

Utah State University

DigitalCommons@USU

Faculty Honor Lectures

Lectures

1-17-1968

Range Nutrition in an Arid Region

Lorin E. Harris

Utah State University

Follow this and additional works at: https://digitalcommons.usu.edu/honor_lectures



Part of the [Other Nutrition Commons](#)

Recommended Citation

Harris, Lorin E., "Range Nutrition in an Arid Region" (1968). *Faculty Honor Lectures*. Paper 74.

https://digitalcommons.usu.edu/honor_lectures/74

This Presentation is brought to you for free and open access by the Lectures at DigitalCommons@USU. It has been accepted for inclusion in Faculty Honor Lectures by an authorized administrator of DigitalCommons@USU. For more information, please contact digitalcommons@usu.edu.



9.2
#36

Utah State University

**RANGE NUTRITION
IN AN ARID REGION**



Logan, Utah 84321

**Lorin E. Harris
Honor Lecture 36
January 17, 1968**



9.2
no. 36



THIRTY-SIXTH FACULTY HONOR LECTURE

RANGE NUTRITION
IN AN ARID REGION

LORIN E. HARRIS

Professor of Nutrition, Animal Science Department

THE FACULTY ASSOCIATION
UTAH STATE UNIVERSITY
LOGAN, UTAH

January 17, 1968

CONTENTS

	Page
FOREWORD	6
INTRODUCTION	7
BASIC METHODS FOR RANGE NUTRITION RESEARCH	10
Measuring Intake and Digestibility	10
The ratio technique	11
Fecal index technique	12
Estimation of total feces by grab samples	16
Obtaining Samples of Actual Forage Ingested	17
The "before and after" method	17
Esophageal fistula method	19
Rumen evacuation method	21
Measuring Metabolizable Energy of Range Plants	21
Methods of Expressing Energy Values	23
Range Meters For Measuring the Distance Traveled By Sheep and Cattle	25
Weighing Range Animals	26
Environmental Influences on Animal Response	28
EXPERIMENTS IN RANGE NUTRITION IN AN ARID REGION	29
Characteristics of the Intermountain Range	29
Winter range	30
Spring and fall range	31
Summer range	32
Examples of Range Experiments	32
An Experiment on the Winter Range	33
The nutrient content of the grazing sheep's diet	33
Experimental plan	33
Live weight changes	37
Blood chemistry	39
Wool production	40
Lamb crop	41
Comparison of experimental controls and controls in a large herd	41
Conclusions and recommendations	42
Nourishing the Rumen Microorganisms	44
Experimental plan	45
Results and conclusions	45

Influence of Nitrogen Intake Upon Rumen Function	48
Experimental plan	48
Results and conclusions	51
UTILIZATION OF RESEDED GRASSES IN AN ARID REGION	53
Grazing Reseeded Grasses in the Spring	53
Experimental area	54
Experimental plan	54
Results and conclusions	59
Grazing Reseeded Grasses from April to December	61
Experimental plan	62
Results and conclusions	63
Control of Invading Sagebrush in Reseeded Range Grasses	66
FULFILLMENT	67
Some Ideas For the Rancher	67
Supplements for sheep on the winter range	67
Grazing scheme for spring and fall	70
Grazing scheme from April to December	72
A Glimpse Into the Future	73

THE COVER:

Dr. Lorin E. Harris is shown here in front of a "Home on the Range." Usually the camp tender and herder stay in a camp such as this. It is moved over the range every 2 to 6 days depending on feed and weather conditions. The mutton is wrapped up and put in the bed during the daytime to keep it from spoiling. Most of our research work was conducted on the range.

FRONTISPIECE:

Sheep eating supplements in individual portable pens.

FOREWORD

Range nutrition has not received attention commensurate with its significance in the economy of the Western States. The critical point to apply the research is on each range unit. It is here that the real battles are being waged. This lecture has been prepared to emphasize some of the range livestock nutrition problems and how they may be solved to increase livestock production.

I appreciate this honor of being the Faculty Research Lecturer for 1967-68. I have drawn freely on the ideas and data of my colleagues to prepare my lecture. I wish to acknowledge their help and the assistance of staff members, and the authors of the books and articles which served as sources of material. Sincere appreciation is given to the graduate students, postdoctoral research associates, and undergraduates at Utah State University who made major contributions to the research work briefly referred to in this lecture; to Millard E. Wilde and J. Malcolm Asplund for helpful suggestions with the manuscript; and to Dorothy Smith for typing the manuscript.

The financial support from Swift and Company, Chicago; the American Dehydrators Association, Kansas City; International Minerals and Chemical Corporation, Chicago; and from Utah State University is greatly acknowledged. I wish to thank Wilford and Wallace Winch, and Israel Hunsaker for furnishing the sheep, James and Carl Deardon, and the Vernon Cattlemen's Association for furnishing the cattle. Range and living quarters were furnished at various times by the Intermountain Forest and Range Experiment Station, Ogden.

I give many thanks to my wife Vola, and my family, who have spent many days without me while I was on the desert and have encouraged me during the past 22 years in pursuit of my range research.

— THE AUTHOR

RANGE NUTRITION IN AN ARID REGION

LORIN E. HARRIS
Professor of Nutrition

INTRODUCTION

On the mountains, in the valleys, on the foothills and on the deserts of the Intermountain West grow millions of tons of vegetation. The chemical energy stored by these plants is a potential source of useful energy for man. Some of the plant material has been used for fuel, other has been used as a source of lumber, chemicals, and paper, but the major part of this vast reservoir is useful to man because it is utilized by livestock. This native vegetation is grazed by livestock and they convert the plant energy to high quality, desirable food energy for man.

In the Intermountain area a major portion of the sheep and cattle subsist on open range all year long. Range plants supply the bulk of the nutrients which support survival and production. To utilize various ranges and to adapt to various climatic conditions, the livestock are grazed in several different environments during the year. In the winter, they graze on semi-deserts (figure 1), in the spring and fall on foothills, and in the summer on the higher mountains. These ranges have a diversity of soil, climate, topography, and vegetation. Therefore, the foraging animal's diet is usually highly variable. The diet may be deficient in essential nutrients or may actually contain certain constituents that are toxic or poisonous.

It is necessary to know what nutrients the vegetation supplies, what it lacks, and how grazing may best be managed to permit livestock to utilize it efficiently yet maintain ecological stability. This presents a classical nutritional problem: How may an existing food supply be altered to meet the metabolic needs of the animal subsisting on it? This would also suggest a classical approach to the problem: (1) Determine the nutrient content and digestibility of the feed, (2) determine the animal's requirements, and (3) supplement the feed until it matches the animal's requirements.

However, the obvious logical approach presents some of the most challenging problems faced by a nutritional scientist. The nutrient requirements of range livestock are not fixed. They vary with the grazing environment and stages of the life cycle of the animal. Under certain conditions, maximum gain may be desired. At other times, survival alone or reproductive efficiency may be the criteria of need.

The diet of a grazing animal is not an easily definable entity. Range livestock graze selectively, eating only certain plants or parts of plants. Their selectivity even on a given range will vary with climatic conditions and the season.

Assuming that both animal requirements and dietary intake could be measured so that a proper supplement could be devised, there is still a third problem. Even though a theoretical supplementation program is known it may not be economical or practical or even possible to supply this material to grazing livestock under some range environments.

In view of these problems, a large part of research in range nutrition has been, and is being devoted to the development and use of refined



Figure 1. Sheep grazing on winter desert range in south-central Utah. The vegetation is sparse. Note the playa in the background.

techniques for studying this classical nutritional problem under the conditions encountered on the arid ranges of America.

The first task in range nutrition research is to measure the nutritive value of the plants which the animals consume. The phases in this first approach have been outlined by Harris *et al.* (1952). They include (1) the determination of factors that affect the chemical composition of a given plant species on the range (Cook and Harris, 1950a), (2) the botanical composition and nutritive content of the animals' diet (Cook *et al.*, 1948; Cook *et al.*, 1951; Cook *et al.*, 1952; Lancaster, 1954; Torell, 1954; and Cook *et al.*, 1954), and (3) the feeding of supplements to correct dietary deficiencies or toxicities (Van Horn *et al.*, 1952; and Harris *et al.*, 1956).

The second task is to obtain animal measures which reflect the nutritive state of the animal. Body weight changes and visual evaluation of the condition of the animal have been and will continue to be valuable indices of range utilization (Clanton *et al.*, 1959). However, more refined techniques which indicate nutritional status with respect to specific nutrients are also being tested and used. These include the nitrogen-creatinine ratio to predict protein deficiency (Butcher and Harris, 1957), hypoproteinemia (low blood protein) (Stare *et al.*, 1958), blood phosphorous level, and level of vitamin A and carotene in the blood and liver (Guilbert, 1937).

In many cases, it is necessary to collect data from animals that are under controlled or partially controlled environments to establish a basis for comparison. This approach has been highly developed in human medicine. However, more and better ways of measuring the nutritive status in animals need to be devised before they can be efficiently applied to range environments.

Under these broad terms of reference, the range nutrition researchers of the Intermountain area have made rapid strides during the past two decades in developing adequate techniques and applying them successfully to current problems in range nutrition.

In this paper I will review with you how my colleagues and I, as researchers, have recognized and attempted to solve some of the perplexing nutritional problems associated with livestock production in an arid or semi-arid region. The review is divided essentially into four parts as follows:

BASIC METHODS FOR RANGE NUTRITION RESEARCH
EXPERIMENTS IN RANGE NUTRITION IN AN ARID REGION
UTILIZATION OF RESEEDED GRASSES IN AN ARID REGION
FULFILLMENT

BASIC METHODS FOR RANGE NUTRITION RESEARCH

Measuring Intake and Digestibility

Reviews on methods of determining the consumption and digestibility of herbage by grazing animals have been prepared by Schneider *et al.* (1955), Vallentine (1956), Reid and Kennedy (1956), Raymond *et al.* (1956), Harris *et al.* (1959) and Bohman *et al.* (1967).

To accurately determine the nutritional value of an animal's diet it is necessary to know the amount of each kind of feed consumed and the digestibility of the feeds. These requisites are impossible to obtain completely for animals grazing the range. As a result, feed intake and digestibility must be estimated by indirect means.

In making these indirect estimates, indicators are used. Indicators include (a) "internal" which occur in the plant and are used to estimate apparent digestibility (those which have been used include lignin, plant chromogens, nitrogen, "normal acid fiber," the methoxyl group, and silica), and (b) "external" indicators which are fed to the animals to estimate feces output without a feces bag and include chromic oxide (chromium sesquioxide), iron oxide, and monastral blue.

When animals are fed in pens, external indicators may also be mixed with the total ration and will serve to estimate digestibility and intake of feed (if total feces are collected with a bag) or feces output (if total intake of feed and external indicator are measured). It should be emphasized that these two uses may be independent and on pasture and range it is not possible to mix the indicator with the feed in a constant proportion.

An important foundation point is that if digestibility of a component of a diet is known and if the fecal output of the component is known, then the intake can be calculated. The measurement of feces output by a grazing animal can be obtained by (1) a feces bag which collects the total feces output or by (2) feeding an "external" indicator to the animal. It is important to keep in mind that the only purpose of the external indicator is to estimate feces output without a feces bag for grazing animals.

All formulas for calculating forage intake and digestibility for grazing animals are based on the application of the above information.

