during spring and summer grazing seasons compared to digestible protein content of the ingested forage and the predicted gain using DG ≃ .08 + .24(DP).

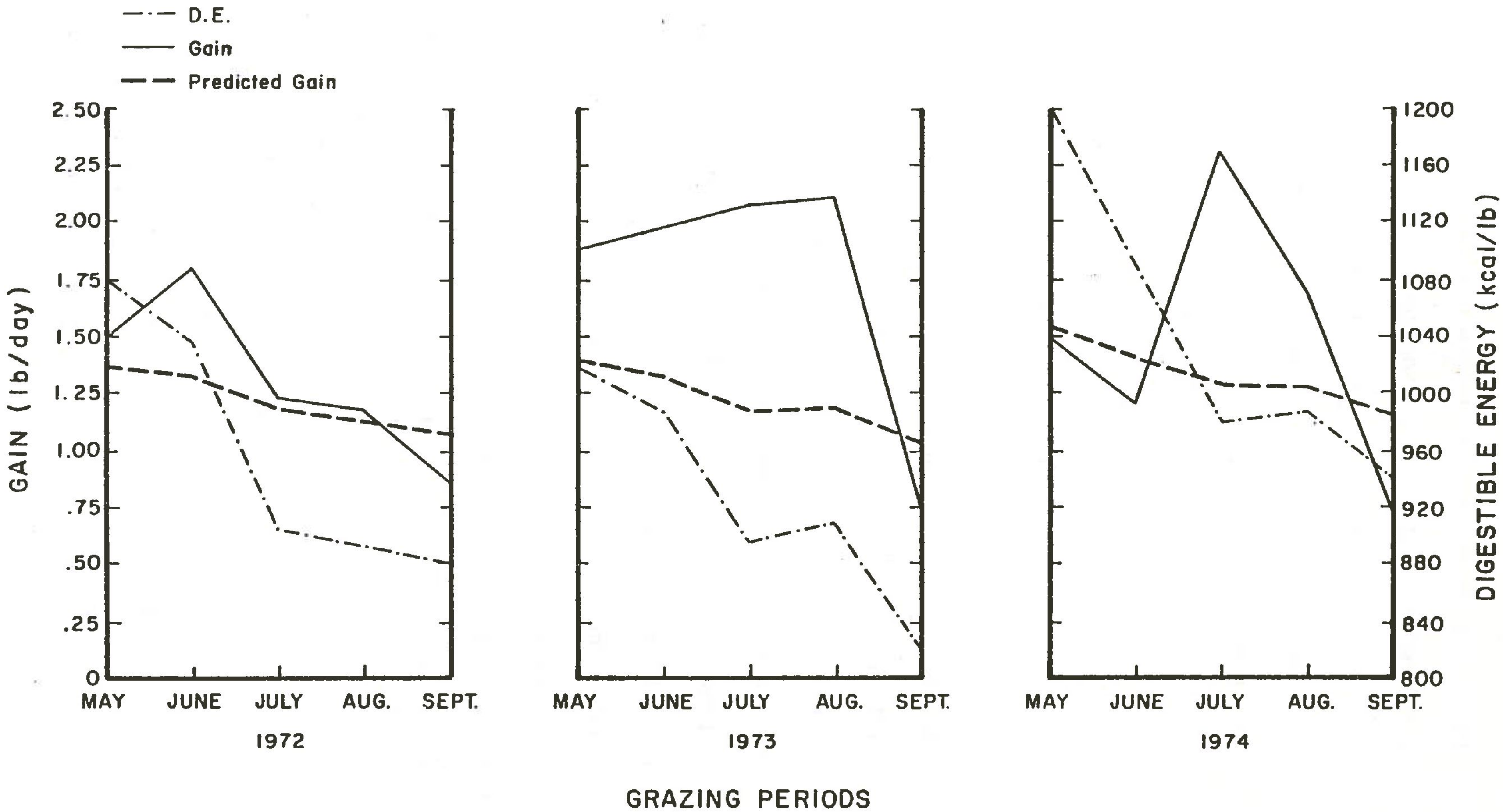

Figure 2. Average daily gain for steers on native range in eastern Colorado during the spring and summer grazing seasons compared to digestible energy content of the ingested forage and the predicted gain using DG ≈ .28 + .001(DE).

phosphorus may be borderline in meeting the requirements of grazing animals, and (2) during winter grazing on desert shrub ranges, the digestible protein, phosphorus, and Vitamin A may be adequate to meet the gestation requirements but the energy furnishing constituents may be borderline. In either case, if the mixture of vegetation includes adequate quantities of both browse and grass, neither of these two situations is likely to arise.

Animal Response

In nearly all cases for animal classes and for all seasons, it was found that the relationship between digestible protein and animal gain was not really linear but rather was exponential as shown in Figures 3, 4, 5, 6, and 7. These graphic relations are shown for animals during the spring, summer, and fall months while females are in lactation and the young are nursing. Admittedly, the daily gain described in the figures does not allow for the influence of initial body weight or condition of flesh among animals within each class but rather deals with averages for a typical animal in western livestock operations. The anticipated gain for a particular class of animal can be determined from the figures by locating the percentage of the digestible protein in the diet along the X axis and by interpolating the respective daily gain along the Y axis.

The data contained in Tables 2, 3, 4, and 5 show the weights for each class of animal on various range types and the expected weight gain in each case, respectively. In the event the animals in question are either smaller or larger than those described in the tables, a direct weight ratio for daily intake and expected gain is appropriate for practical purposes. The gain figures obtained through interpolation (Figures 3-7) should correspond rather closely with body weight and daily gain of the

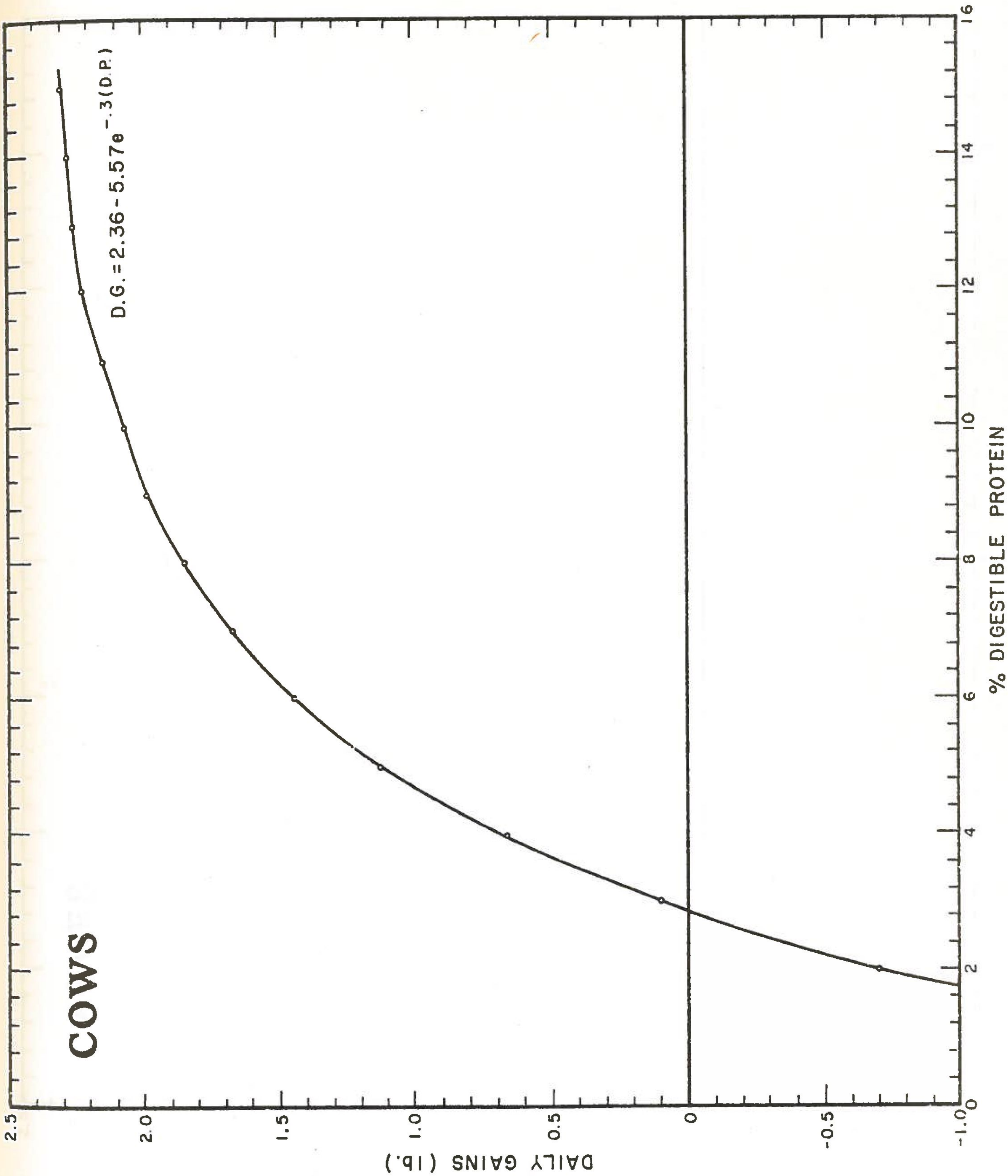

Figure 3. Predicted average daily gain for a typical range cow, during spring and summer, based on the digestible protein content of the diet (dry matter basis).

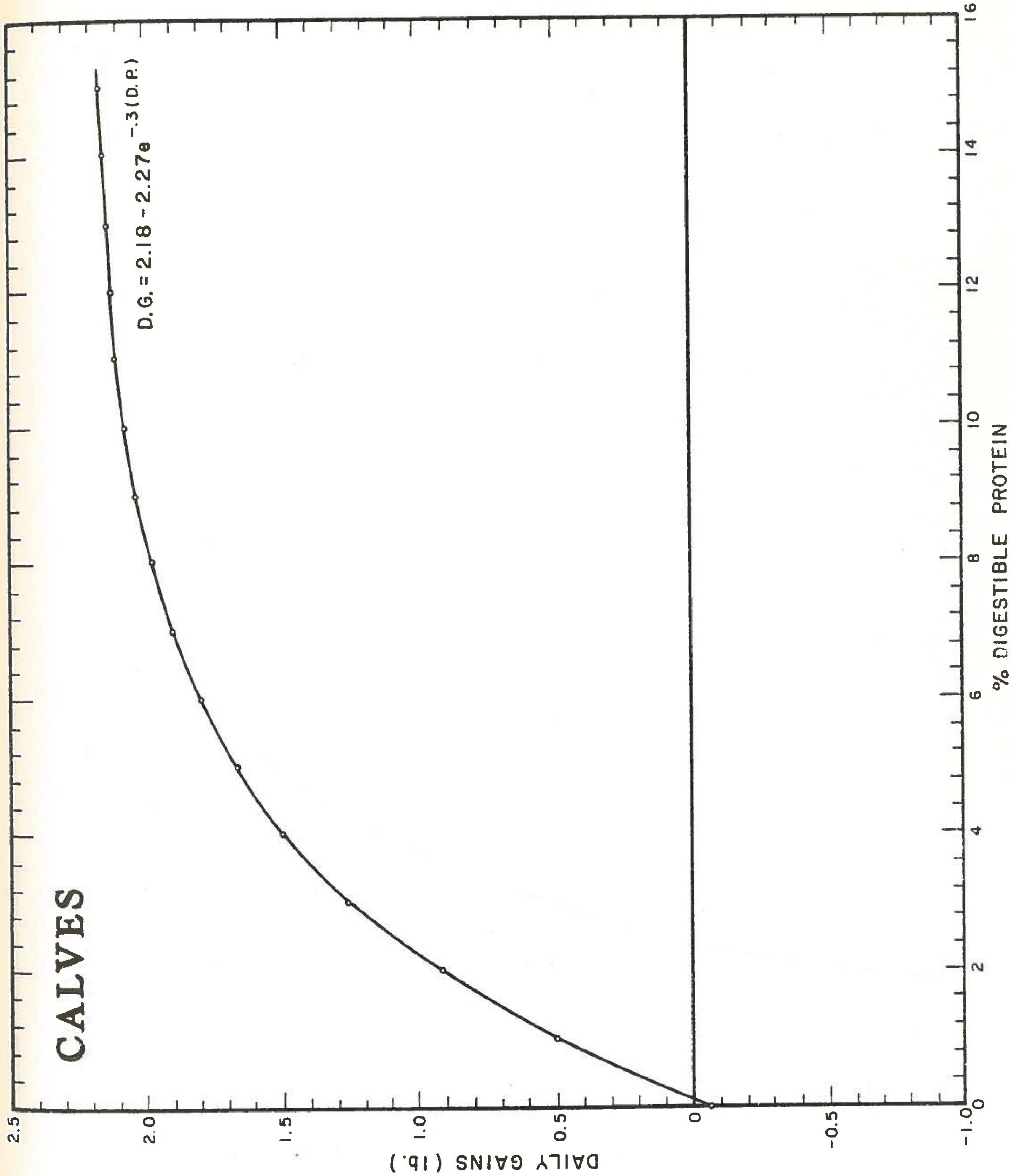

Figure 4. Predicted average daily gain for a typical range calf, during spring and summer, based on the digestible protein content of the diet (dry matter basis).

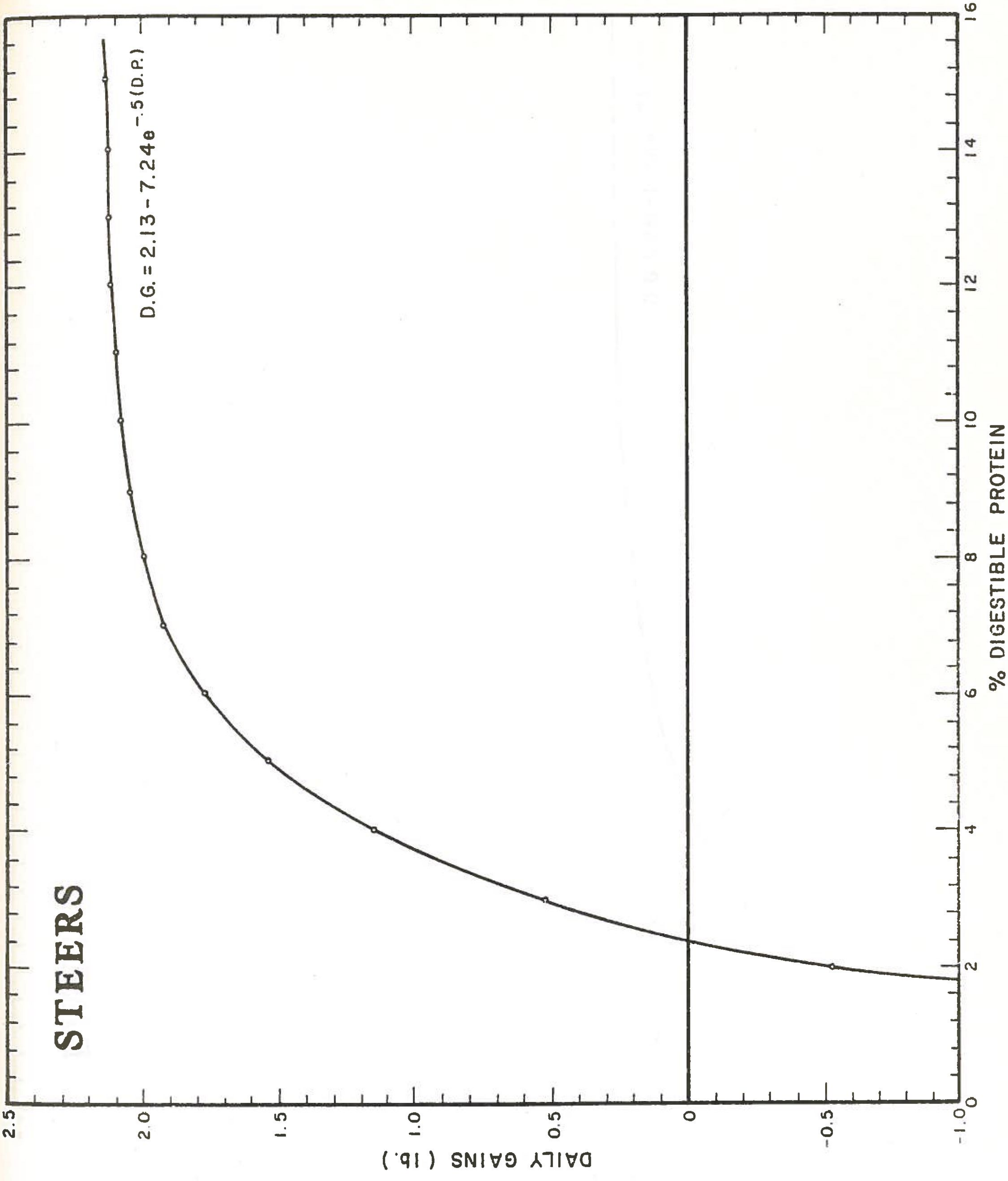

Figure 5. Predicted average daily gain for a typical range steer, during spring and summer, based on the digestible protein content of the diet (dry matter basis).

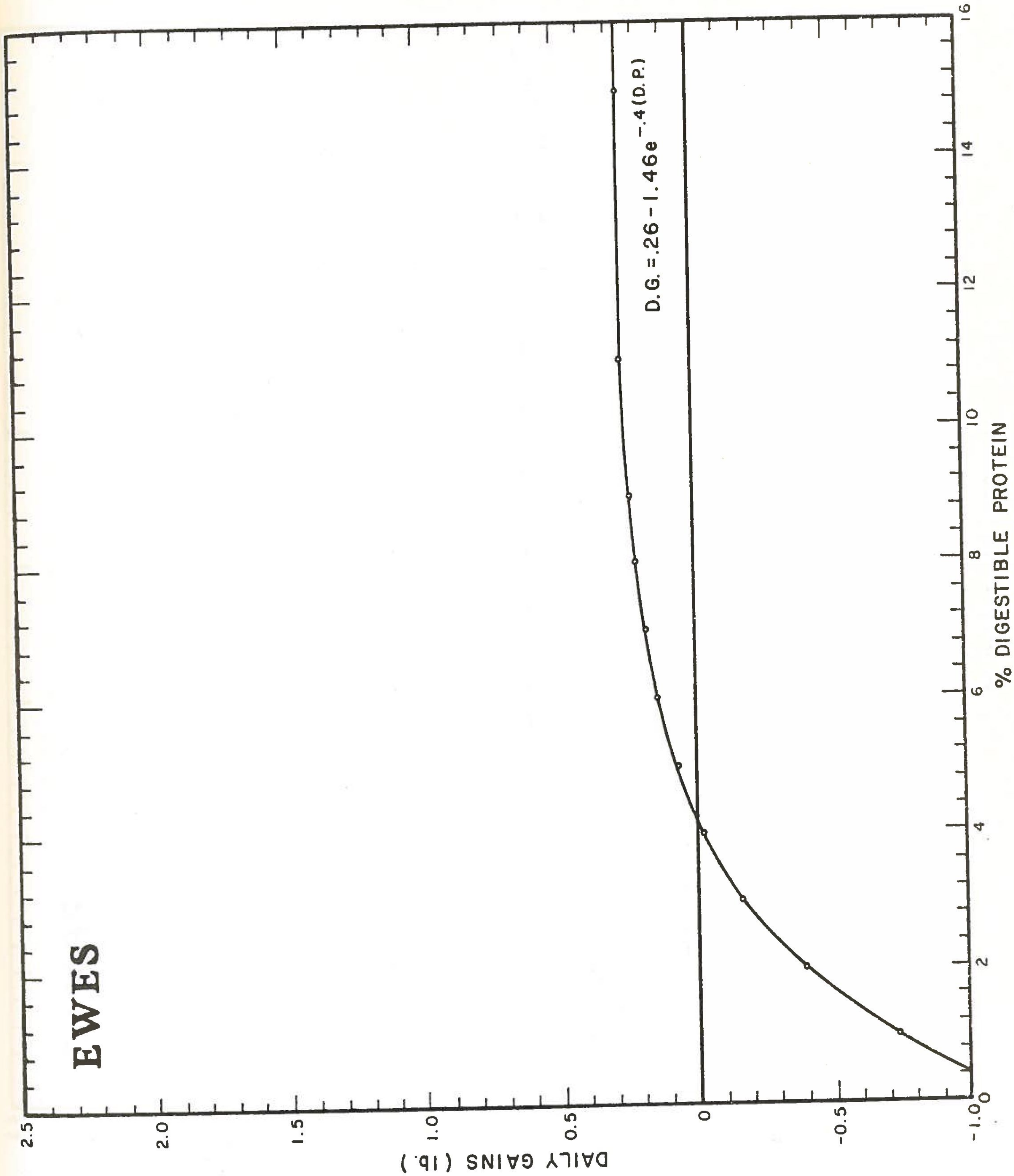

Figure 6. Predicted average daily gain for a typical range ewe, during spring and summer, based on the digestible protein content of the diet (dry matter basis).

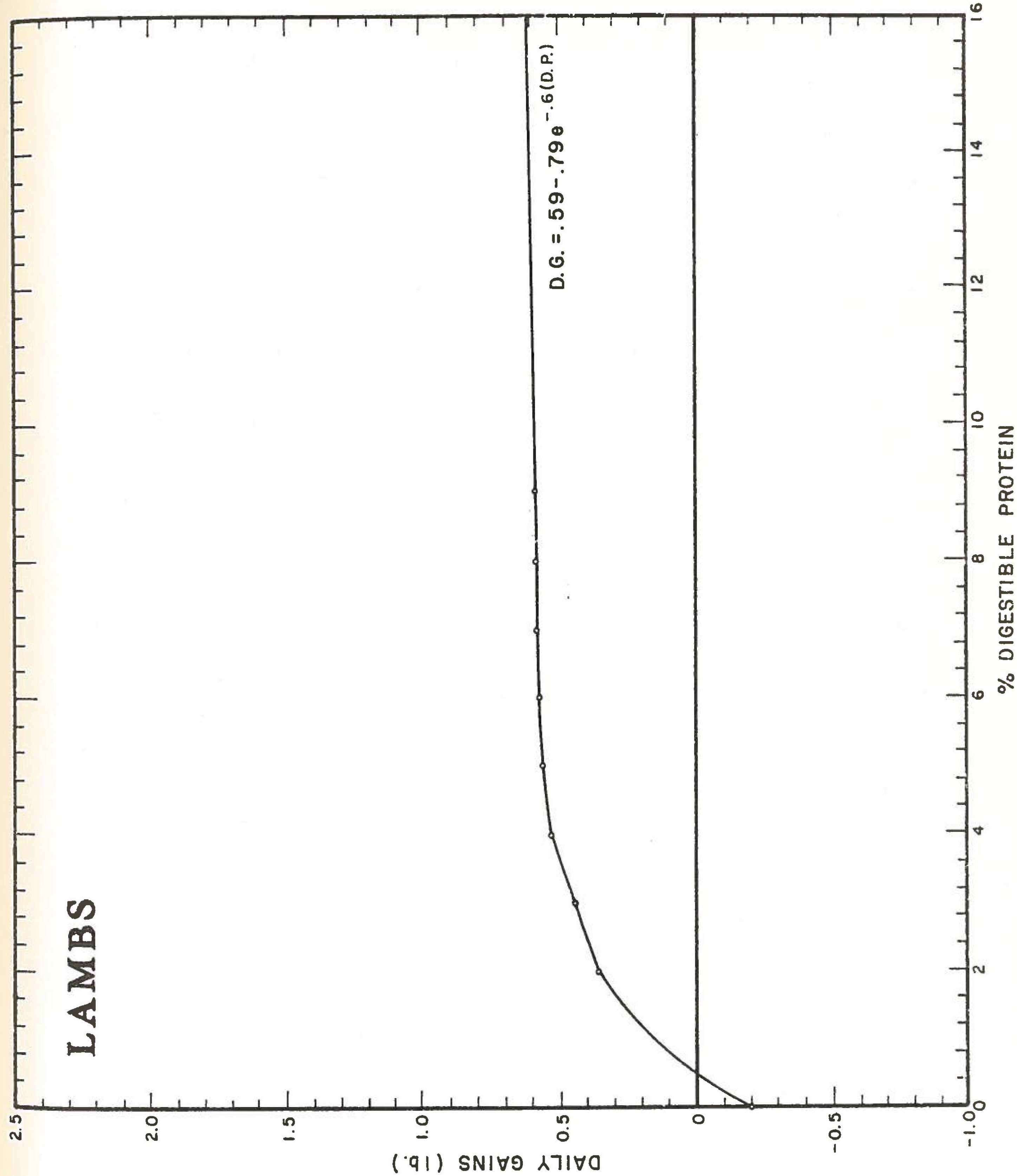

Figure 7. Predicted average daily gain for a typical range lamb, during spring and summer, based on the digestible protein content of the diet (dry matter basis).