Two techniques highly useful to the range nutritionist are those known as (a) the ratio technique and (b) the fecal index technique.
The ratio technique

If the herbage ingested is properly sampled, and the internal indicator is completely indigestible, dry matter intake can be calculated as follows:

$$1 \text{ Dry matter consumed} = \frac{\text{weight of internal indicator in total fecal output}}{\text{level (\%) of indicator in forage}}$$

The following data are used to illustrate the use of formulas I to V:

A grazing sheep on a shadscale (*Atriplex confertifolia*) diet:

1. Fed	10 g	Chromic oxide per day
2. Shadscale	13.0 %	lignin (dry basis)
	7.7 %	protein (dry basis)
3. Feces	1.15%	chromic oxide (dry basis)
	22.6 %	lignin (dry basis)
	6.0 %	protein (dry basis)
4. Feces output	870 g	(dry basis — collected with bag or calculated by formula V)

$$\frac{870 \text{ (dry wt of feces)} \times 22.6 \text{ (\% lignin in feces)}}{13 \text{ (\% lignin in shadscale)}} = 1512 \text{ g dry matter consumed}$$

The apparent digestion coefficient for each nutrient is calculated as follows:

$$\text{II Apparent digestion coefficient (\%)} = 100 - \left[100 \times \frac{\% \text{ internal indicator in forage}}{\% \text{ internal indicator in feces}} \times \frac{\% \text{ nutrient in feces}}{\% \text{ nutrient in forage}} \right]$$

$$100 - \left[100 \times \frac{13.0 \text{ (\% lignin in shadscale)}}{22.6 \text{ (\% lignin in feces)}} \times \frac{6.0 \text{ (\% protein in feces)}}{7.7 \text{ (\% protein in shadscale)}} \right] =$$

$$100 - \left[100 \times 0.575 \text{ (dry matter indigestibility)} \times 0.779 \right] = 55.2\% \text{ apparent digestibility of protein}$$

and

$$100 - \left[100 \times \frac{13.0 \text{ (\% lignin in shadscale)}}{22.6 \text{ (\% lignin in feces)}} \times \frac{100 \text{ (\% dry matter in feces)}}{100 \text{ (\% dry matter in forage)}} \right] =$$

$$100 - (100 \times 0.575 \times 1) = 42.5\% \text{ apparent digestibility of dry matter}$$

Indigestible internal indicators which have been used in the ratio technique include lignin, silica, and methoxyl group. The ratio technique

works well if (1) a method is used to obtain an accurate sample of the forage consumed by the animal and (2) if the indicator is completely indigestible.

Methods which have been used to sample the forage to estimate the diet of a grazing animal include (1) the "before and after method," (2) the esophageal-fistula method, and (3) the rumen-evacuation method. These methods are discussed below.

In some situations, the internal indicator is not always indigestible and also it is sometimes difficult to obtain an accurate sample of the animal's diet. To overcome these difficulties, the fecal index technique has been developed.

Fecal index technique

To obtain basic data for this method, it is necessary to clip forage and feed it in a conventional digestion trial in which the forage intake and feces are quantitatively measured. The feed and feces are then analyzed for an internal indicator, such as chromogen, lignin, nitrogen, methoxyl group, or silica; and for gross energy, organic matter, nitrogen, silica free dry matter, or dry matter. For the fecal index technique, the internal indicator does not need to be indigestible, although that would be ideal. Correction is made for digestibility in the regression equation calculated as indicated below.

At the same time, animals equipped with fecal bags or animals fed an external indicator to calculate total fecal output are grazed on the pasture. Regression equations for the data on the animals fed in the conventional digestion trial are then calculated as shown in figure 2.

After the regression equation in figure 2 is worked out, the concentration of the internal indicator is determined in the feces of the grazing animals. The percent digestibility of the forage can then be calculated by the regression equation.

After the regression equation is established for a particular set of pasture conditions, it is not necessary to have a set of animals fed clipped forage for subsequent trials. The digestibility can be calculated from the concentration of the internal indicator in the feces. *A regression equation under one set of conditions does not work under all sets of conditions. Therefore, each research worker should determine his own regression equation or should make sure that someone else's equation applies to his own experimental conditions.* The regression formula for the line will not always be linear, however, the steeper the slope, the more reliable the estimate will be. Given the data used in the previous sample the dry matter intake can be calculated as follows:

III % indigestibility of dry matter = 100% - % digestibility of dry matter
 100% - 42.5 (% digestibility of dry matter from equation 1) = 57.5% indigestibility of dry matter

NOTE: In actual practice the digestibility of dry matter, 42.5%, would be predicted from the regression equation (figure 2).

IV Dry matter consumption =
$$\frac{\text{Total amount of dry matter in feces} \times 100}{\% \text{ indigestibility of dry matter}}$$

$$\frac{870 \text{ (g dry matter in feces)}}{57.5 \text{ (\% indigestibility of dry matter)}} = 1513 \text{ g dry matter consumed}$$

The most widely used internal indicators are chromogen and lignin. Chromogen appears to be a good indicator for many species (Reid, *et al.*, 1952); however, it does not seem to work for many shrubs on the western ranges (Cook and Harris, 1951). It was found that chemical analyses of the lignin and chromogen content of range forage could be determined with equal accuracy. The differences between duplicate samples and duplicate determinations of the same sample were insignificant at the 1-percent level in all cases. However, when differences among animals were compared by the two methods for various forage species, the lignin ratio technique gave considerably less variability than the chromogen method (table 1).

The coefficient of variation for lignin content of feces among animals grazing big sagebrush (*Artemisia tridentata*) was 11.9 percent com-

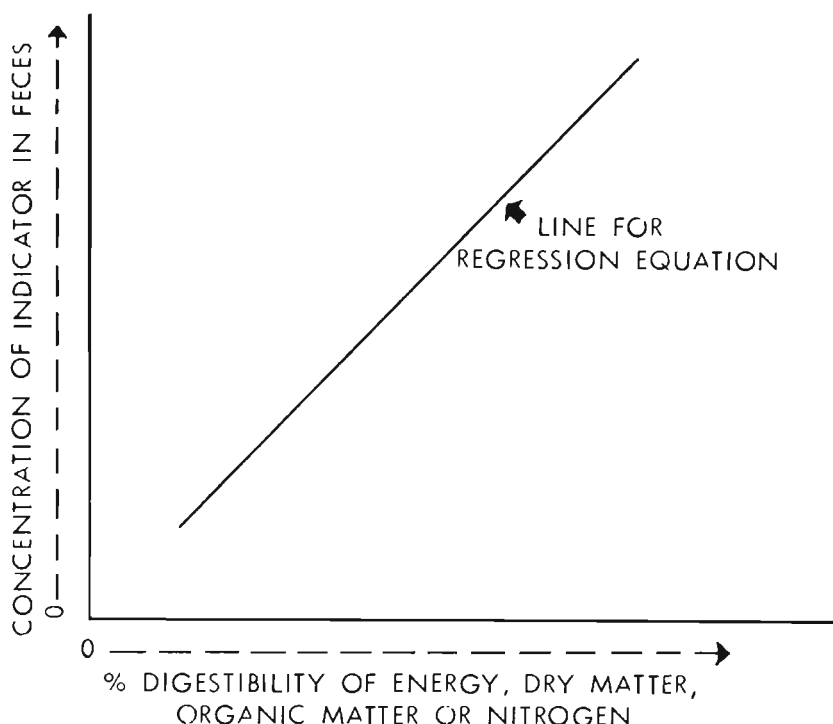


Figure 2. Schematic diagram of regression equation to predict digestibility from concentration of internal indicator in feces.

Table 1. A comparison of the lignin and chromogen content in the feces of six sheep from two forage sources

Sheep	Big sagebrush		Shadscale	
	Lignin content	Chromogen content	Lignin content	Chromogen content
	%	units/g	%	units/g
1	23.4	58	25.0	109
2	24.6	44	23.9	113
3	26.2	50	22.7	96
4	22.3	50	23.7	102
5	24.2	52	24.7	90
6	24.0	56	25.0	112
Mean	24.1	52	24.2	104
Standard deviation	2.9	11.1	2.0	20.8
Coefficient of variation	11.9	21.3	8.3	20.0

pared to 21.3 percent for chromogen content. A similar relationship was found when comparing the lignin and chromogen content of feces from animals grazing shadscale. The coefficients of variation in this comparison were 8.3 percent for lignin and 20.0 percent for chromogen.

The amount of chromogen recovered in the feces while sheep grazed big sagebrush and black sage (*Artemisia nova*) was markedly less than the amount consumed, showing that some of the chromogen was lost or was changed during digestion to give different light absorption values on the spectrophotometer. This of course gave negative digestion coefficients and indicated extremely low quantities of consumed forage (table 2). However, in the case of squirreltail grass the chromogen recovery in the feces seemed high and gave a coefficient of digestibility for dry matter of 68.7 percent which is excessively high for mature dry grass that has been exposed to weathering for a considerable length of time. In addition, calculated dry matter intake was almost 3.2 kilograms (7 pounds) for a 44-kilogram (142-pound) wether which is beyond the amount generally consumed by sheep of this size. Values obtained by the lignin ratio technique agrees rather closely with calculated dry matter intake as presented by the National Research Council (1964) and digestibility of dry matter of similar forages presented by Schneider (1947). Brisson *et al.* (1953) also have shown that the accuracy of chromogen depends on an isoelectric point which may vary under various conditions. Other workers have also shown that chromogen does not work with range plants (Kennedy *et al.*, 1959 and Wheeler, 1962). However, Reid, *et al.*, (1952), Connor *et al.* 1963) and Ridley *et al.* (1963) have shown that the chromogen technique works well for determining the apparent digestibil-

Table 2. Digestibility and dry matter intake of winter range forages calculated by the lignin ratio technique as compared to the chromogen method

Forage species	Number of animals	Average animal weight	Lignin		Chromogen		Dry matter intake		Dry matter digestibility	
			Forage	Feces	Forage	Feces	Lignin tech.	Chromogen method	Lignin tech.	Chromogen method
		kg	%	%	units/g	units/g	kg/day	kg/day	%	%
Big sagebrush	6	66.2	11.9	24.1	177	52	1.44	0.20	50.5	—240.0
Shadscale	6	69.4	12.4	24.1	59	104	1.33	1.21	48.8	43.3
Winterfat	2	68.0	8.1	11.5	74	86	1.50	1.23	29.3	13.8
Black sage	2	59.4	16.1	27.0	120	104	1.39	0.72	40.3	—15.3
Squirreltail grass	2	64.4	8.2	15.4	12	40	1.86	3.15	47.9	68.7
Alfalfa	2	.....	7.9	21.1	147	374	.....	.....	61.9	60.7

ity and forage intake of animals consuming succulent green forage during the summer.

It appears, therefore, that the lignin ratio technique works well with winter range plants high in lignin and that the chromogen ratio technique works well with succulent green forage during the summer.

Estimation of total feces by grab samples

Total feces output for a grazing animal can be determined (1) by using a collection bag or (2) by feeding a quantitative amount of an external indicator to an animal and collecting *grab* samples of feces. A *grab* sample of the feces consists of collecting a small amount at various times during the day instead of collecting the total amount. Total fecal dry matter can be calculated from *grab* samples. This calculation, using the data given in the previous example, is as follows:

$$\begin{aligned} \text{V Fecal dry matter output} &= \frac{\text{amount external indicator fed} \times 100}{\% \text{ external indicator in feces grab sample (dry basis)}} \\ &= \frac{10 \text{ (g chromic oxide)} \times 100}{1.15 (\% \text{ chromic oxide in feces grab sample})} = 870 \text{ g fecal dry matter output} \end{aligned}$$

Using formulas I and II under the ratio method or the regression equation and formulas III and IV under the fecal index method, the dry matter consumption and digestibility can be calculated by collecting *grab* samples of feces without a fecal bag. Chromic oxide appears to be the best external indicator for this purpose. Blank samples containing feces without chromic oxide should be run to correct for naturally occurring materials.

Chromic oxide has been used with success when it has been mixed with the feed or fed as a supplement with the total ration (Edin, 1944; Hamilton *et al.*, 1927-28; Kane *et al.*, 1949; and Schurch *et al.*, 1950). However, with grazing animals it is necessary to feed it apart from the feed. The reliability of capsule feeding of chromic oxide is controversial (Crampton and Lloyd, 1951, and Brannon *et al.*, 1954). A diurnal variation of chromic oxide excretion occurs which must be established under each set of conditions. The usual procedure is to take *grab* samples at times which will represent 100 percent recovery of the chromic oxide, or, if the samples are taken at other times, appropriate corrections for apparent recovery of other than 100 percent must be calculated (Lucas, 1952). The number of *grab* samples to be taken for accurate measurements depends on the frequency of chromic oxide administration. If chromic oxide is administered twice daily to cattle at least 50 *grab* samples must be taken to be within a 5 percent error at any *grab*

sampling time (Brisson¹). For reliable results, Brisson *et al.* (1957) and Border *et al.* (1963a) have found that the preliminary feeding period prior to the start of sampling should be at least 10 days.

Chromic oxide appears to work best when incorporated into paper (Corbett *et al.*, 1960, Border *et al.*, 1963a) or on cellulose (Bohman *et al.*, 1967).

To overcome some of the problems mentioned above, the following recommendations are suggested:

1. Administer paper or cellulose impregnated with chromic oxide and enclosed in a gelatin capsule or mix chromic oxide in the feed. If it is administered in the feed, make up a paste of flour, or a portion of one of the ingredients in the diet and chromic oxide. Bake the paste and grind through a mill, then mix it with the feed.

2. The preliminary period should be at least 10 days in length.

3. The collection period should be at least 7 days in length. Collect at least 50 *grab* samples from each animal.

4. To overcome diurnal variation, collect random samples of feces in the pasture or pen. Each dropping can be marked with lime. If more than one animal is in a pasture, colored polyethylene particles may be administered to the animals so the feces from one animal may be distinguished from another.

Obtaining Samples of Actual Forage Ingested

The "before and after" method

Under winter range conditions in the Great Basin, the sheep's diet is composed of a variety of browse species such as black sage, big sagebrush, shadscale, winterfat (*Eurotia lanata*) and grasses such as galleta grass (*Hilaria jamesii*), Indian ricegrass (*Oryzopsis hymenoides*) and squirreltail grass (*Sitanion hystrix*). In the winter, these species are mature and relatively high in lignin and low in chromogen.

With mixed species of this type, it has been impossible to collect forage samples in the field which represent the animal's diet and feed them in conventional stalls to obtain a regression equation for the fecal index technique. In many cases, the sheep refuse to eat collected forage. With these thoughts in mind, we have used the "before and after" method to predict the percentage nutrient composition of the diet and the lignin

¹ Brisson, G. J., Personal communication (1958).

ratio technique to predict the dry matter intake and digestibility of the diet.

The “before and after” method of determining the sheep’s diet consists of measuring the dry weight and chemical composition of the available forage of each species before and after grazing (Cook *et al.*, 1948, 1950b, and 1951). The difference represents the animal’s diet. The

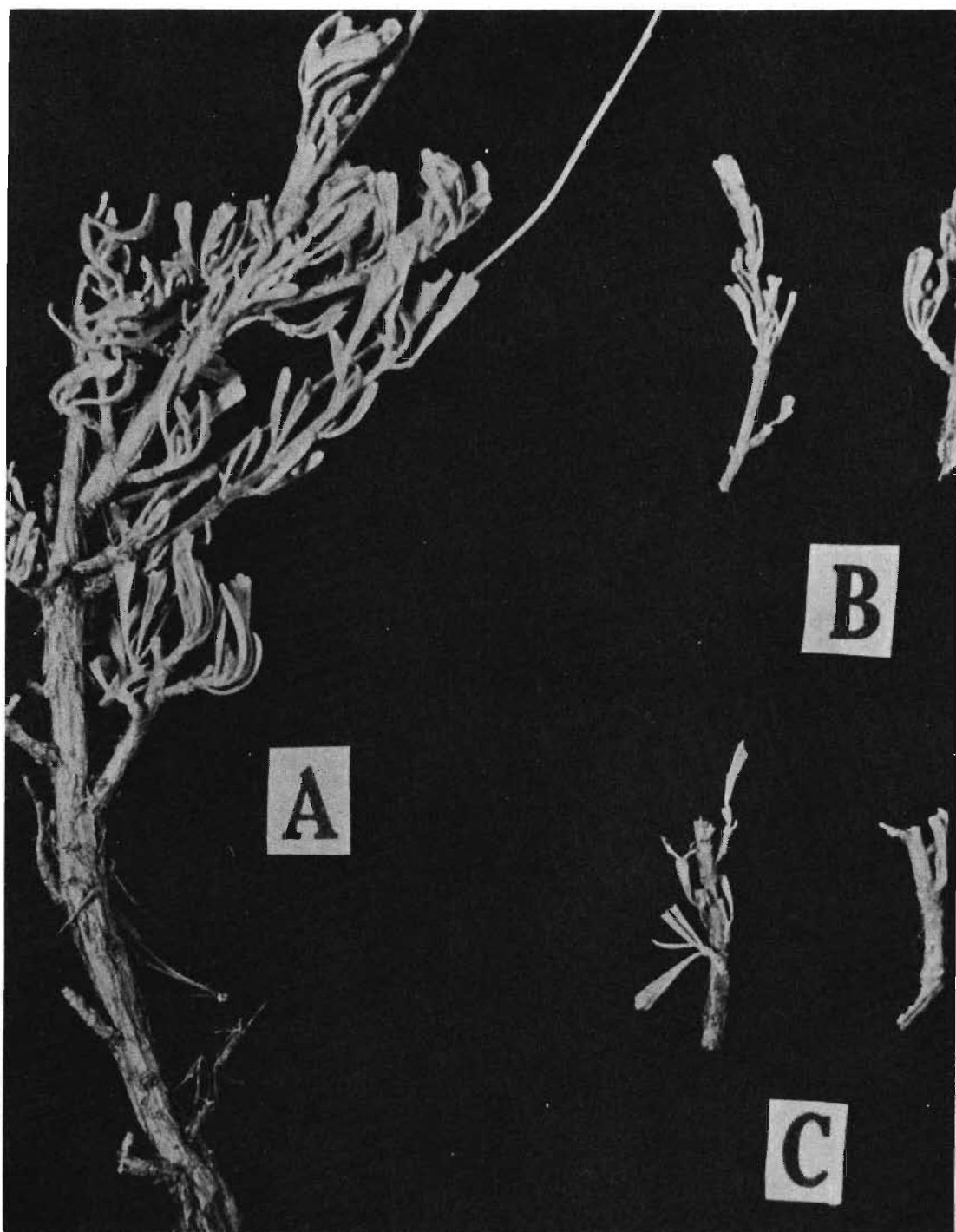


Figure 3. An observation (A) containing many units is collected for browse species such as big sagebrush (*Artemisia tridentata*). Before grazing units (B) and after grazing units (C) consisting of the current year’s growth are picked off the observations.

amount of available forage is measured by collecting plant units from each species before and after grazing along transect lines. The unit in the case of most browse plants can be confined to twigs of current year's growth (figure 3); for bunch grasses, the entire clump; for semi-bunch grasses, only the individual stem; for sod grasses, 1/16 square foot or individual tiller stems; for annuals and most forbs, either the entire plant or an individual stem; and for some coarse broad-leafed forbs, only the leaf and leaf stem.

An illustration of the method of calculating the botanical and chemical composition of a sheep's diet when grazing on the Great Basin winter range is given in table 3.

Total intake of forage and digestibility of the protein and crude fiber of the diet in table 3, can be obtained by the lignin ratio method. This method is particularly applicable on the winter range of the Great Basin. During the winter, the plants are relatively dormant and corrections do not need to be made for growth between collections before and after the sheep graze. The plant species (predominantly browse) are far enough apart so that shattering and trampling are not problems (figure 1).

Esophageal fistula method

A representative sample of a grazing animal's diet is best obtained by the foraging animal. Collection of animal gathered samples was first accomplished in California by means of esophageal fistula (Torell, 1954). The fistula in the esophagus was closed by pulling the wool over the opening. We modified this technique by inserting a plastic cannula with a cap into the esophagus (Cook *et al.*, 1958). Improved operative techniques have been outlined by Bohman *et al.* (1967). Animals are fitted with plastic bags to obtain a sample of the sheep's diet (figure 4). This method works well in sampling many types of plants.

The esophageal fistula is an accurate method of obtaining a sample of the sheep's diet under most conditions. However, if used for chemical analysis certain corrections need to be made for contamination by the saliva (Bath *et al.*, 1956 and Van Dyne and Torell, 1964). There seems to be little contamination of protein, but considerable contamination of minerals. Intake and digestibility are calculated by the ratio-technique using formulas I and II.

Table 3. An illustration showing the method of calculation for botanical and chemical composition of the

Column no.	1	2	3	4	5	6	7
Species and sample	Average density† per 100 sq m	Units per sq m	Average wt per unit	Wt per sq m density (col 2x3)	Total wt per 100 sq. m (col 4x1)	Amount consumed	Utilization
	sq m	no	g	g	g	g/100 m ²	%
<u>Atriplex confertifolia</u>							
Before grazing	1.3	4370	.1231	538	699		
After grazing	1.3	4370	.0921	402	523		
Diff. (ingested)						176	25.2
<u>Eurotia lanata</u>							
Before grazing	3.2	2282	.5264	1201	3843		
After grazing	3.2	2282	.3321	758	2426		
Diff. (ingested)						1417	36.9
<u>Gutierrezia sarothrae</u>							
Before grazing	2.4	6480	.0946	613	1471		
After grazing	2.4	6480	.0854	553	1327		
Diff. (ingested)						144	9.8
<u>Sporobolus cryptandrus</u>							
Before grazing	1.7	180	3.443	6197	10535		
After grazing	1.7	180	2.843	5117	8699		
Diff. (ingested)						1837	17.4
Totals (ingested)						3573	
Percent in diet							

† This represents normal ground cover of each species without artificial rearrangement of the foliage to a



Figure 4. This sheep is equipped with an esophageal fistula. As the sheep eats, the diet is sampled and falls into the bag. When not sampling forage the fistula is closed by putting a plastic cap on the cannula which is in the fistula.

diet on a winter range

8	9	10	11	12	13	14	15	16
Diet	Protein content (col 9x5)		Crude fiber content (col 11x5)		Calcium content (col 13x5)		Phosphorus content (col 15x5)	
%	%	g/100 m ²	%	g/100 m ²	%	g/100 m ²	%	g/100 m ²
	6.88	48	33.3	233	2.59	18	.069	4.8
	6.50	34	35.9	188	2.19	11	.062	3.2
4.93		14		45		7		1.6
	10.12	389	36.7	1410	1.50	43	.099	3.8
	9.00	218	39.0	946	1.37	33	.095	2.3
39.66		171		464		10		1.5
	6.62	97	24.0	353	1.13	17	.079	1.2
	6.53	87	24.8	329	1.13	15	.076	1.0
4.03		10		24		2		0.2
	4.13	535	39.9	4203	0.48	51	.069	7.3
	4.02	350	43.5	3784	0.40	34	.065	5.7
51.38		185		419		17		1.6
		380		952		36		4.9
00.00	7.85		26.80		1.36		.096	

at the percent density.

Rumen evacuation method

To sample the grazing animal's diet by the rumen evacuation technique a cannula is inserted into the rumen as described by Binns and James (1959). For diet sample collection the contents of the rumen and reticulum are removed thoroughly (Lesperance *et al.*, 1960). It is usually advisable to quickly rinse the rumen and then remove the water with a small pump before sampling. The animals are then allowed to graze for 0.5 to 2 hours depending on the availability of the forage. The forage sample is removed from the rumen and reticulum and the original contents are put back in.

The diet sample collected by this method is contaminated with saliva and corrections need to be applied as was described above for the esophageal diet samples. This method does give a total collection (Lesperance *et al.*, 1960), and is better than the esophageal method for sampling some coarse dry grasses.

Measuring Metabolizable Energy of Range Plants

When the total digestible nutrient (TDN) content of big sagebrush, black sage and other similar browse plants was determined, it appeared

that these plants were exceptionally high in TDN compared to their observed value as forage plants.

In view of these facts, methods were devised to determine the metabolizable energy (ME) of range plants (Cook *et al.*, 1952). Metabolizable energy is defined as follows (Harris, 1966):

$$\text{ME} = \text{gross energy intake} - \text{feces energy} - \text{urine energy} - \text{methane energy}$$

The method consisted of using wethers equipped with fecal bags and urinals in temporary enclosures (figure 5). Methane was calculated from the following formula (Swift *et al.*, 1948):

$$\text{methane (gas)} = 2.41 X/100 + 9.8 \text{ (X represents grams of digestible carbohydrates)}$$

Each gram of methane has a calorific value of 13.34 kilocalories.

Since our work was done, Baxter (1962), has suggested that methane may be calculated from the gross energy consumed.