Table 2. Average weight, daily gain, percent digestible protein in diet and daily consupmtion of dry matter for native mixed grass range used for grazing steers and heifers.[1]

Date	Weight (lbs)		Expected daily gain (lbs/day)	Percent digestible protein in diet	Expected daily intake (lbs)	
	Yearling	Calf			Yearling	Calf
May 15	579	---	2.00	8.2	18.0	---
Jun 1	609	---	1.85	6.8	18.9	---
Jun 15	637	---	1.75	6.0	19.7	---
Jul 1	674	---	1.65	5.3	20.3	---
Jul 15	699	---	1.62	5.2	21.0	---
Aug 1	723	---	1.60	5.1	21.5	---
Aug 15	747	---	1.50	5.0	22.0	---
Sep 1	773	---	1.50	5.0	22.5	---
Sep 15	799	---	1.50	5.0	23.9	---
Oct 1	825	390	0.60	4.6	23.4	13.0
Oct 15	---	399	0.62	4.4	23.7	13.3
Nov 1[1]	---	408	0.63	4.4	---	13.6
Nov 15	---	418	0.64	4.4	---	14.0
Dec 1	---	428	0.65	4.4	---	14.3
Dec 15	---	438	0.66	4.4	---	14.7
Jan 1	---	448	0.67	4.4	---	15.0
Jan 15	---	458	0.68	4.4	---	15.4
Feb 1	---	468	0.69	4.4	---	15.7
Feb 15	---	478	0.70	4.4	---	16.0
Mar 1	---	488	0.71	4.4	---	16.4
Mar 15	---	499	0.72	4.4	---	16.7
Apr 1	---	510	0.75	4.7	---	17.0
Apr 15	---	521	1.85	6.4	---	17.3
May 1	---	549	1.95	8.0	---	17.6

[1]From November 1 to April 15 animals normally receive a supplement to balance the diet.

Table 3. Average weight, daily gain, percent digestible protein in diet, and expected daily intake of dry matter on native ranges used for grazing for ewe-lamb units.

Date	Weight (lbs) Ewe	Weight (lbs) Lamb	Expected daily gain (lamb lbs/day)	Percent digestible protein in diet	Expected daily intake (lbs) Ewe-lamb or ewe
			Lactation		
Foothill Range					
Apr 15	125	10	.20	6.8	5.6
May 1	127	13	.45	6.2	5.7
May 15	130	16	.45	5.4	5.7
Jun 1	132	23	.55	5.2	5.8
Mountain Range					
Jun 15	134	31	.52	5.3	5.9
Jul 1	136	39	.51	5.0	6.0
Jul 15	138	47	.52	4.9	6.5
Aug 1	139	55	.53	4.9	7.0
Aug 15	141	63	.53	4.9	7.1
Sep 1	142	71	.52	4.8	7.1
Sep 15	143	79	.51	4.7	6.5
Oct 1	144	86	.50	4.6	6.0
Oct 15	144	92	---	4.4	3.2
			Gestation		
Desert Range					
Nov 1	143	--	---	4.4	5.0
Nov 15	142	--	---	4.4	4.9
Dec 1	141	--	---	4.4	4.8
Dec 15	140	--	---	4.4	4.8
Jan 1	139	--	---	4.4	4.8
Jan 15	139	--	---	4.4	4.7
Feb 1	138	--	---	4.4	4.7
Feb 15	138	--	---	4.4	4.6
Mar 1	137	--	---	4.4	4.5
Mar 15	136	--	---	4.4	4.4
Foothill Range					
Apr 1	126	--	---	4.4	4.2

Table 4. Average weight, expected daily gain, percent digestible protein in diet and daily intake of dry matter for native range used for grazing for cow-calf units.

Date	Weight (lbs)		Expected daily gain (calf lbs/day)	Percent digestible protein in diet	Expected daily intake (lbs)
	Cow	Calf			Cow and calf
			Lactation		
Mixed Grass					
May 15	890	125	1.90	7.6	29
Jun 1	909	153	1.86	7.2	29
Jun 15	927	181	1.77	6.5	30
Jul 1	945	208	1.70	5.4	30
Jul 15	960	234	1.68	5.0	31
Aug 1	975	260	1.68	5.0	31
Aug 15	985	285	1.65	4.9	32
Sep 1	990	310	1.60	4.7	32
Sep 15	1000	335	1.60	4.7	31
Oct 1	1020	360	1.55	4.5	31
Oct 15	1006	383	---	4.4	30
			Gestation		
Mixed Grass and Supplement					
Nov 1	999	---	---	4.4	28
Nov 15	992	---	---	4.4	28
Dec 1	985	---	---	4.4	27
Dec 15	974	---	---	4.4	27
Jan 1	971	---	---	4.4	26
Jan 15	965	---	---	4.4	26
Feb 1	950	---	---	4.4	26
Feb 15	955	---	---	4.4	26
Mar 1	950	---	---	4.4	25
Mar 15	945	---	---	4.4	25
Apr 1	940	---	---	4.4	26
			Lactation		
Mixed Grass and Supplement					
Apr 15	875	73	1.70	5.4	27
May 1	882	99	1.70	5.4	27

Table 5. Average weight, expected daily gain, percent digestible protein in diet, and expected average daily gain for crested wheat or Russian wildrye grass pasturage used for spring grazing for steers, cow-calf and ewe-lamb units.

Date	Weight (lbs)	Weight (lbs)		Weight (lbs)		Expected daily gain (lbs/day)			Percent digestible protein in forage	Expected daily intake of dry matter (lbs)
	Steer	Cow	Calf	Ewe	Lamb	Steer	Calf	Lamb		
Steers										
Apr 1	540					2.3			9.0	15.5
Apr 15	574					2.2			8.5	17.0
May 1	607					2.1			8.1	18.6
May 15	638					2.0			8.0	19.5
Jun 1	668					1.9			6.9	20.3
Jun 15	686					1.8			6.2	21.2
Cow-Calf										
Apr 1		858	70				2.2		9.0	27.5
Apr 15		888	103				2.1		8.5	28.3
May 1		915	135				2.0		8.1	29.0
May 15		938	165				2.0		8.0	29.4
Jun 1		963	195				1.8		6.9	29.8
Jun 15		983	222				1.7		6.2	30.2
Ewe-Lamb										
Apr 1				122	14			0.50	9.0	5.2
Apr 15				126	21			0.52	8.5	5.3
May 1				129	29			0.52	8.1	5.5
May 15				132	37			0.51	8.0	5.8
Jun 1				135	45			0.51	6.9	6.0
Jun 15				137	53			0.51	6.2	6.2

various classes for various seasons as shown in Tables 2-5. Metabolic weight (kg wt$^{.73}$) ratios may appear more accurate, but expected animal response does not necessarily follow this hypothesis.

Steers and replacement heifers on mixed grass range (Table 2) gain from 2 to 1.5 pounds per day from early spring to mid summer and fall while digestible protein varies from about 8.2 to 5.0 percent for this period. It is desirable to maintain a gain about 1.7 pounds per day for steers, if they are being held for finishing in the feedlot during the fall.

Sheep in the Intermountain area are grazed on three seasonal range types during the year (Table 3). Frequently, ewes are lambed on seeded foothill range which produces growth adequate for grazing about the second week in April (Table 3). Lambs are expected to gain about 0.5 pounds per day on the average from birth until weaning in October. The digestible protein during this period varies from about 6.8 to 4.7 percent which is considered adequate for lactating range ewes and nursing lambs.

The average expected daily gain of a nursing calf on mixed grass range varies from about 1.90 pounds per day after birth in May to about 1.55 pounds per day in October. Digestible protein in the diet during this period varies from about 7.6 to 4.5 percent (Table 4).

When crested wheatgrass (*Agropyron cristatum*) and Russian wildrye (*Elymus junceus*) grass are used for early spring grazing by steers, cow-calves, and ewe-lambs, the expected gain is about 2.3 to 1.8 pounds per day, 2.2 to 1.7 pounds per day, and 0.50 to 0.51 pounds per day respectively for steers, calves, and lambs (Table 5).

The nutrient requirements presented in Table 6 are believed to be minimum requirements for optimum range livestock production. The

Table 6. Recommended nutrient requirements for cattle and sheep under range conditions during gestation and lactation on a dry-matter basis.[1]

Phase of production	Percentage of ration or amount/pound of feed					
	DP[2] (%)	TDN[3] (%)	DE[3] (kcal/lb)	ME[4] (kcal/lb)	P (%)	Carotene (mg/lb)
Gestation	4.4	46	830	665	0.17	0.16
Lactation						
First 8 weeks	5.4	57	1120	900	0.22	1.6
Last 12 weeks	4.5	49	880	700	0.20	1.6

[1]Nutrient requirements are slightly higher for sheep because smaller animals have a somewhat higher metabolic requirement per unit of body weight.

[2]DP represents "digestible protein".

[3]Calculated by deducting allowance for higher ether extract in browse in the diet. TDN represents "total digestible nutreints" and DE represents "digestible energy".

[4]ME represents "metabolizable energy".

information was developed from approximately 15 years of research at the Utah Experiment Station and represents a practical level of nutrition requirements that can be met for range animals at reasonable costs (Cook and Harris, 1968b).

The nutrient content of the grazing animal's diet is, to a large degree, dependent upon the composition and growth stage of the vegetation forming the diet. Figures 8, 9, 10, and 11 display the seasonal nutrient content of three forage classes in relation to the nutrient requirements of cattle and sheep during gestation and lactation. The nutrient content of all three forage classes are adequate during early growth. However, as maturity is approached, browse species are highest in protein, phosphorus, and carotene while grasses are highest in energy.

Range Management and Forage Nutrient Quality

The seasonal fluctuation of forage nutrient quality can become a limiting factor of range livestock production. Therefore, management programs developed for rangelands must recognize both the quantity and quality of the forage available for livestock grazing.

Seasonal Use and Nutrient Content of Range Types

Various management techniques have been developed in the Great Plains area to reduce the need for expensive feed supplements during the winter grazing period. Most livestock operators in this area of eastern Colorado use grazing rotation systems on both the shortgrass and mixed grass range types. The rotation systems are designed to allow portions of the range to remain ungrazed during the spring and summer so that the herbage can be used during the winter with a minimum amount of feed

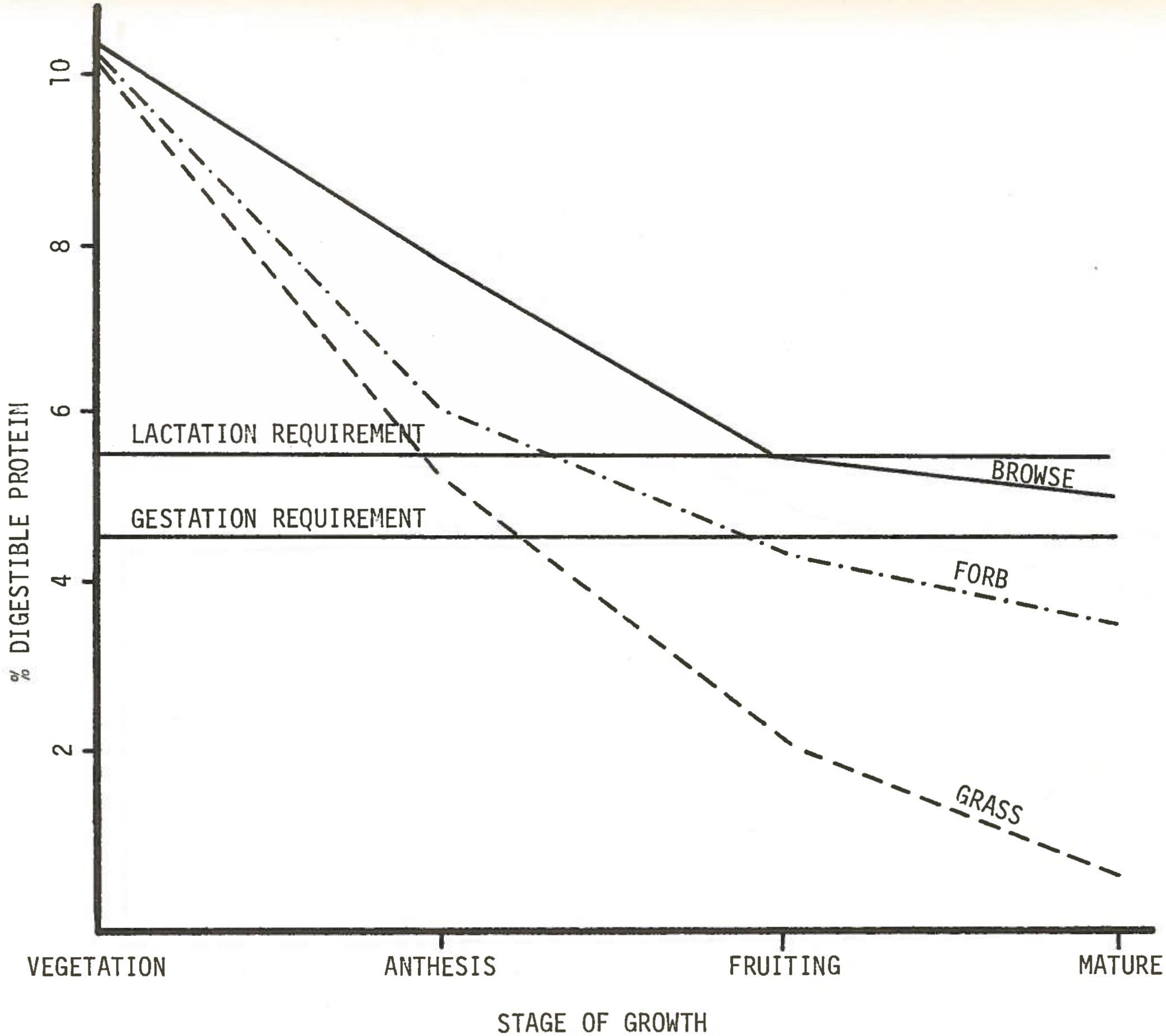

Figure 8. Seasonal content of digestible protein for three forage classes in relation to the nutrient requirements (dry matter basis) of cattle and sheep under range conditions during gestation and lactation.