Comparative energy values are given for three plants in table 4. Black sage and big sagebrush are high in gross energy (GE), TDN, and digestible energy (DE), while squirreltail grass is rather low in GE and about equal to the other plants in TDN and DE. However, black sage

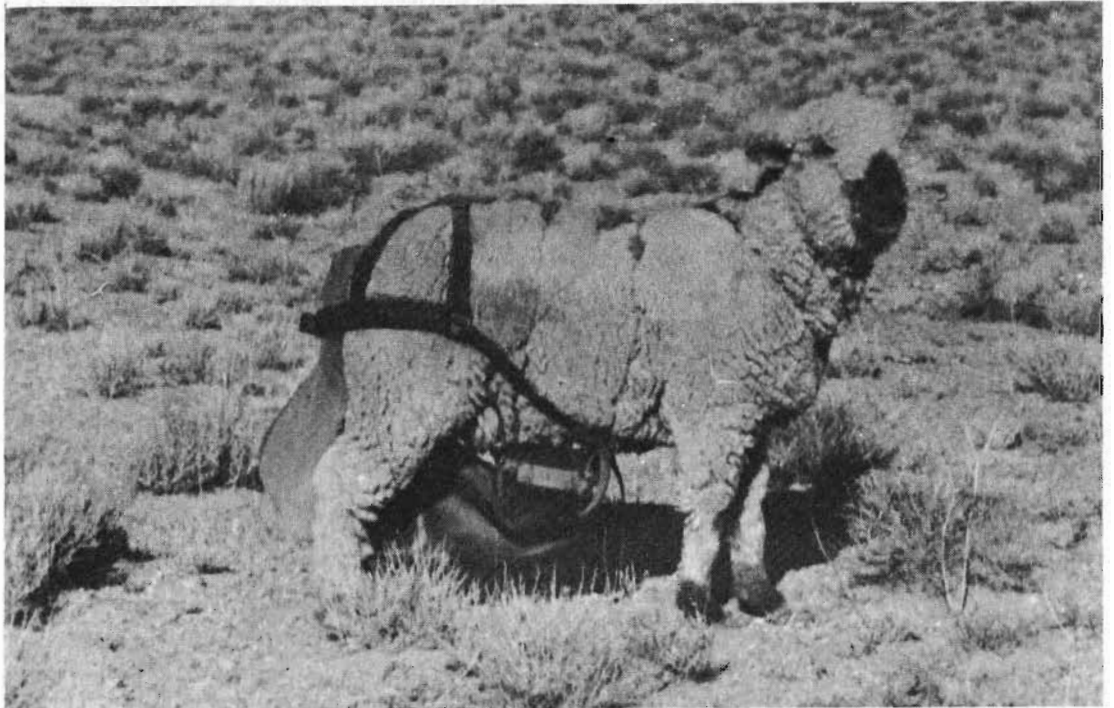


Figure 5. A sheep equipped to collect feces and urine while grazing on the range so that the energy of the feces and urine may be determined. These values are needed to calculate metabolizable energy.

and big sagebrush are much lower in ME than squirreltail grass. It is believed that this difference is caused by the large content of volatile oils in black sage and big sagebrush. Therefore, ME is a better index of energy value of range plants than DE or TDN. We have also devised methods to collect feces and urine from cattle when they are grazing (Border *et al.*, 1963b).

Methods of Expressing Energy Values

The requirements of animals and the energy value of feeds and diets in the United States have been expressed primarily on the TDN system. However, in 1955 the Animal Nutrition Committee of the National Research Council (NRC) passed a resolution to express energy requirement in terms of calories and expressed the desire that information be gathered on the GE, DE, ME, and net energy (NE) of feeds and diets in order that the TDN system can be replaced. In view of this resolution, I prepared a glossary of energy terms for the Animal Nutrition Committee of the National Research Council based on the calorie system (Harris 1962, 1966). The conventional system is briefly outlined in figure 6. The calorie system is now being used in all the NRC Nutrient Requirement Reports, and by the NRC Animal Nutrition Committee on Feed Composition (Crampton and Harris, 1964).

Any change from the use of TDN to DE, ME, or NE, in feed description or in nutrient requirement tables, will make it necessary either

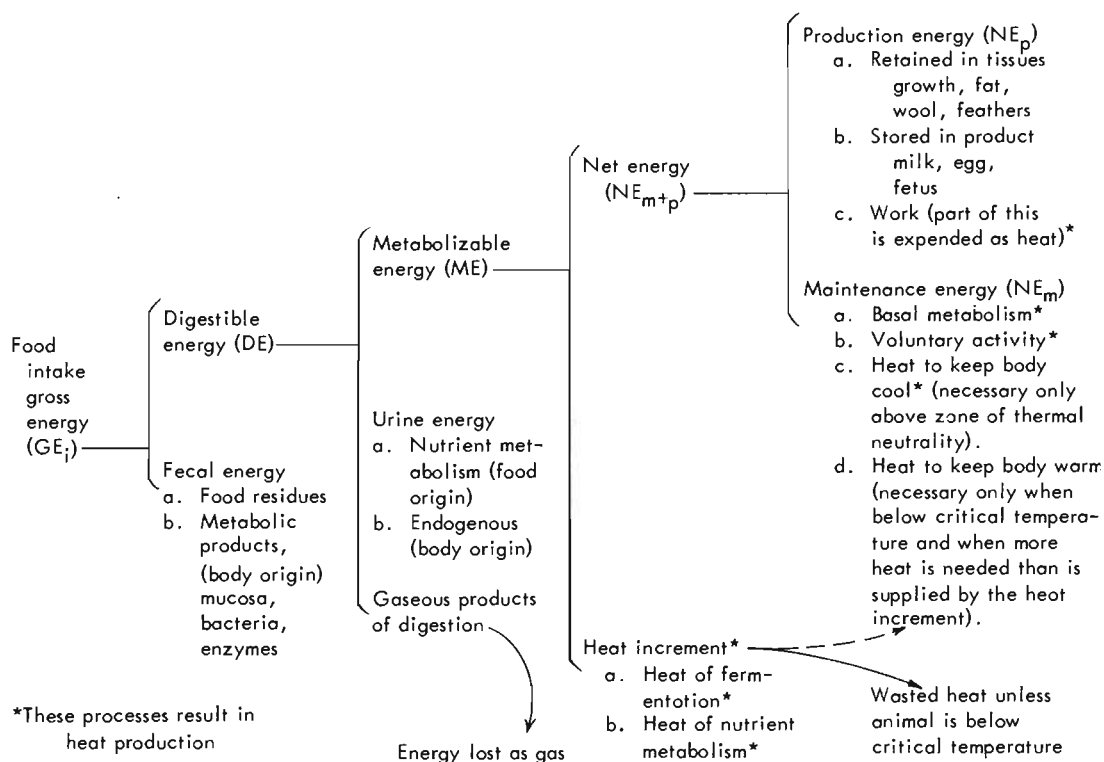


Figure 6. The conventional scheme of partition of food energy as it is utilized by the animal.

Table 4. Comparison of methods of expressing the energy value of three common desert range plants

Species	Gross energy	TDN	Digestible energy	Metabolizable energy
	kcal/kg	%	kcal/kg	kcal/kg
Black sage	5101	49.5	2124	1044
Big sagebrush	4830	43.4	1948	1130
Squirreltail grass	3787	50.4	2022	1704

to abandon the present extensive TDN data or to find means of converting these values to accurate corresponding calorie figures. Crampton *et al.*, (1957), and Swift (1957), have worked out satisfactory procedures to make this conversion.

The Animal Nutrition Committee of the National Research Council in their November, 1958 meeting adopted 4.409 kilocalories per gram (2,000 kilocalories per pound) of TDN to convert it to DE. A summary of the formulas to be used by the NRC Animal Nutrition Committee on Feed Composition² are as follows:

$$\text{DE (kcal/kg)} = \frac{\text{TDN \%}}{100} \times 4409$$

$$\text{ME (kcal/kg) for ruminants} = \text{DE (kcal)} \times 0.82$$

$$\text{ME (kcal/kg) for swine} = \text{DE (kcal/kg)} \left[\frac{(96 - 0.202 \times \text{protein \%})}{100} \right]$$

Net energy values for some cattle feeds including net energy for maintenance (NE_m) and net energy for gain (NE_{gain}) may be estimated from formula developed by Lofgreen.³

$$\text{Log } F = 2.2577 - 0.2213 \text{ ME}$$

$$\text{NE}_m = 77/F$$

$$\text{NE}_{\text{gain}} = 2.54 - 0.0314 \text{ F}$$

The terms used in the formulas are those defined by Harris (1966) and are on a dry matter basis (moisture free).

² Earle W. Crampton and Lorin E. Harris, unpublished data.

³ Personal communication.

1. ME is the metabolizable energy in kcal/g of dry matter (DM) (or megal/kg DM).
2. F is the grams of dry matter per unit of $W^{0.75}$ required to maintain energy equilibrium.
3. NE_m is the net energy for maintenance in kcal/g DM (megal/kg DM).
4. NE_{gain} is the net energy for gain in weight in kcal/g DM (megal/kg DM).

To convert NE_m and NE_{gain} to kcal/kg the values are multiplied by 1000.

Some of the formulas were developed under farm conditions and not under range conditions. However, they may be used until more adequate ones are devised.

Range Meters for Measuring the Distance Traveled by Sheep and Cattle

Cattle and sheep travel long distances to obtain feed and water when grazing on the range. Since considerable energy is expended in these activities, we decided it was important to determine the distance traveled by range animals in order to obtain information for calculating the energy requirements.

Our first studies involved the use of a range meter (figure 7) which

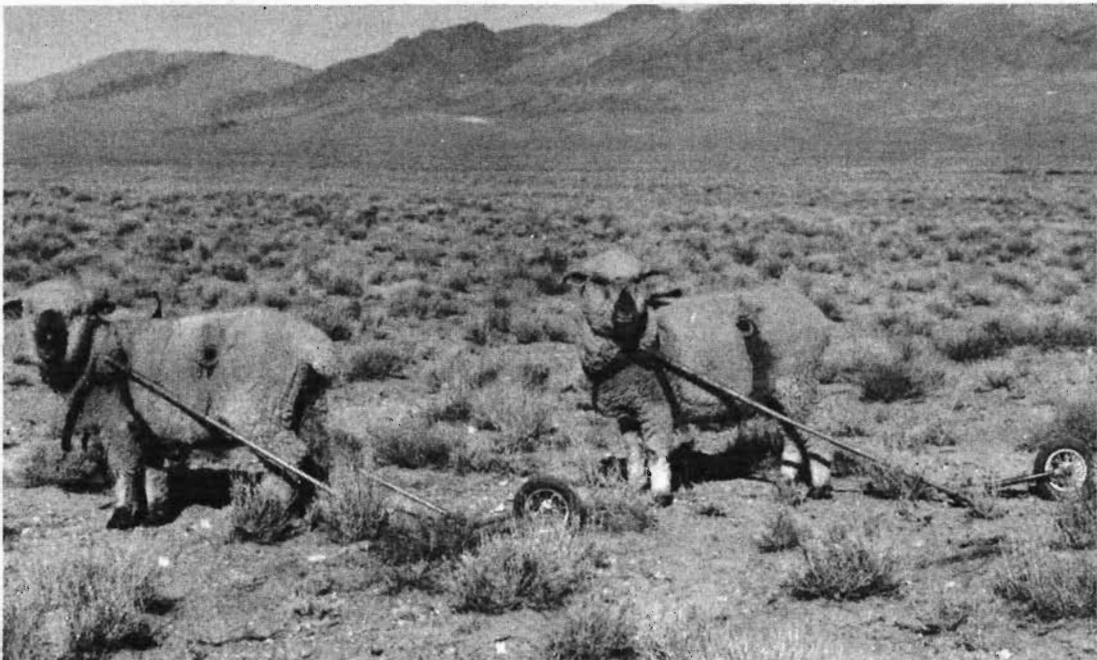


Figure 7. Sheep equipped with range meters to measure the distance traveled. The sheep also have rumen cannula inserted into the fistula. These cannulae do not seem to hurt the animals. The sheep were fed supplements through these rumen cannulae.

we developed for measurement of the distance traveled by sheep (Cresswell and Harris, 1959). In a pasture of 259 hectares (1 mile square) on a winter saltbush-type range, we found that sheep traveled an average of 4.6 kilometers (1.6 miles) a day to obtain their feed (Morris *et al.*, 1965).

In another experiment we tested the range meter on four Hampshire ewes and four Rambouillet ewes. Rambouillet ewes traveled about 25 percent farther than Hampshire ewes in a 1.0 hectare (2.5 acre) pasture.

This difference between breeds presents some interesting considerations. The Rambouillet breed originated from the Spanish Merino. Merino sheep were developed to graze the rather arid, hilly areas of Spain in an environment not unlike the Intermountain West. The utility of this breed depended upon its ability to graze over a wide area of sparse vegetation to obtain feed as well as its propensity to flock together. On the other hand, the Hampshire breed was developed to be useful in lush, small enclosed pastures in England. Neither foraging aggressiveness nor flocking ability were of concern.

On western ranges, most of the sheep have considerable Rambouillet breeding even though crosses with the British breeds are being introduced. It is a challenging breeding problem to improve the mutton producing ability of the range sheep without losing the vital abilities of aggressive foraging and flocking. One new breed, the Columbia, developed from a cross of the Rambouillet and Lincoln breeds, traveled distances intermediate to the Rambouillet and Hampshire when foraging.

While active foraging may provide a sheep with an increased supply of feed, it may also increase its energy requirements. Breed differences must be considered in range nutrition experiments.

We have also developed a range meter for cattle (figure 8). However, it has not been tested under range conditions.⁴

Weighing Range Animals

Methods of weighing animals on experiments have been reviewed by Baker *et al.* (1947); Bean (1948); Lush *et al.* (1928); Patterson (1947); Whiteman *et al.* (1954); Balch and Line (1957); and Koch *et al.* (1958).

With portable equipment and three to five men, we have found it possible to individually weigh 60 to 100 sheep or cattle per hour. This

⁴ Cresswell and Harris, unpublished data.

handling has not adversely affected the animal response, as animals that were weighed frequently responded equally well when compared to animals weighed less frequently.

The important thing in weighing animals in pastures or ranges is to avoid bias between treatments, and attempt to have all animals at the same intestinal fill within a replication or within a block of treatments.

Allen (1946), weighed animals at 0.5 hour-intervals throughout the day and reported that weighing just before feeding time in the morning “was found to be the time when the average variation from day to day was least and when the range between extremes was narrowest. These facts indicate that just before feeding is probably the most suitable time for weighing when changes in weight are being studied.” . . . “For milking cows, variation can be further reduced at this time, which precedes the normal milking time, by deducting the contents of the udder as determined by subsequent milking.”

With these facts in mind it is suggested that weighing procedures be standardized as follows:



Figure 8. A range meter to measure the distance traveled by cattle.

1. Gather animals late at night and put them in a corral without feed or water or corral animals at daylight (before they have eaten) and keep them off feed and water. Begin weighing soon after daylight, but give the animals sufficient time to urinate and defecate before weighing is started. Follow the same procedure each time.

2. Mix all animals in a large corral within a replication or block of treatments and weigh at random. Avoid weighing animals by lot, pasture or treatment as this creates a bias among treatments.

3. Deduct the contents of the udder of milking cows as determined by subsequent milking.

4. One-day weights are sufficient if there are a number of animals per treatment. If accuracy is wanted on individual animals, two or three day weights should be taken (Koch *et al.*, 1958).

5. Weather changes on the day or days immediately prior to weighing influence body weights by plus or minus 5 percent. That is, if the weather has been warm, but if the day before weighing is cold, a sharp drop in weight will be expected. This seems to be related to water fill, even though the animals are off feed and water for 12 to 16 hours.

6. Animals taken from dry feeding and put on pasture lost intestinal fill (Balch and Line, 1957). If absolute gains in weight are needed, a standardizing period with the same kind of feed at the beginning and end of the trial is desirable to reduce variability of intestinal fill.

7. Where scales are not available in some field experiments, relatively accurate data can be obtained by measuring the heart girth and calculating the weight (Kendrick *et al.*, 1936; and Gaines *et al.*, 1941).

Environmental Influences on Animal Response

Weather is a very common environmental influence (Butcher and Harris, 1962). By comparing range animals and animals under controlled feeding (both under similar weather conditions) it has been found that the weather, especially snow, has its greatest influence in reducing feed availability rather than the direct effect of the snow and cold on the animal itself. Under extreme conditions, however, there may be death losses from cold, especially if the cold is associated with snow or rain. Sheep that have been recently shorn are especially sensitive to cold and wet storms.

There is an indirect effect of weather which causes large variations in amount of feed available on ranges and the season that this feed is available. This results in great variations in animal diets and requires

careful management to recognize the nutritive state of the animal. For instance, carotene supplementation has been shown to give little response when animal blood measures indicated a borderline carotene or vitamin A deficiency. A similar situation was found with vitamin A injection. However, during the season of these range experiments our uncontrolled weather provided rain or snow at such a time that all animals had access to enough green feed, even in late winter, to apparently meet the vitamin A requirement of the animals.

Snow was found to be completely adequate as a water source for sheep on winter range or even on alfalfa hay. Not only was the snow adequate, but there was no measurable added feed cost or reduced productivity of sheep with 5 or more centimeters (1.95 inches) of wool when snow was the only source of water.

All environmental factors are very important in designing and evaluating range experiments. Most range experiments are actually designed as a means of modifying the environment.

EXPERIMENTS IN RANGE NUTRITION IN AN ARID REGION

Characteristics of the Intermountain Range

The Intermountain range area lies between the Rocky Mountains and the Sierra Nevada and Cascade Ranges. It includes the major part of Utah and Nevada, and it extends into western Colorado, northern Arizona, eastern California, and much of the western half of Wyoming. Its northern boundary includes about one-fourth of the southeast portion of Oregon and most of the southern half of Idaho.

This region has an irregular topography and hence is highly variable in soil and climate. Precipitation is low, especially in the foothills and on the deserts, and tends to be more abundant in the non-growing season and the summers are hot and dry as a result.

The vegetation over the majority of the area is predominantly deeply rooted, semi-desert shrubs, almost all of which belong either to the *Compositae* or to the *Chenopodiaceae* families.

While our research was conducted primarily in the Great Basin area, the results generally can be applied to this entire region.

As far as livestock are concerned, this region may be divided into three general range areas depending on use: winter range, spring and

fall range, and summer range. Cattle and sheep graze on the winter range from about November to March. They are then trailed or trucked to the spring range where they stay until the latter part of June. They are then trailed or trucked to the high mountains (National Forest) or summer range where they graze until about September 15 to October 15. Then they are trailed or trucked to the fall range where they stay until they are taken again to the winter range.

Of course, many ranch operators have a base farm. This farm may produce alfalfa and meadow hay or meadow pasture. If the winter is severe, some of the hay may be fed as emergency feed on the range. Some operators feed meadow hay in the winter and use the range during the spring, summer, and fall.

Winter range

The winter range area consists of valley floors and low mountains containing numerous coves and alluvial fans which separate the valley basins varying from 6.2 to 9.3 kilometers (10 to 15 miles) in width (figure 1).

Poor drainage conditions coupled with low precipitation result in concentration of salt in most of the soil profiles. In general, the salt is near the surface of the valley floor, and at deeper levels on the slopes.

The annual precipitation of 152 to 178 millimeters (6 to 7 inches) occurs principally as winter snows and spring rains or sleet. Only occasional summer showers occur which vary in intensity and generally are local in nature. There is considerable freezing and thawing, and for much of the winter cold weather predominates. Usually the snow is less than 150 millimeters (6 inches) deep. This is ideal for grazing livestock as the snow furnishes water and softens the dry, dormant vegetation making it more palatable. However, when the snow is deep, it covers most of the vegetation and the livestock must be fed emergency feeds such as alfalfa or meadow hay or a low protein pellet. Summers are hot and dry and are characterized by maximum temperatures of 32 to 38 C (90 to 100 F).

The vegetation consist mainly of the northern desert shrub salt-bush type. Dominant shrubs are *Atriplex spp.*, chiefly shadscale, greasewood (*Sarcobatus vermiculatus*), black sage, big sagebrush, yellow bush (*Chrysothamnus stenophyllus*), winterfat, and desert molly (*Kochia vestita*). Grasses are subdominant and are generally sparce. Important species are Indian ricegrass, squirreltail grasses, galleta

grass, and blue grama grass (*Bouteloua gracilis*). Forbs are of little significance. Locally, annual invaders such as Russian-thistle (*Salsola kali* var. *tenuifolia*) and cheatgrass (*Bromus tectorum*) may furnish large percentages of the forage, especially in the fall and early spring. Halogeton (*Halogeton glomeratus*) a poisonous plant, which causes some livestock losses, was introduced a few years ago and has now spread over this entire area.

Spring and fall range

The spring and fall range consists largely of the foothills and depleted dry farm land. This type of range lies in a zone of 279 to 356 millimeters (11 to 14 inches) of rainfall. About 75 percent of the precipitation falls during the 8 months from October to May. Probably 60 percent of the yearly total falls as snow. There is more summer precipitation in the southern part than in the northern part of this area. Summer precipitation often comes as thunder showers, sometimes with cloudburst intensity. The elevation of these ranges is 1524 to 2134 meters (5000 to 7000 feet). Much of this area is now being reseeded to drought resistant grasses such as crested wheatgrass (*Agropyron cristatum*), Russian wildrye (*Elymus junceus*), intermediate wheatgrass (*Agropyron intermedium*), and tall wheatgrass (*Agropyron elongatum*).

In the spring and fall there are intermittent periods of freezing and thawing weather with rain and snow. This type of weather is rather unfavorable for lambing and calving operations. Because of the inclement weather, some operators use portable shelters for lambing ewes, others use canvas covered sheds and corrals where the ewes may be fed supplementary feed while they are lambing. Calving sheds have also been developed in some areas, particularly where meadow hay is available to feed the heifers and cows just before calving.

The dominant shrubs on the spring and fall range include big sagebrush, rubber rabbitbrush (*Chrysothamnus nauseosus*) and bitterbrush (*Purshia tridentata*). Much of the area is being slowly invaded by various species of Juniper such as *Juniperus utahensis*.

Grass species include bluebunch wheatgrass (*Agropyron spicatum*), Sandberg bluegrass (*Poa secunda*), western wheatgrass (*Agropyron smithii*), Indian ricegrass, squirreltail grass, Great Basin wildrye (*Elymus cinereus*), and cheatgrass, an introduced annual that has spread over much of the western spring and fall range and is present in varying amounts.

Prominent forbs on the spring and fall ranges of this area are desert globemallow (*Sphaeralcea ambigua*), Nevada lupine (*Lupinus nevadensis*).

sis), Utah sweetvetch (*Hedysarum boreale*), longleaf phlox (*Phlox longifolia*), false dandelion (*Agoseris spp.*), loco (*Astragalus cibarius*), and such annuals as Russian thistle, clasping pepperweed (*Lepidium perfoliatum*), and halogeton.

Summer range

The summer range includes primarily the National Forest and some private areas. These areas are usually above 2,134 meters (7,000 feet). Livestock utilize them only during the summer. Precipitation is 375 to 875 millimeters (15 to 35 inches). Most of it falls as snow, but there are some spring, fall, and summer rains. Because of the high altitude, this range is cool in the summer.

The terrain is characterized by steep slopes and ridges. However, there are grassy parks and meadows in some high mountainous areas. Soils are often shallow with little soil maturity in the profile.

The vegetation is lush during the spring and early summer, but may become dry during late summer. There are a great many species of range plants on this area (Cook *et al.*, 1948). The dominant browse species include big sagebrush (very little is consumed on the summer range), aspen (*Populus tremuloides*), snowberry (*Symphoricarpos rotundifolius*), chokecherry (*Prunus demissa*), and serviceberry (*Amelanchier alnifolia*). Some of the prominent grasses include mountain brome (*Bromus carinatus*), beardless wheatgrass (*Agropyron inerme*), basin wildrye (*Elymus cinereus*) and Kentucky bluegrass (*Poa pratense*), an introduced species.

There are many forbs, a few of the most important include western yarrow (*Achillea lanulosa*), hoary aster (*Aster canescens*), fremont geranium (*Geranium fremontii*), aspen peavine (*Lathyrus leucanthus*), tailcup lupine (*Lupinus candatus*) and mulesears wyethia (*Wyethia amplexicaulis*).

Examples of Range Experiments

Our research has been conducted on the winter desert range, on the spring and fall range in the foothills, and on the summer range in the high mountain areas. Of these ranges, the first two are more likely to produce forage which is deficient in nutrients. Of course, reseeded summer range in the foothill areas may also be low in nutrients.

Following are some examples of our research on the winter range and spring and fall range which have utilized some of the techniques discussed above to solve some of our range nutrition problems. For examples of our experiments on the mountainous summer range see Cook *et al.* (1965, 1967).

An Experiment on the Winter Range

Our first experiment was conducted in Pine and Wah Wah Valleys, west of Milford, Utah, in 1946-47 (Harris *et al.*, 1956). I have chosen this experiment as an example because it describes how we developed and applied several classic techniques (Harris *et al.*, 1952) to solve nutrition problems on the winter range.

The nutrient content of the grazing sheep's diet

Our experimental area was on a typical shadscale winter desert range. We first determined the percentage composition of the diet of our experimental sheep by using the "before and after" method. Digestibility and dry matter intake were determined by the lignin ratio technique. Metabolizable energy was determined by collecting and analyzing the feces and urine for energy and estimating the energy in the methane as described previously.