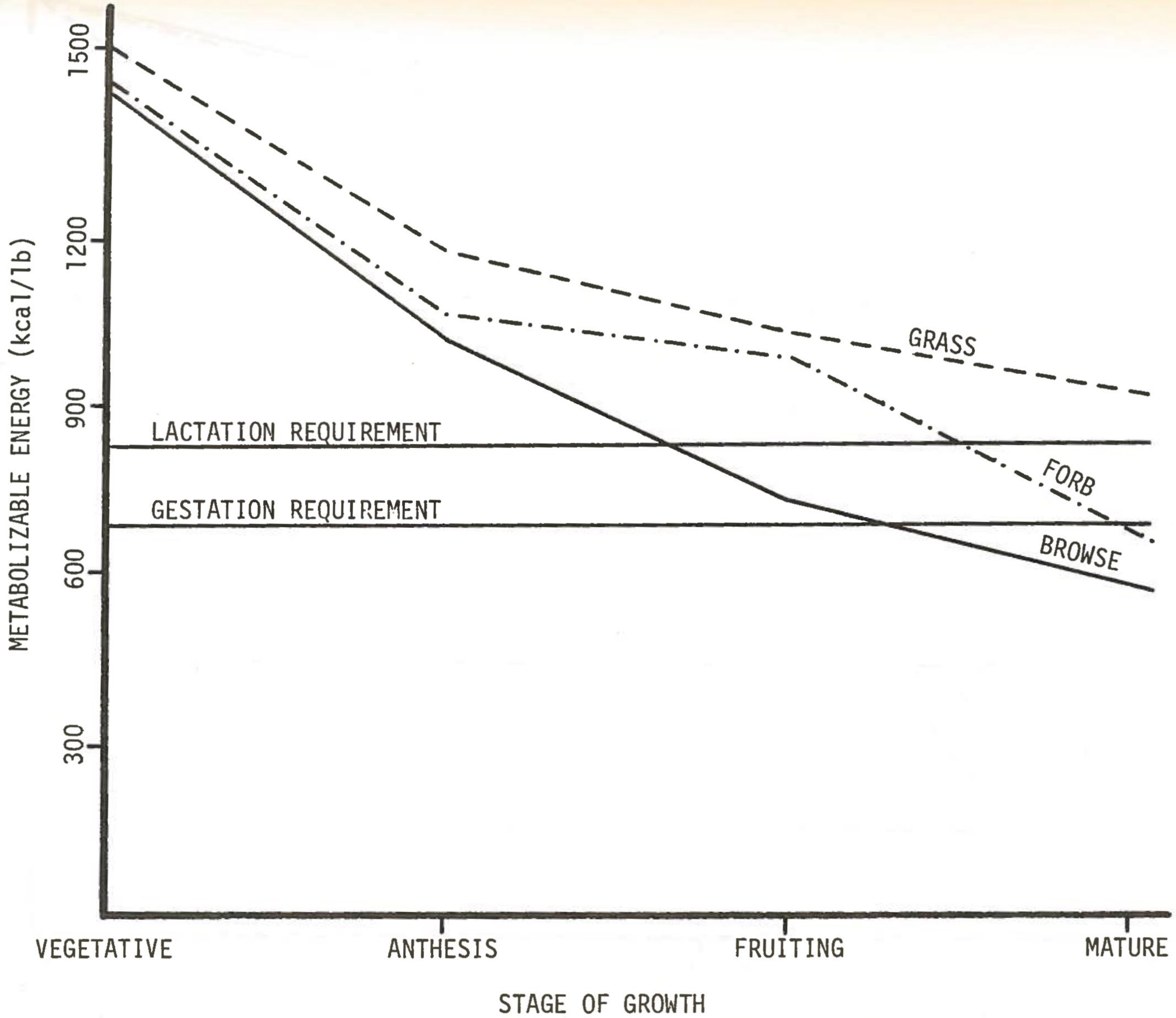

Figure 9. Seasonal content of metabolizable energy for three forage classes in relation to the nutrient requirements (dry matter basis) of cattle and sheep under range conditions during gestation and lactation.

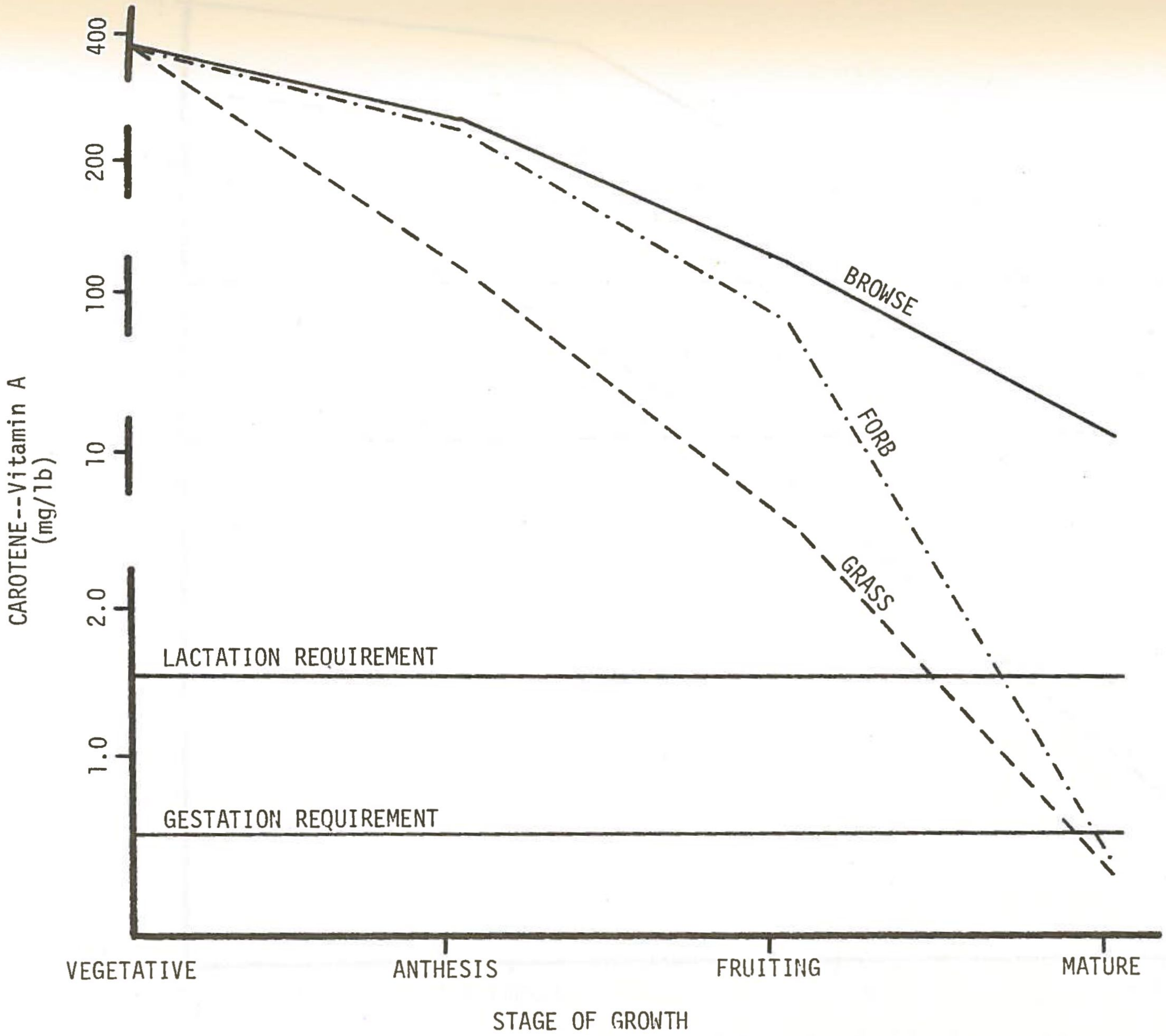

Figure 10. Seasonal content of carotene (Vitamin A) for three forage classes in relation to the nutrient requirements (dry matter basis) of cattle and sheep under range conditions during gestation and lactation.

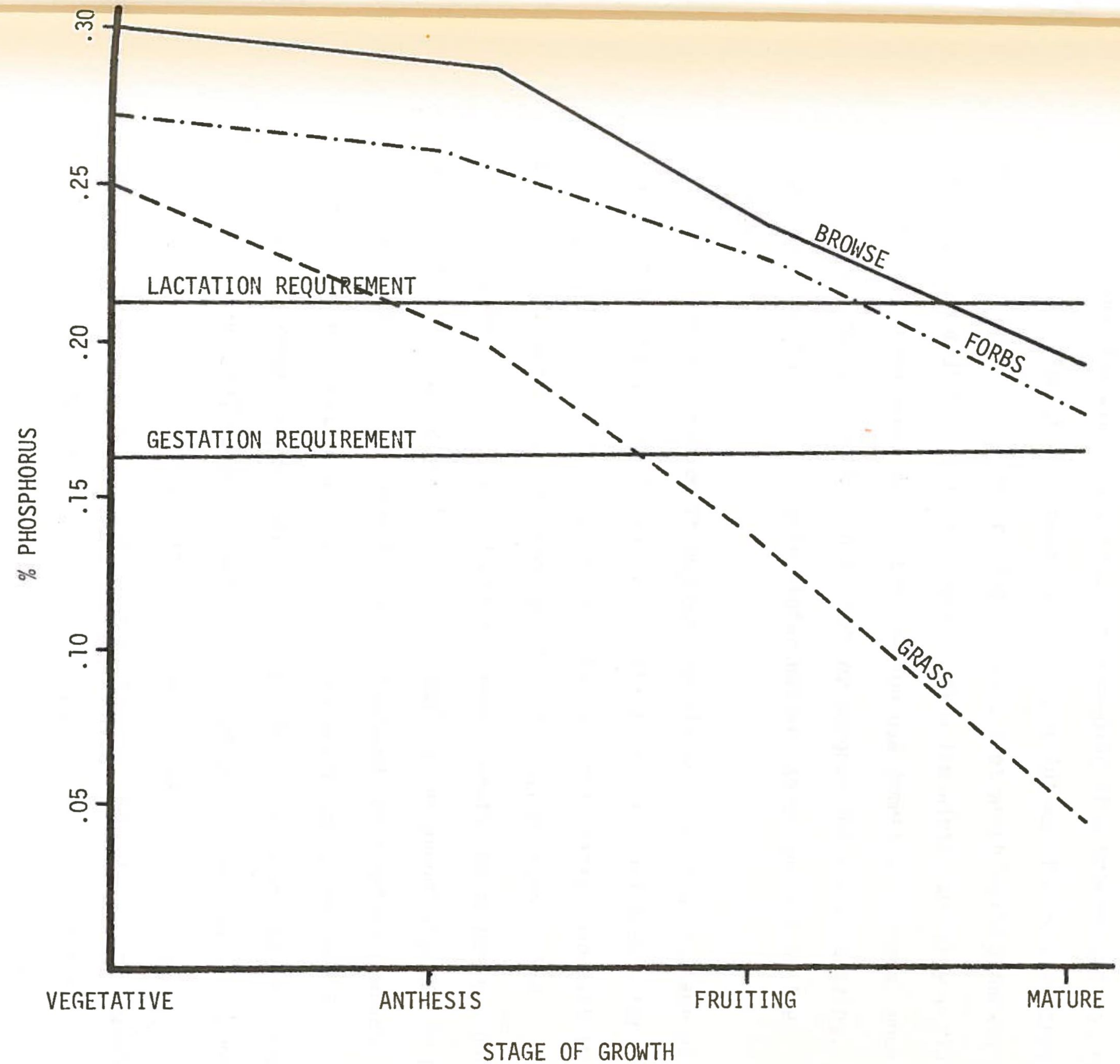

Figure 11. Seasonal content of phosphorus for three forage classes in relation to the nutrient requirements (dry matter basis) of cattle and sheep under range conditions during gestation and lactation.

supplement. Ranchers in the Great Plains area are also being encouraged to interseed four-wing saltbush (*Atriplex canescens*) into the native prairie types for winter grazing. Interseeding of a browse species, such as four-wing saltbush, increases the nutrient intake of carotene, phosphorus, and protein in the grazing animal's diet which would otherwise be deficient in a diet of mature grasses during the winter dormancy period. In contrast, some operators in this region use domestic or annual wheat pasture or crop aftermath such as corn or sorghum for winter grazing, thus reducing the need for both winter native ranges and winter feed supplements.

The universal problem throughout the plains area is a shortage of early spring grazing which can furnish the nutrient requirements for early calving or lambing. Spring grazing is particularly important in the southeast portion of Colorado which is typical of much of the southern Great Plains. Early lactation requirements can be met during April and early May by grazing seeded annual rye or annual wheat. In the northern portion of the Great Plains, introduced cool-weather grasses such as crested wheatgrass or Russian wildrye are sometimes used for early spring range for calving or lambing. Such practices can increase yields of weaner calves by as much as 70 to 80 pounds per cow and as much as 20 to 30 pounds of weaner lamb per breeding ewe (Cook, 1966).

Livestock operators of the Intermountain Region make use of seasonal rangelands by moving livestock from one geographical or altitudinal range to another. The desert ranges are used during the winter from about November 1 to April 5, and the foothill or intermediate elevation ranges are used during the spring from about April 5 to June 15. The mountain ranges are used during the summer from about June 15 until about October 1.

The ability of forage species to meet the nutritional requirements of foraging livestock is critical for optimal livestock production on rangelands. It is common belief that animals do not need a supplement during the late spring and summer grazing seasons since green plant growth from a wide variety of plant species meet the nutrient demands of foraging animals in all phases of production. In like manner, it is generally believed that during the fall and winter supplements are necessary to meet the nutrient requirements of livestock since the forage is mature and inclement weather may seriously reduce daily intake. However, the Intermountain Region, like the Great Plains area, lacks suitable native range for early spring grazing when cows and ewes are coming into lactation from about April 1 to May 15.

Desert range types in Colorado

Information obtained from dietary field studies on desert range make it possible to calculate approximate diets of sheep and cattle. The species composition of a grazing animal's diet has a substantial impact on its nutrient intake on winter range. Browse species in the diet supply greater amounts of protein, phosphorus, and carotene while grasses are higher in energy. Therefore, the desert ranges of the west slope of Colorado were classified as follows: (1) saltbush range, (2) sagebrush range, and (3) grass range.

Saltbush range. On ranges predominantly composed of saltbush (*Atriplex confertifolia*), the diet of sheep averages about 60 percent browse and 40 percent grass. The diet of cattle on similar ranges averages about 40 percent browse and 60 percent grass. The composition of the sheep diet contains considerably more digestible protein and phosphorus than the diet of cattle on similar range. Cattle consume more energy than sheep because of the greater abundance of grass in the diet. However, both diets are slightly deficient in protein and phosphorus and the sheep diet is slightly deficient in energy (Table 7). On the basis of 1.5 pounds of supplement per day for cattle and 0.25 pounds per day for sheep, the sheep supplement should contain about 10 percent total protein and 0.5 percent phosphorus while the supplement for cattle would require 13 percent total protein and 0.8 percent phosphorus (Table 7).

Sagebrush range. On typical desert sagebrush ranges, the differences in nutrient content of the diet for cattle and sheep are pronounced (Table 7). With the possible exception of periods of inclement weather, sheep need no additional protein; however, their diet is borderline in phosphorus content. In contrast, cattle require about 17 percent total protein and 0.9 percent phosphorus when fed at the rate of 1.5 pounds of supplement per day.

Grass range. Desert ranges that are composed largely of grass furnish adequate quantities of energy. However, during the winter forage on desert grass ranges are seriously deficient in protein and phosphorus. A supplement to satisfy the nutrient deficiencies in a sheep's diet when fed at 0.25 pounds per day should contain 17 percent total protein and 1.1 percent phosphorus while supplement for a cow's diet when fed at 1.5 pounds per day should contain about 20 percent total protein and 1.2 percent phosphorus. Animals grazed on desert grass range longer than 120 days would require a carotene or Vitamin A supplement. Sun cured alfalfa hay fed at the rate of about 0.3 pounds per day per head for sheep and 2.0 pounds per day for cattle would meet the dietary

Table 7. Average nutrient content of the diet of cattle and sheep during winter for the three general types of desert range and the recommended supplements for each kind of livestock and each type of range.

		Predominantly saltbush range		Predominantly sagebrush range		Predominantly grass range	
		Cattle	Sheep	Cattle	Sheep	Cattle	Sheep
Nutrient content of diet							
Digestible protein	(%)	4.0	4.2	3.8	4.4	3.6	3.9
Phosphorus	(%)	0.13	0.15	0.12	0.14	0.10	0.12
Metabolizable energy	(kcal/lb)	690	669	720	660	763	737
Recommended composition of supplements when fed at the rate of 0.25 and 1.5 pounds daily per head for sheep and cattle, respectively.							
Total protein	(%)	12.8	10.4	16.5	0.0	20.4	17.2
Digestible protein	(%)	10.5	8.5	13.6	0.0	16.7	14.1
Phosphorus	(%)	0.8	0.5	0.9	0.7	1.2	1.1
Recommended composition of supplements when fed at the rate of 0.33 and 2 pounds daily per head for sheep and cattle, respectively.							
Total protein	(%)	10.9	9.0	13.5	0.0	16.5	14.1
Digestible protein	(%)	8.9	7.4	11.1	0.0	13.5	11.6
Phosphorus	(%)	0.6	0.4	0.7	0.6	1.0	0.9

requirements for carotene. However, if the hay were fed in a pellet form at the rate of about 0.5 pounds per head per day for sheep and about 3 pounds per head per day for cattle the protein, phosphorus, and carotene deficiences of the diet would also be met.

Changes in the nutrient content of the diet of livestock on desert ranges are primarily a result of changes in floristic composition of the diet. The changes in the nutrient content of range forage species as a result of leaching and shattering of seed as the season advances are minor on winter ranges.

Desert ranges that have a variety of grass and browse will provide adequate nutrients for gestating animals during at least early and mid winter unless adverse weather hampers forage selectivity and limits daily intake. During late winter all nutrients may be slightly deficient depending upon the vegetation type and weather conditions (Appendix Table 11).

Mountain range types in western Colorado

The nutrient content of a foraging animal's diet decreases during both spring and summer as the seasons advance on foothill and mountain ranges (Table 8). The nutrient decrease observed during the spring grazing season on foothill ranges is generally more marked than the decrease observed during the summer grazing season on mountain range.

Digestible protein and other nutrients are adequate for lactation and growth of yearling calves after plants enter the rapid growth period in the spring (Early Spring, Table 8). However, supplements are required during the early spring until sufficient amounts of green foliage are present on the ranges to form the bulk of the animal's diet.

Table 8. Average digestible protein and its relationship to digestible energy, phosphorus, and carotene in two seasonal range types of the Intermountain Region of Colorado.

Seasonal range	Grazing period	Digestible protein (%)	Digestible energy (kcal/lb)	Phosphorus (%)	Carotene (mg/lb)
Spring (foothill)	Early	8.8	1295	0.28	>15.0
	Mid	5.6	1194	0.22	>15.0
	Late	5.4	1120	0.20	>15.0
Summer (mountain)	Early	9.0	1255	0.31	>15.0
	Mid	6.4	1104	0.29	>15.0
	Late	4.9	975	0.24	>15.0

Foothill range. Most native foothill range in the Intermountain Region does not furnish adequate nutrients for lactating animals until new growth is available in May (Appendix Table 12). However, these ranges are generally expected to furnish adequate diets for lactating animals during April before sufficient new growth is available. The lack of new growth on native foothill range during April is the major limiting factor to livestock production throughout this area. The most appropriate use of foothill range is during late May and the first part of June after which animals should be moved to higher mountain brush types. It is unwise to graze foothill ranges from April 1 until July 1 and again in the fall because of the physiological requirements of the plants. Even when these ranges are used only from May 1 to June 21 the early season and late season use should be rotated.

Introduced cool season grasses for early spring grazing in April and the first part of May have been beneficial to most livestock producers in Colorado; however, domestic winter wheat and winter annual rye are more successfully used for this prupose in southeastern Colorado (Appendix Tables 13 and 14). These seedings break dormancy around April 1 providing adequate levels of early plant growth for lactating animals about one month earlier than the native ranges.

Mountain range. All nutrients are adequate on most mountain range during the summer season, although digestible protein may become borderline in September unless adequate amounts of palatable forbs and browse are available (Table 8).

The native mountain brush type (Appendix Table 15) at intermediate elevations furnishes adequate amounts of nutrients even in May when new growth first emerges, but grazing at this early date, when the soil is damp and the new growth is small, is believed deleterious to range condition if practiced continuously year after year. Mountain brush ranges are more appropriately grazed during June before animals move on to the aspen and conifer ranges at the higher elevations.

The mountain brush range types are not physically large enough in area to support the demands for all animals needing this late spring or early summer grazing. Therefore, surplus animals of the Intermountain region are held longer on the native and developed foothill ranges or are allowed to enter the aspen and conifer ranges somewhat earlier.

The higher mountain ranges can be grazed lightly the last week in June provided this early seasonal use is rotated on several areas from year to year. Again, it is stressed that an adequate nutritional diet is available to grazing animals while in lactation on the mountain summer ranges provided there is an assortment of forage classes present (Appendix Table 16).

Mixed and shortgrass ranges in Colorado

The plains of eastern Colorado are adequate in nutrients for grazing animals in lactation from May until October, but are deficient from October until May for animals in gestation or growing steers and replacement heifers (Appendix Tables 17 and 18). If a supplement is fed between October and May, it should contain protein, phosphorus and perhaps from January to May Vitamin A. Browse species such as four-wing saltbush or prairie sage (*Artemisia bigelovi*) provide adequate levels of nutrients when available on winter range. The presents of these browse species on range used during the winter make supplements unnecessary except during inclement weather. This is an incentive to interseed four-wing saltbush into the prairie types or protect it where it now exists for winter use.

Mixed grass. In Colorado the mixed grass range types are found primarily in the sandy soil groups that follow along most of the larger river drainages that carry water from the Rocky Mountains through the Great Plains. These ranges furnish adequate nutrients for lactating cows and growing yearling steers and heifers throughout the spring and summer (Table 9). If earlier spring forage is desired (April 1), crested wheatgrass or Russian wildrye grass should be seeded. Mixed grass ranges grazed in the fall furnish an adequate level of nutrients for animals in gestation.

Mixed grass ranges grazed during the winter are decidedly deficient in protein, phosphorus, and carotene but are generally adequate or sometimes borderline in digestible energy. Since carotene or Vitamin A has about a three to four month's supply stored in the body, Vitamin A requirements would not normally be considered deficient until late winter unless the winter was preceded by a dry summer and fall. Browse species in the diet, such as four-wing saltbush or sandsage (*Artemisia filifolia*), can limit the nutritional deficiencies in the winter diet of grazing livestock. In any event, there should be no need for Vitamin A supplements unless animals have been on dry grass at least three or four months.

Short grass. These ranges have many of the same characteristics as mixed grass ranges from the standpoint of seasonal changes. However, mixed grass ranges have a greater variety of forage species and are found under higher rainfall areas that provide slightly higher forage yields.

In general, the short grasses are somewhat lower than mixed grass species in digestible protein and energy during early spring growth which starts about May 15 (Table 9). If earlier spring range is desired for

Table 9. Average digestible protein and its relationship to digestible energy, phosphorus, and carotene in two grassland types of the Great Plains area starting with spring when new growth is initiated.

Grassland type	Grazing period	Digestible protein (%)	Digestible energy	Phosphorus (%)	Carotene (mg/lb)
Mixed grass	Spring	11.6	1353	0.26	>15.00
	Summer	6.1	1151	0.21	>15.00
	Fall	4.4	851	0.17	>15.00
	Winter	2.1	820	0.11	> 0.09
Short grass	Spring	7.1	1297	0.26	>15.00
	Summer	5.4	1122	0.22	>15.00
	Fall	4.4	871	0.20	>15.00
	Winter	3.4	850	0.15	> 0.06

calving or lambing range, winter domestic wheat, crested wheatgrass, or Russian wildrye grass seedings can be used.

Shortgrass species cure better on the ground than most of the mixed grass species. As a result, they are somewhat higher in most nutrients than the mixed grasses during fall and winter. Nevertheless, shortgrass ranges are deficient or borderline in digestible protein, phosphorus, and carotene for gestating animals during the winter. Digestible energy is generally adequate during the winter unless snow covers the vegetation reducing daily intake. The phosphorus content of the forage is borderline during the winter but meets gestation requirements of grazing animals. Vitamin A may become deficient after the plants have been dormant for four months or more due to the depletion of the animal's storage reserves (Table 9).

Use of Forage Sorghums for Increased Efficiency

Livestock operators of the plains area are often interested in producing grass fat beef animals or at least maximizing gain from grass before sending their steers to the feedlots. The integration of forage sorghums in a grazing program can improve weight gains of grazing livestock. Hybrid forage sorghums can be grazed during the winter by growing steers. The steers could then graze the native range during the spring and summer until the sorghum is again green and lush and the native ranges are starting to mature and turn brown. Sorghums are relatively high in essential nutrients during late summer and do indeed complement the native range either for cows and calves or for growing steers (Appendix Table 19).