When the nutrient content of the diet of our sheep was compared with the nutritive requirements of a 130-pound ewe as proposed by the National Research Council (1949), it was found to be low in phosphorus, protein, and energy (figure 9). However, it was exceedingly high in calcium.

Experimental plan

Using the above data as a guide, various amounts of phosphorus, protein, and energy supplements were fed to experimental ewes and the effects on maintenance of weight and production of wool and lambs were measured. In November 1947, 144 ewes were selected at random from a typical range herd. They were segregated into six groups: lambs, yearlings, 3-year olds, 4-year olds, 5- to 6-year olds, and over 6-year olds, and allotted at random to the treatments outlined in table 5. Thirty-six animals were not fed supplements and they served as controls. In addition to the controls, the treatments consisted of two levels of phosphorus, two levels of protein, and two levels of energy supplements for a total of seven treatments. The phosphorus supplements consisted of monosodium phosphate fed at the rate of 13 grams (0.029 pound) each

second day for the first level and 17 grams (0.038 pound) for the second level. Protein supplement consisted of solvent extracted soybean meal pellets fed at two levels, 128 grams (0.28 pound) and 256 grams

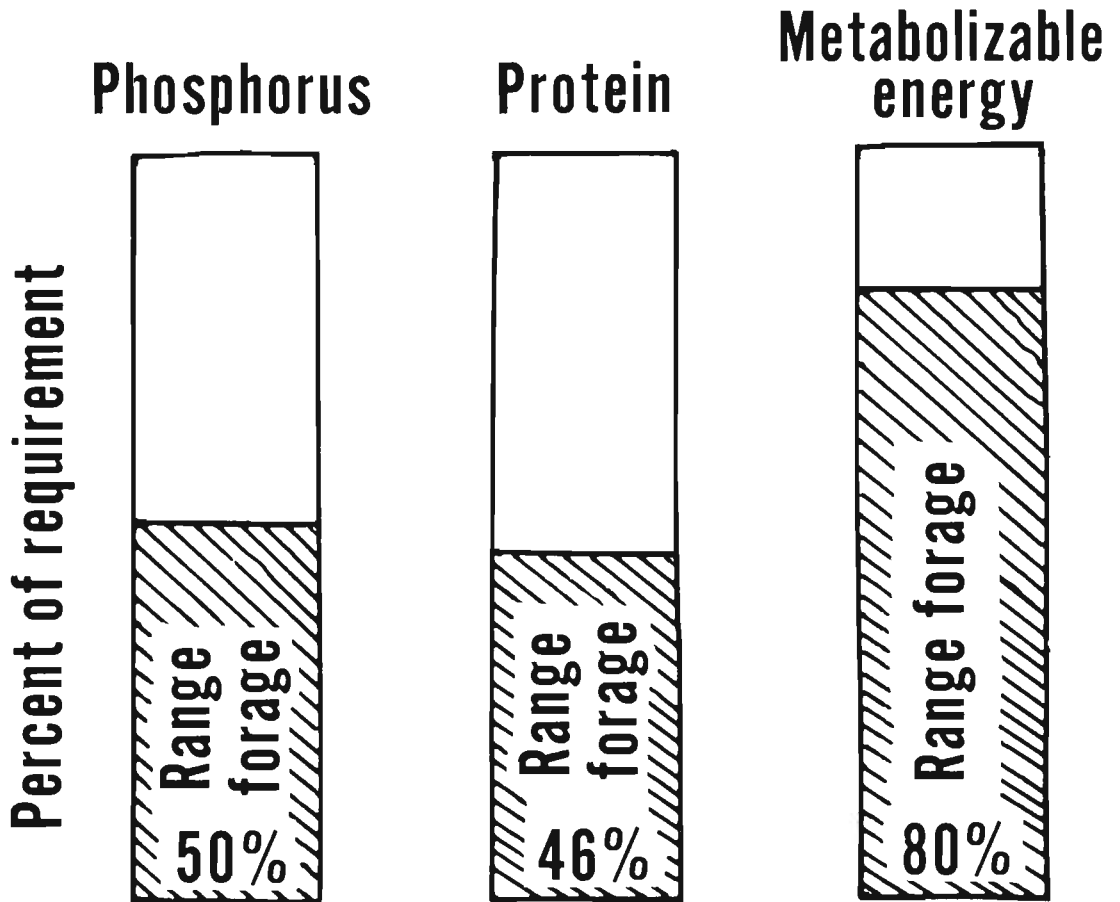


Figure 9. The National Research Council nutrient requirements for sheep show that shade-scale type winter range forage supplies 50 percent of the phosphorus, 46 percent of the protein, and 80 percent of the metabolizable energy needed by range ewes.

Table 5. Experimental design to compare six ages of sheep when fed two levels each of whole barley grain, solvent extracted soybean meal pellets, and monosodium phosphate, 1947-48

		Lambs	3 Year- lings	4 years old	5 to 6 years old	Over 6 years old	Total sheep numbers
		Number of sheep per treatment †					
Control		6	6	6	6	6	36
Barley, grain	182 g	3	3	3	3	3	18
Barley, grain	364 g	3	3	3	3	3	18
Soybean meal	128 g	3	3	3	3	3	18
Soybean meal	256 g	3	3	3	3	3	18
Monosodium phosphate	13 g	3	3	3	3	3	18
Monosodium phosphate	17 g	3	3	3	3	3	18
Total sheep numbers		18	18	18	18	18	108

† Three replications (twice as many control ewes as other ewes).

(0.56 pound) each second day. The energy supplement was supplied in the form of whole barley grain fed at the rate of 182 grams (0.40 pound) and 364 grams (0.80 pound) each second day.

The sheep were grazed together on the open range during the day and were corraled each night (figure 10). They were put into individual pens at dawn and were fed their designated supplement individually in buckets. Using this procedure and 56 individual pens, it was possible to feed all the sheep on the experiment in less than 2 hours. Whole barley (energy) and solvent extracted soybean meal pellets (protein) were weighed into paper bags and put into a tray with individual compartments. Each bag had a number corresponding to the brand number of the sheep to receive it. The monosodium phosphate was weighed into bottles, dissolved in water, and fed as a drench. Experimental results have shown that such individual feeding can be practiced on the range without adversely affecting the performance of the sheep (Harris *et al.*, 1952).

Supplementary feeding was started November 25, 1947 and continued until April 28, 1948. The sheep then left the winter range and trailed from Wah Wah Valley to the Salina Canyon foothill spring range, a distance of 150 miles. The ewes were fed supplements every second day on the trail until they reached the foothill ranges May 14. To accomplish this, the portable pens were moved to a new location every second day. The ewes reached the lambing grounds on May 16 and lambing started May 23.

During the winter, the ewes were weighed approximately every 28 days and also at shearing time before starting on the trail, and at the end of trailing (figure 11). The lambs were weighed at birth and at weaning time.

To determine if the ewes were deficient in phosphorus or vitamin A and to note the effect of feeding the supplements, blood samples were taken February 13 and 14, from two-thirds of the ewes selected at random within each treatment. Vitamin A was determined by the method of Dann and Evelyn (1938). Blood hemoglobin was determined by the acid hematin method of Cohen and Smith by using a Fisher electrohemometer as outlined by Hawk, Oser, and Summerson (1937). Inorganic plasma phosphorus was determined by the modified Fiske and Subbarow method as given by Kock (1935). We used a field laboratory (Harris *et al.*, 1952).

The grease weight of the fleeces of all the ewes was obtained at shearing time on April 21 and 22. Side samples were scoured to determine yield of clean wool. Staple length was determined by making three measurements of the side samples.

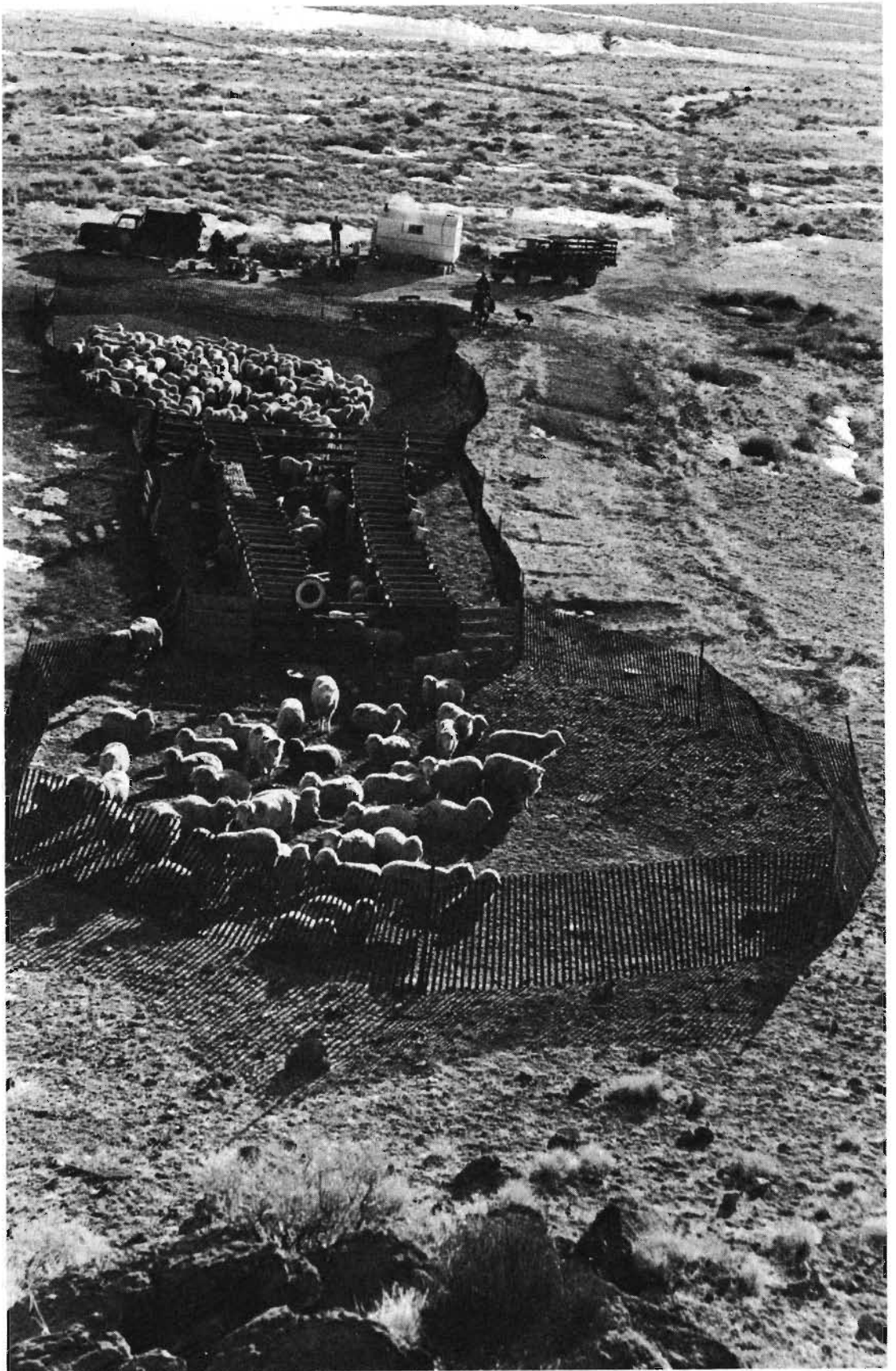


Figure 10. Individual portable pens for sheep. Holding corrals are on each end. Pens are moved every 2 to 3 weeks. Trays are used to hold each sheep's feed. Sheep are fed in buckets. We have also devised portable pens for cattle (Harris et al., 1957).

Live weight changes

With the exception of ewes receiving the high level of monosodium phosphate, all supplemented ewes maintained weight through the winter better than unsupplemented ewes (figure 12). Ewes receiving the low level of barley maintained their weight considerably better than the controls but not nearly as well as the other groups.

While the ewes were being trailed from April 28 to May 14, supplements had little effect on gains. During this time the ewes had access to green, growing range forage. The most critical period on the winter range was from mid-February to the first part of April. To prevent death loss during the periods of stress on the trail such as inclement weather, it is important that ewes be fed during January and February. However, if a supplement is fed on the trail, a low protein supplement should be fed because the range forage is usually growing at this time and is high in protein.

The ewes body weight from November 17 to May 14 represents the developing lamb as well as the body weight of the ewe. Weight gains decreased as age increased after animals reached 1 year of age. Older

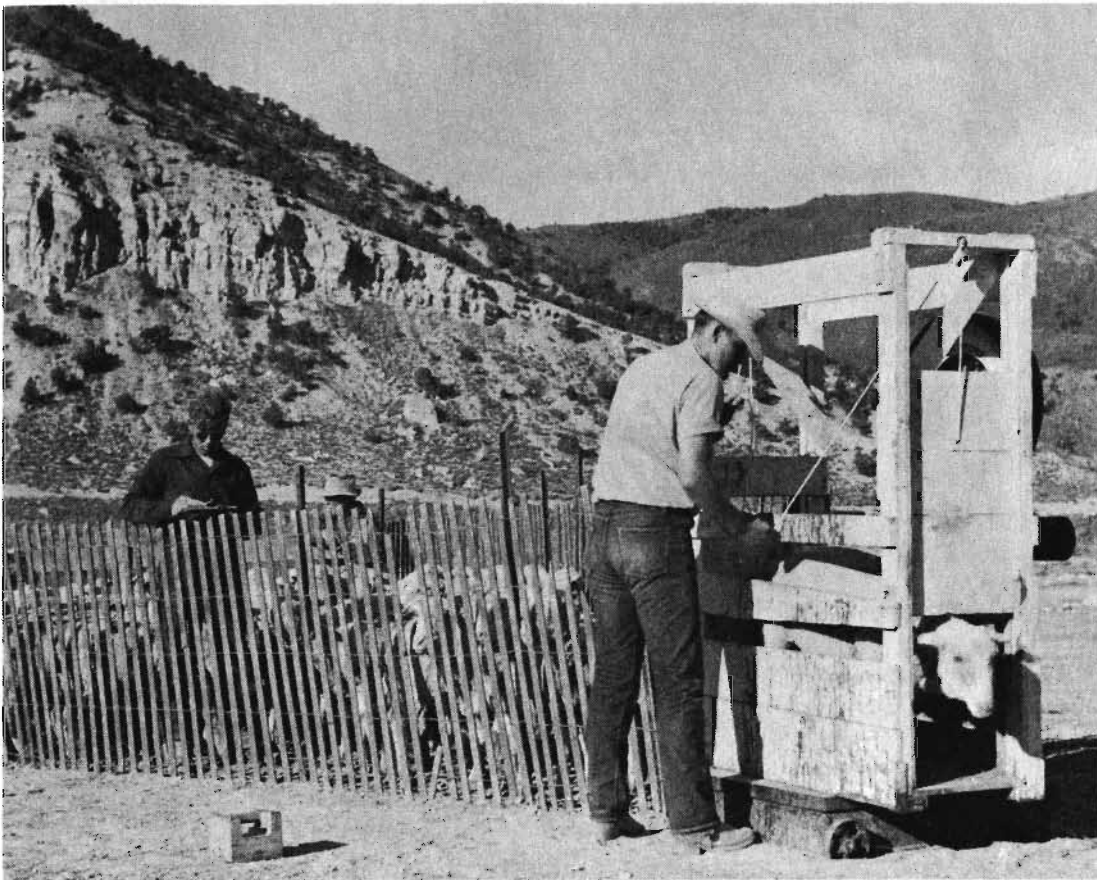


Figure 11. Portable weighing crate and platform scale. Back door of weighing crate is raised as front door is raised. This entices sheep to enter crate.

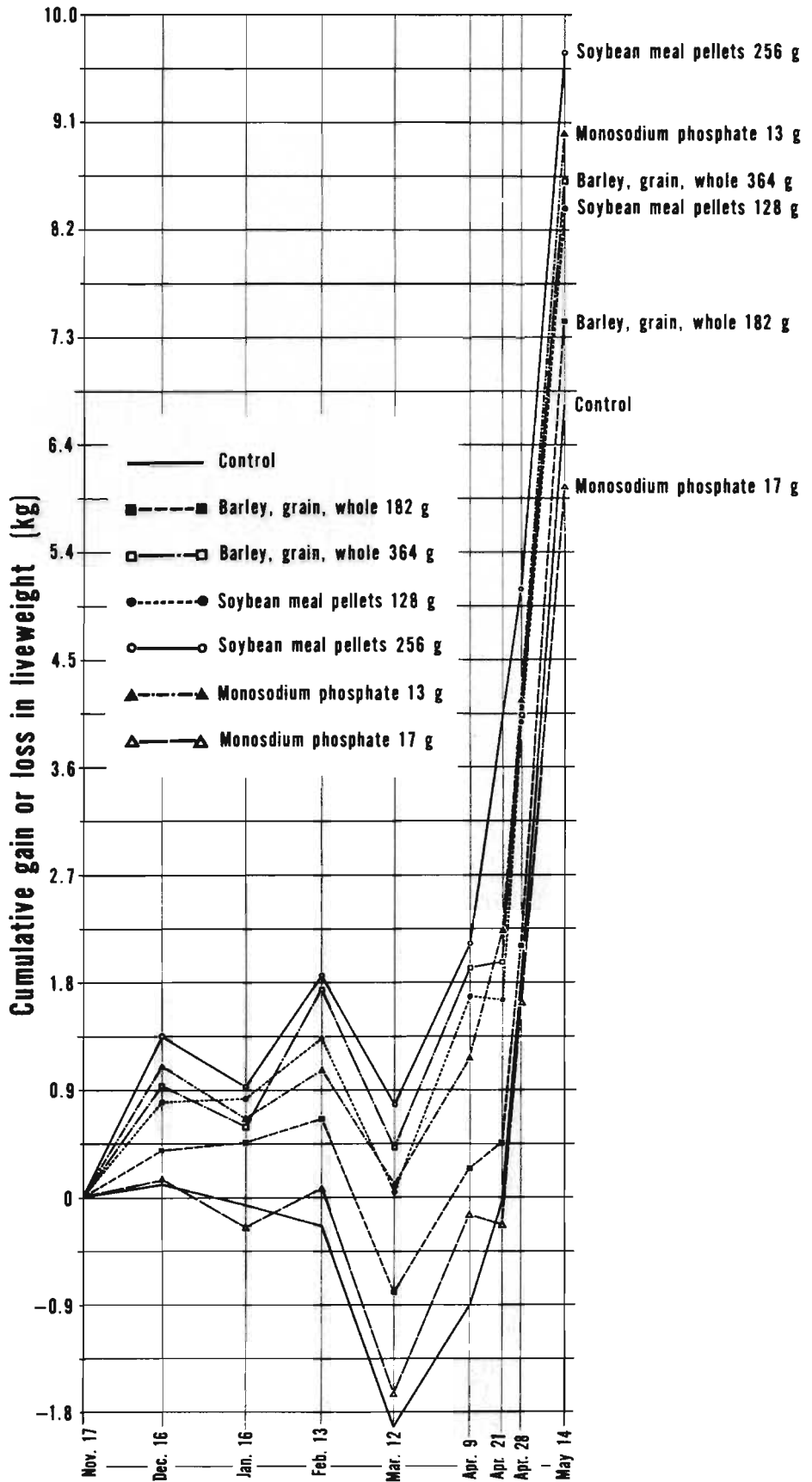


Figure 12. The cumulative gain or loss in live weight of ewes fed various quantities of supplements every second day.

ewes were subject to excessive weight losses during cold and stormy weather and recovered more slowly than younger animals.

Blood chemistry

The control ewes had less phosphorus in their blood than any group receiving supplements. There was no significant difference among the groups receiving supplements. Ewes receiving the high level of phosphorus had less hemoglobin than those receiving the low level (tables 6 and 7). Supplements had no significant effect on vitamin A in the blood plasma. Hemoglobin tended to increase with the age of the ewe up to 5 or 6 years of age; then there was a decline. The level of blood phosphorus decreased as the ewes became older. The average values

Table 6. Values for blood hemoglobin, plasma inorganic phosphorus, and plasma vitamin A for ewes fed various supplements from November 25 to February 13

Supplement	Level of supplement each 2nd day	Hemoglobin Phosphorus		Vitamin A
		mg/100 ml	mg/100 ml	μ /100 ml
Control	.....	11.6	3.14	19.4
Barley, grain	182 g	11.3	3.41	20.0
Barley, grain	364 g	15.5	3.56	17.9
Soybean meal	128 g	11.4	4.08	20.2
Soybean meal	256 g	11.7	3.62	22.3
Monosodium phosphate	13 g	11.6	4.02	19.2
Monosodium phosphate	17 g	10.5	3.96	16.7

Table 7. Analysis of variance of hemoglobin, plasma inorganic phosphorus, and plasma vitamin A for data in table 6

Source of variation	Degrees of freedom	Mean squares		
		Hemoglobin	Phosphorus	Vitamin A
Treatments	6	1.97	1.4862	38
Control vs. treatment	1	0.90	4.1783*	0
Kinds of supplements	3	1.34	1.6568	68
Barley, grain 1 vs. 2	1	1.34	0.1261	26
Soybean meal 1 vs. 2	1	0.30	1.2788	28
Monosodium phosphate 1 vs. 2	1	0.77	0.0198	40
Age	5	7.15*	3.4936**	66
Treatment x age	30	6.41**	0.8990	41
Error	42	1.64	0.8499	44
Total	83			

*Significant at 0.05 level

**Significant at 0.01 level

were: lambs, 4.29 milligrams phosphorus per 100 milliliters; yearlings 4.26; 3-year olds, 3.75; 4-year olds, 3.32; 5- to 6-year olds, 3.38; and more than 6-years old, 3.11. The age of the ewes did not have any significant effect on vitamin A in the blood plasma.

Wool production

The high level of soybean meal produced significantly more clean wool than any of the other treatments (tables 8 and 9). The high level of phosphorus and the high level of soybean meal both produced significantly higher yields of clean wool than did the lower levels. The high and the low levels of barley gave about the same wool yields, both considerably higher than the controls. The high level of soybean meal produced longer wool than the low level. There was a decline in weight of clean wool and length of wool with age above 1 year. Lambs produced

Table 8. Weight of clean wool of ewes in six age groups fed three supplements at two levels compared to ewes receiving no supplement, November 25 to April 14

Treatment	Supplement fed each 2nd day	Lambs	Ages of ewes in years					Mean
			1	3	4	5 to 6	Over 6	
		Weight of wool for each age						
		kg	kg	kg	kg	kg	kg	kg
Control	.....	1.61	1.97	1.87	1.88	1.89	1.35	1.76
Barley, grain	182 g	1.79	1.92	1.89	2.31	1.72	1.39	1.83
Barley, grain	364 g	1.51	2.35	2.18	1.68	1.52	1.69	1.82
Soybean meal	128 g	1.58	1.76	1.74	1.83	1.83	1.50	1.71
Soybean meal	256 g	1.98	1.87	2.01	2.00	2.10	1.69	1.94
Monosodium phosphate	13 g	1.65	1.69	1.59	1.56	1.43	1.58	1.58
Monosodium phosphate	17 g	1.43	1.90	2.23	2.04	1.86	1.58	1.84
Means		1.64	1.93	1.92	1.90	1.77	1.51	1.78

Table 9. Analysis of variance of clean wool weights and length of wool

Source of variation	Degrees of freedom	Mean square	
		Weight	Length
Treatments	6	1.1268*	0.2536
Kinds of supplements	3	0.5229	0.0642
Barley grain levels	1	0.0038	0.2178
Soybean meal levels	1	2.3716*	1.0000**
Monosodium phosphate levels	1	2.8168**	0.1112
Age	5	3.3801**	2.4876**
Treatment x age	30	0.5609	0.1649
Error	102	0.3890	0.1263
Total	143		

*Significant at 0.05 level

**Significant at 0.01 level

slightly more wool than the ewes over 6 years of age and had wool about as long as the 3-year-old ewes.

Clean wool and grease wool were significantly increased by phosphorus and protein supplements. Barley alone increased the amount of wool only slightly.

Lamb crop

All ewes receiving supplements had a higher lamb crop than the controls with the exception of those fed barley (figure 13). The high level of soybean meal and the low level of phosphorus produced a larger lamb crop at docking time than the other feeds. However, animals receiving both levels of phosphorus and both levels of protein produced appreciably higher lamb crops at lambing than did the controls. The supplements did not affect the weaning weight of the lambs.