Nutrient Content of Range Supplements

The nutrient content of the more common supplements are shown in the Appendix Table 20. Concentrate supplements do not contain adequate amounts of carotene to be considered a supplemental source. However, suncured hay--both grass and alfalfa--if properly harvested and stored furnish substantial amounts of carotene.

Nutrient Content of Range Forages in Colorado

Range forage has a period of rapid initial growth following intermittent dormant periods brought on by cold winter weather or because of an extended dry period when the plants are forced into dormancy. During periods of rapid growth, range plants contain adequate amounts of the essential nutrients and meet the nutrient requirement of foraging livestock. The dark green color associated with plant growth is an indication of a high nutrient content. When plants mature or when plants are forced into dormancy because of frost or dry climatic conditions, the herbage looses its green color and turns a straw color. The change in coloration indicates that the nutrients are either being leached from the aerial plant tissue or being translocated to the crowns, twigs, and roots.

Forage classes

In order to show the general advantages of providing a diversity of forage classes for grazing animals, reference is made to the Appendix Table 21. It is noted that all three forage classes have about the same nutrient content during the early growing stage, but, as plants mature, the browse species are highest in protein, phosphorus, and carotene while grasses are highest in energy and forbs remain intermediate in all respects.

Major forage species

By no means have all of the range plants of Colorado been analyzed for nutrient content. However, about 60 plant species have been studied sufficiently to make generalized estimates of the nutritional values of the range types where they occur (Appendix Table 22).

Computerized ranch planning programs are dependent upon the nutritional value of the animal's diet and the most effective means of satisfying deficiencies when they occur in the range forage. In general, suitable grazing forage is more economical to a ranch operation than the purchase of a supplement, but it is not always possible to furnish a suitable range or forage diet because of climatic conditions.

Animal Unit Equivalent

The animal unit equivalent for various types and classes of livestock is based herein upon the quantity of range forage consumed per day (Table 10). This assumes that the range is moderately grazed and adequate forage is available at all times. Calculations do not represent conversion factors for exchanging types of livestock on the range since different species of animals consume different species of plants and use various topographic areas differently.

The standard animal unit represents a cow in gestation that has produced a calf the preceding spring (Table 10). The animal unit equivalents were calculated from the daily dry matter intake needed to satisfy

Table 10. Average gain per day, total digestible nutrients per pound gain, daily consumption and animal unit equivalent for various kinds of livestock operations.

Kind of animal	Season	Average weight (lbs)	Gain per day (lbs)[1]	TDN per lb gain (lbs)	Daily consumption (lbs)	Animal unit equivalent
Ewe & lamb	Spring	134	0.50	6.7	5.5	0.20
	Summer	142	0.50	7.3	6.6	0.25
	Average	139	0.50	7.1	6.2	0.23
	Winter	139	--	---	4.7	0.17
AVERAGE		139	--	11.5	5.2	0.19
Cow & calf	Spring	892	2.14	8.4	28.9	1.07
	Summer	956	1.42	12.5	31.8	1.18
	Average	919	1.84	9.7	30.1	1.12
	Winter	960	--	---	26.8	1.00
AVERAGE		934	--	14.3	28.4	1.06
Steer	Spring	590	2.25	5.1	18.4	0.69
	Summer	775	1.75	7.1	22.4	0.84
	Average	667	2.04	5.8	20.1	0.75
	Winter	435	0.39	19.1	13.9	0.52
AVERAGE		551	1.22	7.9	16.9	0.63

[1]Gain per day is based upon lamb and calf gain only.

the requirements for the various physiological functions such as growth and lactation during spring and summer and maintenance and gestation during late fall and winter except for replacement heifers and steers which are calculated to include both maintenance and growth requirements.

The cow nursing a calf during the summer is equivalent to 1.8 animal units. The yearling steer during the spring and summer months is considered about 0.75 of an animal unit. However, this yearling steer is about 0.66 of a cow-calf unit during this same period. The animal unit equivalent for steers varies from 0.52 to 0.84. A growing steer weighing about 635 pounds consumes about as much forage as a 900 pound dry cow that did not produce a calf. The growth requirement for the smaller steer requires a larger daily intake of forage per unit of weight than the maintenance requirements for a heavier, dry cow. It must be remembered that growing animals and lactating females consume more forage than animals of the same weight in only body maintenance situations. The ewe varies from 0.20 to 0.25 of an animal unit, depending upon the physiological functions to be performed.

Use of Protein in Computerized Ranch Planning

It is difficult for a livestock operator to analyze all of the opportunities available to him for increased efficiency of production. The overall components of the ranching enterprise form a complex of interactions and are, therefore, difficult to evaluate for optimum production. A rancher usually selects the management alternatives with which he is familiar and that appear to meet his goals. However, many alternatives may not be considered because the rancher is not aware that they apply to his operation and secondly the outcome of each alternative may not be known for his ranch because research is too remote and indefinite with respect to site responses. It is, therefore, helpful to form a decision framework that can use computers to organize and subsequently aid in the evaluation of potential management alternatives in relation to an individual ranch operation.

The Computer Optimization PLANning system called COPLAN represents a systems analysis approch that can serve as an aid in the selection of the appropriate management alternatives for a ranching enterprise on a least cost basis (Child and Evans, 1976). The planning procedure requires all known information relating to the management of the land resource and animal husbandry. The process involves a logical but complicated thought process that quantifies most components and functions of the total ranch system. The research reported in this paper was developed to determine the minimum number of forage quality measures that would be required to adequately represent the nutritional aspects of a ranch livestock system. On the basis of this research, it would appear that digestible protein as a forage quality measure would adequately relate animal response to the nutritional aspects of rangelands.

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APPENDIX

Table 11. Average percent digestible protein in the overall forage for three major desert range types of Colorado during the year.

Date	Percent digestible protein		
	Predominantly saltbush	Predominantly sagebrush	Predominantly grass
Jan	4.0	3.9	3.6
Feb	3.8	3.6	3.4
Mar	4.2	4.0	3.8
Apr	9.4	9.8	8.0
May	8.2	8.8	6.8
Jun	7.3	7.0	5.6
Jul	6.5	6.0	4.9
Aug	5.3	6.0	4.5
Sep	5.1	6.0	4.4
Oct	5.0	6.0	4.3
Nov	4.6	5.0	4.0
Dec	4.4	4.5	3.5

Table 12. Average percent digestible protein in a typical diet on sagebrush-grass foothill ranges.

Date	Percent digestible protein
Jan	3.2
Feb	3.1
Mar	3.4
Apr	4.0
May	7.8
Jun	5.2
Jul	4.6
Aug	4.1
Sep	4.0
Oct	3.8
Nov	3.6
Dec	3.4

Table 13. Average percent digestible protein in seeded crested wheatgrass and Russian wildrye on foothill range in northern Colorado.

Date	Crested wheatgrass	Russian wildrye
Jan	2.6	3.9
Feb	2.4	3.6
Mar	2.8	4.0
Apr	10.0	12.0
May	8.0	8.0
Jun	4.3	6.1
Jul	3.5	5.2
Aug	2.6	4.7
Sep	3.0	4.4
Oct	3.1	4.4
Nov	3.5	4.0
Dec	3.0	4.0

Table 14. Average percent digestible protein in domestic winter wheat and winter rye pastures.

Date	Domestic winter wheat	Winter annual rye
Jan	12.6	11.4
Feb	10.8	10.0
Mar	10.0	8.5
Apr	8.0	7.5
May	6.5	6.2
Jun	5.0	5.0
Jul	---	---
Aug	---	---
Sep	---	---
Oct	15.3	14.0
Nov	14.0	13.6
Dec	13.7	12.0

Table 15. Average percent digestible protein for native and two seeded types in mountain brush range types.

Date	Percent digestible protein		
	Native species	Seeded wheatgrasses or Russian wildrye	Grass-alfalfa mixture
May	8.2	11.8	12.5
Jun	8.0	9.5	10.0
Jul	7.6	6.5	8.0
Aug	6.2	5.2	7.8
Sep	5.0	5.0	7.6
Oct	4.3	5.0	7.5

Table 16. Average percent digestible protein for the overall forage on mountain summer range of Colorado.

Date	Percent digestible protein	
	Predominantly grass	Predominantly browse
Jul 1-15	8.2	9.6
Jul 16-30	7.0	8.2
Aug 1-15	5.6	6.8
Aug 16-30	5.0	6.0
Sep 1-15	4.8	5.3
Sep 16-30	4.6	4.8
Oct 1-15	4.1	4.6
Oct 16-30	4.0	4.4

Table 17. Average percent digestible protein in diets of cattle on three major range types of the great plains of Colorado.

Date	Percent digestible protein		
	Shortgrass plains; southeastern Colo.	Mixedgrass	
		Sandy rolling plains; northwestern Colo.	Sandy soil types; Akron, Colo.
Jan	3.3	3.0	3.0
Feb	3.2	2.7	2.6
Mar	3.1	2.5	2.4
Apr	4.0	2.5	2.3
May	8.6	12.0	11.6
Jun	8.1	10.0	11.2
Jul	5.4	8.5	6.9
Aug	5.4	5.2	5.4
Sep	4.9	4.7	4.9
Oct	4.2	4.4	4.4
Nov	4.0	3.4	3.2
Dec	3.4	3.0	3.1

Table 18. Average percent digestible protein in cattle diets for two major range sites of the plains types of northeastern Colorado for the grazing season from June to December.

Date	Percent digestible protein	
	Shortgrass loamy plains site	Mixedgrass sandy meadow site
Jun	9.0	9.0
Jul	8.5	8.5
Aug	6.5	8.2
Sep	6.2	7.9
Oct	4.7	4.6
Nov	4.5	4.2
Dec	4.0	3.9

Table 19. Average percent digestible protein in hybrid sorghums primarily for summer grazing pastures in the Great Plains.

Date	Percent digestible protein
Jan	2.5
Feb	2.1
Mar	2.0
Apr	1.9
May	1.8
Jun	13.1
Jul	10.4
Aug	7.5
Sep	5.9
Oct	3.0
Nov	2.9
Dec	2.6

Table 20. Average chemical content of commonly fed hays and concentrates as supplements to the range or as winter rations for range livestock.

	Total protein (%)	Digestible protein (%)	Metabolic energy (kcal/lb)	Digestible energy (kcal/lb)	Phosphorus (%)	Carotene (mg/lb)
Hays						
Alfalfa	15.6	11.0	903	1325	.26	61.10
Grass (domestic)	6.3	4.1	780	895	.10	7.7
Grass (natural	5.9	3.6	725	880	.08	4.5
Concentrates						
Barley	11.8	9.2	1106	1350	.40	---
Corn	6.9	8.7	1151	1404	.27	---
Cottonseed meal	15.0	37.0	1229	1500	1.10	---
Milo	8.7	11.0	1166	1422	.28	---
Safflower	16.3	13.0	1209	1476	.27	---
Sorghum	8.5	10.9	1180	1440	.32	---
Soybean oil meal	44.0	36.9	1166	1442	.59	---
Wheat	11.2	13.4	1120	1440	.40	---

Table 21. Average nutrient content of the three forage classes during various stages of growth and seasons of the year.

Forage class	Stage of growth	Season	Nutrient content: Total protein (%)	Digestible protein (%)	Metabolic energy (kcal/lb)	Digestible energy (kcal/lb)	Phosphorus (%)	Carotene (mg/lb)
Grasses	Vegetative	Spring	18.5	12.0	1186	1543	.29	78.00
	Head	Summer	12.0	7.2	954	1192	.24	46.10
	Seed	Summer	10.3	4.9	898	1047	.21	18.25
	Shatter	Winter	6.0	2.4	836	964	.10	00.25
Forbs	Vegetative	Spring	18.9	12.3	1135	1476	.46	97.41
	Head	Summer	12.6	7.4	922	1142	.32	62.13
	Seed	Summer	10.9	5.3	901	1037	.27	17.40
	Dormant	Winter	6.1	3.2	675	810	.14	00.27
Browse:	Vegetative	Spring	19.7	13.4	986	1243	.39	65.00
	Head	Summer	17.1	10.8	842	1010	.35	48.13
	Seed	Summer	15.3	5.8	824	964	.33	19.40
	Dormant	Winter	9.6	4.8	605	775	.16	9.48

Table 22. Stages of growth and nutrient content of major forage species on ranges of Colorado.

SPECIES NAME		Stages of Growth	Season	Total Protein (%)	Digestible Protein (%)	Metabolic Energy (kcal/lb)	Digestible Energy (kcal/lb)	P%	Carotene (mg/lb)
Scientific	Common								
Agropyron cristatum	Crested wheatgrass	5th leaf	Spring	20.3	16.2	1325	1656	.27	---
		Early head	Spring	12.6	6.6	1083	1352	.23	45.00
		Anthesis	Spring	10.7	5.9	951	1189	.18	---
		Seed	Summer	9.3	4.0	854	1017	.14	---
		Shatter	Winter	8.2	3.9	760	890	.12	00.06
Agropyron elongatum	Tall wheatgrass	4th leaf	Spring	16.8	11.7	1009	1325	.21	---
		6th leaf	Spring	13.8	8.9	950	1187	.16	53.80
		Early head	Spring	10.9	7.2	947	1182	.16	---
		Anthesis	Summer	8.5	5.0	946	1109	.14	---
		Shatter	Winter	8.3	4.3	750	900	.12	00.10
Agropyron inerme	Beardless wheatgrass	4th leaf	Spring	14.1	9.9	1175	1468	.26	---
		Boot	Summer	10.4	5.2	978	1225	.16	42.00
		Seed	Summer	5.9	3.4	917	1100	.15	---
		Shatter	Winter	5.0	2.5	800	1012	.14	00.50
Agropyron intermedium	Intermediate wheatgrass	6th leaf	Spring	13.9	7.7	934	1180	.23	---
		Anthesis	Spring	10.4	6.0	930	1165	.19	65.00
		Anthesis	Spring	11.0	6.0	930	1225	.16	---
		Hard dough	Summer	10.1	6.4	1002	1190	.16	---
		Shatter	Winter	9.0	5.4	802	1100	.14	00.12

Table 22.--Continued.

SPECIES NAME		Stages of Growth	Season	Total Protein (%)
Scientific	Common			
Agropyron smithii	Western wheatgrass	4th leaf	Spring	9.4
		Boot	Spring	15.0
		Seed	Summer	7.0
		Shatter	Winter	5.4
Agropyron trichophorum	Pubescent wheatgrass	5th leaf	Spring	16.5
		Early head	Spring	11.1
		Preanthesis	Spring	9.7
		Seed	Summer	8.3
		Shatter	Winter	7.2
Agrostis alba	Red Top (pasture)	Vegetative	Spring	17.9
Andropogon scoparius	Little bluestem	Vegetative	Spring	12.0
		Head	Summer	10.0
		Seed	Summer	8.4
		Shatter	Winter	5.0
Andropogon gerardi	Big bluestem	Vegetative	Spring	11.6
		Head	Summer	9.0
		Seed	Summer	7.0
		Shatter	Winter	4.9

Digestible Protein (%)	Metabolic Energy (kcal/lb)	Digestible Energy (kcal/lb)	P%	Carotene (mg/lb)
5.0	1068	1365	.20	---
11.1	1080	1350	.26	60.00
3.9	1000	1269	.16	---
2.6	995	1160	.10	00.10
11.9	1159	1449	.24	---
6.8	987	1234	.18	30.00
5.8	943	1178	.16	---
3.8	799	1090	.11	---
3.2	750	978	.10	00.06
13.6	1220	1537	.21	54.30
8.2	1401	2021	.26	65.40
5.9	---	1640	.21	25.10
5.2	---	1266	.16	---
3.2	---	976	.11	00.08
7.8	1365	1989	.24	45.00
5.4	---	1540	.22	35.00
4.0	---	1100	.16	---
3.0	---	905	.11	00.10

Table 22.--Continued.

SPECIES NAME Scientific	Common	Stages of Growth	Season	Total Protein (%)	Digestible Protein (%)	Metabolic Energy (kcal/lb)	Digestible Energy (kcal/lb)	P%	Carotene (mg/lb)
Artemisia	Fringed	Vegetative	Spring	13.8	9.5	1111	1389	.30	---
frigida	sagebrush	Bloom	Spring	12.4	10.7	1444	1806	.35	---
		Fruit	Spring	16.2	13.6	1458	1779	.35	69.00
		Seed	Spring	16.6	11.9	1309	1571	.25	---
		Dormant	Summer	15.3	9.21	1313	1563	.19	---
		Shatter	Summer	12.1	6.3	1086	1358	.17	---
		Shatter	Winter	6.6	2.2	940	1034	.17	18.00
Artemisia	Black	Vegetative	Spring	14.9	8.9	1171	1452	.14	65.16
nova	sage	Seed	Summer	13.1	6.2	1100	1375	.13	40.24
		Seed	Fall	9.8	5.0	1120	1381	.11	30.00
		Shatter	Early Winter	8.8	4.5	1004	722	.14	20.10
		Shatter	Late Winter	8.9	4.4	975	625	.16	19.61
Artemisia	Bud	Vegetative	Spring	17.3	13.7	911	1160	.33	10.80
spinescens	sage								
Artemisia	Big	Vegetative	Spring	12.7	7.8	1240	1443	.19	60.00
tridentata	sagebrush	Seed	Summer	11.9	6.3	1000	1125	.18	45.00
		Shatter	Fall	9.7	5.8	1015	900	.16	31.00
		Shatter	Early Winter	9.6	5.7	1126	884	.14	29.00
		Shatter	Late Winter	9.5	5.2	848	659	.16	25.00

Table 22.--Continued.

SPECIES NAME		Stages of Growth	Season	Total Protein (%)
Scientific	Common			
Atriplex	4-wing	Vegetative	Spring	17.4
canescens	saltbush	Seed	Summer	14.5
		Seed	Summer	12.6
		Shatter	Winter	10.1
Atriplex	Shadscale	Vegetative	Spring	13.3
confertifolia		Seed	Summer	12.5
		Shatter	Fall	9.0
		Shatter	Early Winter	8.8
		Shatter	Late Winter	8.8
Atriplex	Nutall	Vegetative	Spring	16.0
nuttallii	saltbush	Seed	Summer	11.0
		Shatter	Fall	9.3
		Shatter	Early Winter	9.4
		Shatter	Late Winter	9.5
Bassia	Smother	Flower	Spring	18.2
hyssopifolia	weed	Flower	Spring	15.8
		Seed	Summer	16.1

Digestible Protein (%)	Metabolic Energy (kcal/lb)	Digestible Energy (kcal/lb)	P%	Carotene (mg/lb)
9.4	1180	1560	.21	65.00
8.6	1140	1350	.20	---
6.5	1060	1300	.19	25.00
5.8	847	1059	.10	18.01
9.1	918	1157	.17	25.00
8.1	920	1165	.14	22.00
5.0	1000	1275	.08	---
4.4	916	1099	.06	---
4.2	898	1042	.06	12.10
8.9	897	1109	.18	28.10
6.6	875	1088	.17	18.06
4.8	840	1050	.11	---
4.6	833	999	.16	---
4.4	747	925	.10	08.60
14.7	817	1062	.28	---
11.9	746	910	.34	41.10
12.8	901	1081	.33	---

Table 22.--Continued.

SPECIES NAME Scientific	Common	Stages of Growth	Season	Total Protein (%)	Digestible Protein (%)	Metabolic Energy (kcal/lb)	Digestible Energy (kcal/lb)	P%	Carotene (mg/lb)
Bouteloua	Sideoats	Vegetative	Spring	7.9	4.4	1145	1431	.22	25.15
curtipendula	grama	Head	Spring	5.4	3.5	1167	1340	.20	---
		Seed	Summer	4.8	1.8	990	1086	.17	10.00
		Shatter	Winter	3.8	1.6	930	1043	.18	00.05
Bouteloua	Blue	Vegetative	Spring	9.8	5.8	1364	1689	.26	---
gracilis	grama	Head	Spring	9.2	5.5	1350	1680	.18	31.00
		Seed	Summer	6.4	4.2	1117	1285	.15	---
		Shatter	Winter	5.3	3.4	909	1008	.14	00.75
Bromus	Mountain	Vegetative	Spring	18.0	10.0	1616	1990	.19	55.00
carinatus	brome	Head	Summer	10.0	5.4	1312	1640	.17	30.00
		Seed	Summer	6.5	3.0	915	1090	.12	10.90
Bromus	Smooth	Vegetative	Spring	15.0	8.6	1914	2205	.36	65.15
inermis	brome	Head	Spring	10.9	6.6	1807	2184	.27	---
		Head	Summer	9.2	4.7	1770	2160	.24	---
		Seed	Summer	5.7	3.4	1498	1647	.20	4.40
		Shatter	Fall	5.4	3.0	1010	1210	.17	00.18
Buchloe	Buffalo	Vegetative	Spring	6.9	5.9	888	1145	.26	22.00
dactyloides	grass	Head	Spring	7.9	4.8	770	1018	.25	---
		Seed	Summer	6.0	3.2	767	915	.18	---
		Shatter	Winter	5.7	2.9	697	897	.16	00.50

Table 22.—Continued.

SPECIES NAME Scientific	Common	Stages of Growth	Season	Total Protein (%)	Digestible Protein (%)	Metabolic Energy (kcal/lb)	Digestible Energy (kcal/lb)	P%	Carotene (mg/lb)
Calamagrostis	Reedgrass	Vegetative	Spring	14.9	8.4	---	1989	.21	55.00
rubescens		Head	Summer	12.6	6.8	---	1260	.17	---
		Seed	Summer	10.2	5.2	---	1092	.15	2.00
Calamovilfa	Sand reed	Vegetative	Spring	15.2	8.6	---	1910	.26	59.00
longifolia		Head	Summer	12.9	7.2	---	1328	.19	---
		Seed	Summer	10.6	5.3	---	1121	.17	3.00
Carex	Nebraska	Vegetative	Spring	14.7	12.3	1228	1535	.26	65.04
nebraskensis	sedge	Head	Spring	12.1	9.7	1130	1435	.24	---
		Seed	Summer	12.0	9.0	1114	1373	.20	62.00
		Shatter	Winter	6.7	4.3	820	1025	.15	00.60
Cercocarpus	mahogany	Vegetative	Spring	18.1	11.3	1194	1492	.26	60.00
spp.		Head	Summer	16.3	9.4	1038	1340	.21	---
		Seed	Summer	12.2	6.0	1036	1243	.20	15.40
Chenopodium	Lambs-	Vegetative	Spring	12.4	11.5	---	1687	.24	60.00
album	quarter	Head	Summer	17.0	15.4	---	1698	.38	---
		Seed	Summer	17.8	10.2	---	1258	.16	---
		Shatter	Winter	5.7	2.9	---	1052	.09	00.09

Table 22--Continued.

SPECIES NAME Scientific	SPECIES NAME Common	Stages of Growth	Season	Total Protein (%)	Digestible Protein (%)	Metabolic Energy (kcal/lb)	Digestible Energy (kcal/lb)	P%	Carotene (mg/lb)
Chrysothamnus viscidiflorus	Rabbit brush	Vegetative	Spring	18.9	14.9	1376	1647	.35	---
		Head	Spring	10.18	8.5	1295	1581	.18	---
		Seed	Summer	8.9	7.4	1230	1479	.16	---
		Shatter	Winter	7.9	5.5	750	900	.15	---
Dactylis glomerata	Orchard grass	Vegetative	Spring	13.6	9.5	1807	2205	.33	29.6
		(pasture)	Summer	8.6	4.5	1409	1806	.26	---
Deschampsia caespitosa	Hairgrass	Vegetative	Spring	16.7	12.9	---	2019	.26	48.00
		Head	Summer	14.5	10.4	---	1649	.21	---
		Seed	Summer	12.3	6.0	---	1088	.16	10.80
Elymus cinereus	Giant Wild Rye	Vegetative	Spring	12.6	6.4	1121	1523	.27	25.00
		Head	Summer	9.3	4.2	900	1300	.22	---
		Seed	Summer	6.3	3.2	808	1186	.08	00.37
		Shatter	Winter	3.0	1.1	507	662	.06	00.93
Elymus junceus	Russian Wild Rye	Vegetative	Spring	11.6	8.1	960	1192	.16	60.00
		Head	Summer	10.2	7.4	900	1098	.15	---
		Seed	Summer	7.6	5.2	850	1020	.14	---
		Shatter	Winter	6.4	3.0	820	1000	.14	01.10

Table 22.--Continued.

SPECIES NAME		Stages of Growth	Season	Total Protein (%)	Digestible Protein (%)	Metabolic Energy (kcal/lb)	Digestible Energy (kcal/lb)	P%	Carotene (mg/lb)
Scientific	Common								
Ephedra nevadensis	Brigham tea	Dormant	Winter	6.1	3.1	532	686	.10	07.60
Eragrostis curula	Weeping lovegrass	Head	Summer	9.2	5.9	1079	2293	.06	65.00
Eurotia lanata	Winter fat	Vegetative	Spring	15.1	9.0	960	1238	.27	35.00
		Head	Summer	14.0	8.2	842	1086	.18	25.00
		Seed	Summer	10.9	6.1	749	943	.19	20.00
		Shatter	Winter	10.9	6.0	488	610	.14	5.00
Festuca arizonica	Arizona fescue	Vegetative	Spring	10.5	8.9	1062	1292	.26	---
		Head	Summer	10.0	6.3	920	1150	.23	---
		Seed	Summer	7.5	4.6	833	1042	.19	---
		Shatter	Winter	6.5	3.0	825	990	.13	---
Festuca elatior	Meadow fescue	Vegetative	Spring	19.3	8.9	1090	1362	.32	55.00
Festuca thurberi	Thurber fescue	Vegetative	Spring	17.1	9.3	1328	1674	.37	---
		Head	Summer	11.3	8.7	1225	1531	.17	---
		Seed	Summer	5.8	3.9	965	1188	.12	---
		Shatter	Winter	4.0	1.8	785	942	.09	---

Table 22.--Continued.

SPECIES NAME		Stages of		Total
Scientific	Common	Growth	Season	Protein (%)
Grayia spinosa	Hop sage	Vegetative	Spring	15.6
		Head	Summer	12.4
		Seed	Summer	9.6
		Dormant	Winter	7.4
Hilaria jamesii	Galleta grass (curly)	Vegetative	Spring	10.9
		Head	Summer	9.9
		Seed	Summer	9.0
		Shatter	Winter	5.6
Koeleria cristata	Junegrass	Vegetative	Spring	9.6
		Head	Summer	8.3
		Seed	Summer	5.5
		Shatter	Winter	4.6
Kochia americana	Desert molly	Vegetative	Spring	18.7
		Head	Summer	16.9
		Seed	Summer	9.5
		Shatter	Winter	7.5

Digestible Protein (%)	Metabolic Energy (kcal/lb)	Digestible Energy (kcal/lb)	P%	Carotene (mg/lb)
8.9	990	1260	.29	65.00
7.2	860	1042	.25	---
4.9	775	900	.20	---
4.4	655	650	.19	03.00
5.6	845	1250	.20	---
5.4	845	1200	.06	---
4.4	621	904	.12	25.00
1.9	429	680	.08	00.92
7.6	960	1265	.20	45.00
6.5	940	1116	.19	---
3.2	899	1079	.18	---
2.7	858	1031	.10	00.06
9.9	981	1114	.26	19.9
8.6	926	1036	.22	05.80
5.9	723	985	.20	---
5.0	686	785	.14	---

Table 22.--Continued.

Scientific	Common	Stages of Growth	Season	Total Protein (%)	Digestible Protein (%)	Metabolic Energy (kcal/lb)	Digestible Energy (kcal/lb)	P%	Carotene (mg/lb)
Kochia	Fireweed	Vegetative	Spring	14.5	13.5	1178	1473	.36	---
scoparia		Head	Spring	19.8	16.9	1034	1294	.34	---
		Seed	Summer	17.9	14.3	836	1036	.23	---
		Shatter	Winter	12.3	7.9	710	832	.13	---
Lolium	Ryegrass	Vegetative	Spring	13.2	6.8	1001	1261	.29	---
spp.		Head	Summer	8.9	4.3	642	860	.18	96.7
		Seed	Summer	7.9	3.9	549	698	.12	---
Medicago	Alfalfa, (grazed)	Vegetative	Spring	19.3	12.6	1125	1960	.31	96.00
sativa	aerial, (gra.)	Early bloom	Spring	14.4	10.2	956	1114	.28	56.00
	fresh (gra.)	Milk stage	Summer	12.9	8.6	891	1062	.22	44.00
Medicago	Alfalfa hay	All analyses	---	15.6	11.0	806	985	.23	100.00
sativa	(on as-fed	Immature	Spring	19.1	13.4	838	1024	.27	86.60
	basis)	Early bloom	Spring	16.2	12.1	822	1004	.22	70.00
		Mid bloom	Spring	15.2	11.1	822	1004	.21	64.00
		Full bloom	Spring	14.0	10.0	770	945	.20	47.04
		Milk stage	Spring	13.8	9.9	709	850	.20	39.00
		Mature	Summer	12.4	7.4	670	830	.18	36.00
Melilotus	Sweetclover	Vegetative	Spring	16.1	12.7	1050	1312	.26	70.00
spp.		Seed	Summer	13.0	7.0	614	750	.17	9.10

Table 22.--Continued.

SPECIES NAME		Stages of Growth	Season	Total Protein (%)
Scientific	Common			
Muhlenbergia montanas	Mountain muhly	Vegetative	Spring	13.0
		Head	Summer	8.3
		Seed	Summer	6.6
		Shatter	Winter	4.0
Oryzopsis hymenoides	Indian ricegrass	Vegetative	Spring	16.3
		Head	Summer	10.9
		Seed	Summer	8.4
		Shatter	Winter	3.7
Phleum pratense	Timothy hay	All analyses---		6.8
		Immature	Spring	10.3
		Early bloom	Spring	7.6
		Full bloom	Summer	6.8
		Mature	Summer	5.1
Poa fendleriana	Mutton grass	Vegetative	Spring	16.3
		Head	Summer	10.4
		Seed	Summer	7.6
		Shatter	Winter	7.3

Digestible Protein (%)	Metabolic Energy (kcal/lb)	Digestible Energy (kcal/lb)	P%	Carotene (mg/lb)
6.5	1066	1332	.22	29.00
4.3	925	1156	.17	---
2.9	817	981	.17	---
2.8	670	804	.07	---
9.0	1276	1660	.26	35.00
5.6	992	1240	.25	00.40
4.2	851	983	.15	---
1.4	760	908	.09	00.09
3.1	975	1913	.17	12.00
6.5	859	1063	.30	107.9
4.2	758	955	.23	---
3.4	695	891	.18	---
1.8	685	811	.15	04.60
12.8	1140	1447	.07	---
8.8	1106	1428	.23	75.00
5.9	1007	1259	.21	---
2.6	892	1046	.12	00.09

Table 22.--Continued.

SPECIES NAME		Stages of Growth	Season	Total Protein (%)	Digestible Protein (%)	Metabolic Energy (kcal/lb)	Digestible Energy (kcal/lb)	P%	Carotene (mg/lb)
Scientific	Common								
Poa	Kentucky	Vegetative	Spring	19.3	13.7	1307	1634	.19	76.00
pratensis	bluegrass	Head	Summer	14.3	11.0	1269	1521	.25	---
		Seed	Summer	8.0	5.7	1049	1259	.09	---
		Dormant	Winter	5.2	3.2	827	993	.12	05.06
Quercus	Gambell's	Vegetative	Spring	19.2	12.5	1025	1255	.30	68.00
gambellii	Oak	Fruit	Summer	17.8	11.3	945	1153	.29	46.00
		Seed	Summer	14.1	7.2	880	1012	.26	20.00
Purshia	Antelope	Vegetative	Spring	19.4	16.3	1361	1770	.26	95.00
tridentata	bitterbrush	Flower	Summer	14.5	10.4	1159	1449	.24	69.00
		Seed	Summer	8.9	5.9	1027	1296	.17	---
		Dormant	Fall	8.1	6.0	990	1083	.19	15.00
Salsola	Russian	Vegetative	Spring	18.0	15.5	1057	1374	.20	98.00
iberica	thistle	Head	Summer	15.5	12.9	911	1093	.15	15.00
		Seed	Summer	10.2	6.8	765	880	.18	04.10
		Shatter	Winter	3.1	1.3	640	904	.10	00.08
Salix	Willow	Vegetative	Spring	15.2	9.0	1500	1963	.35	65.00
spp.		Budding	Summer	12.3	8.3	1200	1640	.27	49.00
		Flower	Summer	10.9	5.6	1040	1205	.26	15.00

Table 22.--Continued.

SPECIES NAME Scientific	Common	Stages of Growth	Season	Total Protein (%)	Digestible Protein (%)	Metabolic Energy (kcal/lb)	Digestible Energy (kcal/lb)	P%	Carotene (mg/lb)
Sambucus spp.	Elderberry	Vegetative	Spring	14.3	8.9	1743	2203	.39	124.00
		Flower	Summer	8.3	4.9	1346	1616	.27	---
		Seed	Summer	6.9	4.4	1090	1200	.24	65.00
Senecio serra	Butterweed	Vegetative	Spring	12.9	9.1	1561	1743	.33	93.00
		Flower	Summer	10.0	7.6	1277	1532	.26	---
		Seed	Summer	9.2	5.6	1127	1240	.24	56.00
Symphoricarpos vaccinioides	Snowberry	Vegetative	Spring	12.6	7.5	1201	1526	.30	97.00
		Flower	Summer	7.4	4.7	1156	1445	.24	---
		Seed	Summer	6.7	4.1	985	1132	.22	41.00
Secale cereale	Domestic rye	Vegetative	Spring	19.4	11.6	956	1160	.26	89.90
		Head	Spring	14.7	8.2	778	898	.24	69.50
		Seed	Summer	10.3	4.8	578	705	.09	15.60
Setaria italica	Millet foxtail	Head	Spring	8.3	5.0	837	1024	.20	---
Sitanion hystrix	Squirrel tail grass	Vegetative	Spring	11.0	9.0	1182	1477	.24	25.00
		Head	Summer	9.9	8.2	1169	1403	.24	---
		Seed	Summer	6.8	3.9	1169	1340	.14	00.05
		Shatter	Winter	5.9	2.2	691	818	.08	00.04

Table 22.--Continued.

SPECIES NAME Scientific	Common	Stages of Growth	Season	Total Protein (%)	Digestible Protein (%)	Metabolic Energy (kcal/lb)	Digestible Energy (kcal/lb)	P%	Carotene (mg/lb)
Sorghum	Johnson	Vegetative	Spring	14.7	9.3	1292	1572	.31	96.00
vulgare	grass	Bloom	Summer	12.7	8.3	1150	1401	.28	---
		Head	Summer	11.1	8.1	1046	1373	.26	65.00
		Seed	Fall	13.3	6.7	953	1094	.24	60.00
Sorghum spp.	Milo	Field grazed		4.9	2.1	---	682	.10	---
Sphaeralcea	Scarlet	Vegetative	Spring	18.9	12.2	1344	1618	.18	---
coccinea	globemallow	Full leaf	Summer	11.0	9.4	1270	1522	.18	---
		Mature	Summer	10.9	8.1	1264	1416	.15	---
		Dormant	Winter	8.0	6.6	928	1021	.15	---
Sporobolus	Alkali	Vegetative	Spring	8.8	5.3	950	1197	.24	45.00
airoides	sacaton	Head	Summer	7.6	4.2	890	1095	.22	---
		Seed	Summer	6.2	3.4	880	1012	.14	25.00
		Shatter	Winter	3.5	1.4	750	891	.08	00.67
Sporobolus	Sand	Vegetative	Spring	9.0	5.4	1090	1374	.24	46.00
cryptandrus	dropseed	Head	Summer	7.3	4.2	973	1134	.22	---
		Seed	Summer	6.4	3.9	933	1100	.10	00.52
		Shatter	Winter	5.2	1.6	913	1043	.05	00.61

Table 22.--Continued.

SPECIES NAME		Stages of Growth	Season	Total Protein (%)	Digestible Protein (%)	Metabolic Energy (kcal/lb)	Digestible Energy (kcal/lb)	P%	Carotene (mg/lb)
Scientific	Common								
Stipa comata	Needle & thread	Vegetative	Spring	12.8	9.0	1252	1590	.36	95.00
		Head	Summer	11.3	7.4	988	1230	.25	---
		Seed	Summer	8.9	4.9	937	1132	.22	00.83
		Shatter	Winter	7.0	3.5	775	881	.17	97.00
Stipa viridula	Green needlegrass	Vegetative	Spring	13.6	6.9	1250	1587	.32	---
		Head	Summer	11.4	5.1	1120	1140	.22	---
		Seed	Summer	10.0	4.9	1025	1230	.20	---
		Shatter	Winter	6.9	3.2	995	1094	.18	01.10
Trifolium hybridum	Clover, alsike	Vegetative	Spring	16.6	10.3	981	1226	.34	65.00
		Head	Summer	12.9	8.6	774	949	.22	164.40
Triticum spp.	Wheat pasture (domestic)	Vegetative	Spring	14.6	6.2	1145	1390	.36	207.00
		Boot	Spring	12.3	5.3	1100	1205	.26	---
		Head	Spring	8.1	3.4	1060	1219	.24	40.00
Vicia sativa	Common vetch	Vegetative	Spring	15.2	7.9	923	1210	.34	140.00
		Head	Spring	3.8	2.9	670	804	.21	40.00

Table 22.--Continued.

SPECIES NAME		Stages of Growth	Season	Total Protein (%)	Digestible Protein (%)	Metabolic Energy (kcal/lb)	Digestible Energy (kcal/lb)	P%	Carotene (mg/lb)
Scientific	Common								
Yucca spp.	Yucca (pods)	Prebloom	Summer	12.0	8.7	---	1862	.31	---
		Bloom	Summer	11.0	9.8	---	1828	.32	---
		Green Pods	Summer	10.2	7.3	---	1360	.33	---
		Mature	Winter	9.0	5.4	---	1157	.52	---
Zea mays	Corn stalks	Fieldgrazing		3.8	1.0	---	660	.09	---