Comparison of experimental controls and controls in a large herd

The experiment described above is a fairly simple one; however, it did show that some of the classic procedures for conducting nutritional research could be used on the range. For example, it was found that sheep could be herded in a small group and could be fed individually on

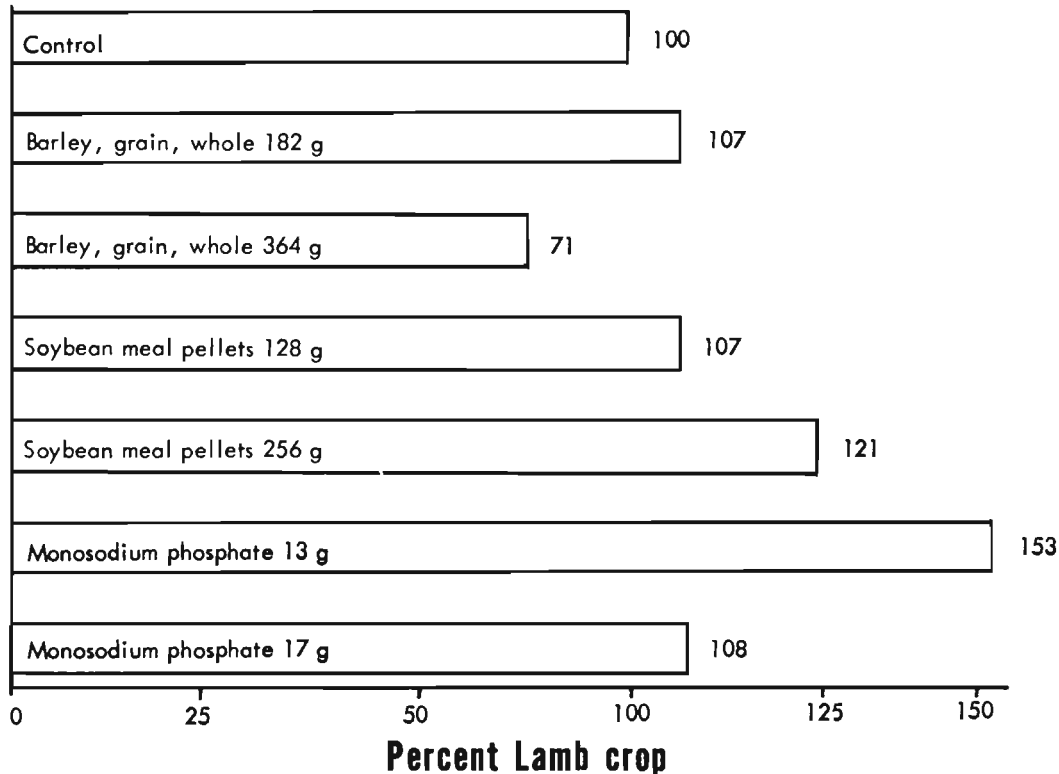


Figure 13. Percentage lamb crop of ewes fed three supplements at two levels compared to ewes receiving no supplement, November 25 to May 14.

the range. The handling of the sheep did not affect them adversely. To test this, we had a random sample of ewes in the regular large herd of 2,000 ewes to compare with our experimental controls. The data in table 10 shows that the experimental control ewes did as well as those in the large herd. When I was in Australia and Scotland a few years ago, I found that our individual feeding technique was being used in both countries.

In a later experiment, we used a factorial design and fed three levels of barley, three levels of soybean meal, and three levels of monosodium phosphate (Harris *et al.*, 1956). The results of this trial were similar to the ones described. The following conclusions and recommendations are based on both trials.

Conclusions and recommendations

Supplemented animals produced higher lamb crops than those not supplemented. Generally the low levels were just as effective as the high levels in increasing lamb numbers. Lambs and yearlings gained more than older animals. Ewes over 6 years old gained little weight during the winter. Two-, 3- and 4-year old ewes produced the heaviest fleeces. As the age of the ewe advanced beyond 5 years, the amount of wool declined. Ewes from 2 to 5 years old produced the most lambs per ewe bred. Old ewes produced less wool and less lambs and death losses were higher. In addition, these ewes consumed feed which otherwise could be used by younger and more productive ewes.

From these experiments, we found that range sheep go through cycles of inadequate and adequate nutrition. During summer they gain and in the fall and early part of winter they usually maintain their weight or gain slightly. During winter there is a critical period some time between January and April when inclement weather and sometimes poor

Table 10. Comparison of experimental controls and large herd of sheep

Item		1947		1948		1949		Average	
		Expt. controls	Large herd	Expt. controls	Large herd	Expt. controls	Large herd	Expt. controls	Large herd
Gain Nov. to May	kg	1.82	0.44	0.58	-0.17	1.56	2.58	1.32	0.95
Grease wool	kg	4.14	3.84	3.70	3.67	4.31	4.39	4.06	3.96
Scoured wool	kg	1.76	1.67	1.50	1.52	1.60	1.65	1.62	1.61
Staple length	cm	5.67	5.46	4.84	4.87	5.82	5.79	5.44	5.38
Lamb crop	%	114	104	92	78	89	100	98	94
Ewes lambing	%	82	88	70	66	79	77	77	77

range conditions cause excessive weight loss. As plant growth starts in early spring, they again gain rapidly. If conditions are severe, some supplement should be fed to prevent excessive weight losses during the winter. However, it would not be economical to feed supplements to even maintain the weight of the ewes during this period.

In the early National Research Council's recommendations for feeding ewes, the nutrient requirements were planned to have sheep lose weight in the spring and summer (lactation period) and gain weight during the winter (pregnancy period). Our range work has shown that western range ewes gain weight during the summer and lose weight during the winter. Using the results of our research, we now have a section on range nutrition in the latest National Research Council (1964) Nutrient Requirement Report on Sheep.

With the above thoughts in mind, our latest nutrient requirements for range ewes are shown in table 11. These requirements apply only to range sheep during the winter.

There was significant variation response to feeding in different years. Because of changing weather conditions, the sheep operator must exercise judgment and skill in feeding supplements to obtain maximum economic returns. A phosphorus supplement probably should always be fed on winter range since it can be supplied at nominal cost. The feeding of protein and energy should be determined by the condition of the sheep, the kind and amount of the forage available and climatic conditions. Observation showed that certain ewes, particularly those 2, 3, or 4 years of age stayed in good flesh and produced well on little supplemental feed. Supplementing all ewes in a band regardless of age and condition may not be the most practical for a rancher. It may be cheaper to separate the lambs, yearlings, old ewes, and those in poor condition and operate them separately.

Table 11. Suggested nutrient requirements for a 130 pound ewe for most efficient economic production on winter range of the Intermountain Region †

	Daily intake of dry matter		Digestible protein (dry basis)	Metabolizable energy (dry basis)		Phosphorus (dry basis)
	kg	lb	%	kcal/kg	kcal/lb	%
Range forage	1.50	3.30	2.6	1410	640	0.09
Supplement	0.13	0.29	24.9	2092	949	1.08
Requirement	1.63	3.59	4.4	1466	665	0.18

†When these requirements are used it is assumed that the ewes will graze on mountainous (National Forest) land during the summer.

Nourishing the Rumen Microorganisms

The demonstration in earlier experiments that animal performance could be improved by supplementary feeding of small amounts of phosphorus and protein (Harris *et al.*, 1956), raised several basic biological questions which were further investigated. A large population of bacteria and protozoa exists in the rumen and reticulum, the first two of the four stomach compartments of ruminant animals (figure 14). These microorganisms are a necessary adjunct to the digestive capacity of the host. Among other functions, they convert otherwise unavailable highly polymerized polysaccharides such as cellulose and pectins to volatile fatty acids which are used by the host as a source of energy. They also convert non-protein nitrogen materials in the plant and other compounds such as urea and ammonium salts to bacterial protein which, in turn, may be digested by the host animal to amino acids and utilized.

In view of the above facts, we designed an experiment to determine if the beneficial effects of supplementation could be the result of increas-

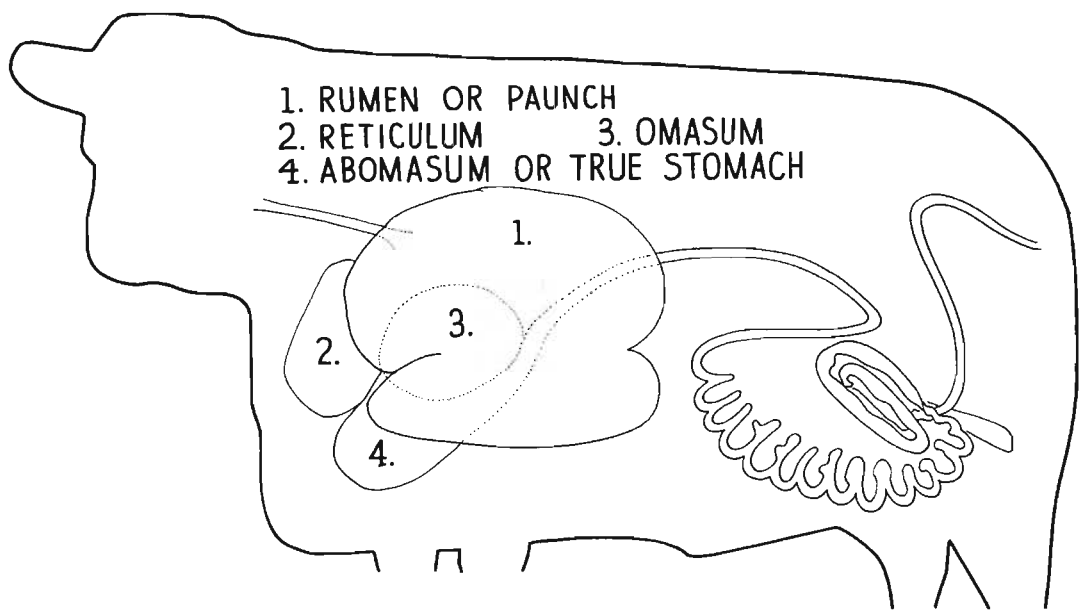


Figure 14. Ruminants have a four compartment stomach as shown in this schematic diagram. When a non-protein nitrogenous compound such as urea is fed to a ruminant the following takes place:

Urea plus urease (in rumen) \rightarrow ammonia

Ammonia + rumen juices + bacteria \rightarrow bacterial proteins

Bacterial proteins + enzymes in digestive tract \rightarrow amino acids which are absorbed and converted to meat, milk and wool

When a ruminant consumes cellulose, the following takes place:

Cellulose + bacteria in rumen \rightarrow butyric, propionic and acetic acids

These acids are absorbed and utilized as energy by the host animal.

ing the activity of rumen microorganisms by supplying additional nutrients to this symbiotic culture (Morris *et al.*, 1965). This was studied by using rumen-fistulated sheep on a typical winter desert shrub range (figure 1) on which the dominant species of shrubs were winter fat and shadscale and the grasses were Indian ricegrass and galleta grass.

The sheep were kept in a 259 hectare (1 section) pasture at the Desert Range Experiment Station. We developed a portable laboratory in a "Home on the Range" to handle many of the chemical determinations.

Experimental plan

The sheep were supplemented with 0, 3 grams, (0.0066 pound) or 6 grams (0.013 pound) of nitrogen from wheat gluten and 0, 2, grams (0.0044 pound) or 2.65 grams (0.0058 pound) of phosphorus from monosodium phosphate in a 3 x 3 factorial design. Rumen fluid samples were withdrawn at 0, 3, 6, 9, and 12 hours after the administration of the supplement and analyzed for phosphorus, ammonia, and volatile fatty acid content. Cellulose digestion was estimated by determining the loss of weight in digestion of cotton thread suspended in a Dacron chiffon bag in the rumen. Seven coils of thread 3 meters (9.8 feet) long were placed in the bag in the rumen at the beginning of a determination. One coil was removed after 24 hours in the rumen; thereafter, one coil was removed at each 72 hour interval until all seven coils were removed. A linear regression equation was computed for rate of cellulose digestion for each sheep.

The diet of the sheep was sampled by esophageal-fistulated sheep (figure 4). Dry matter intake and digestibility were calculated by the lignin-ratio technique. Metabolizable energy was determined by collecting total feces and urine (figure 5) and calculating methane as described above.

Results and conclusions

Phosphorus supplementation increased the concentration of phosphorus in the centrifuged rumen liquor (figure 15). The effect of a supplement of 2 or 2.65 grams (0.0044 or 0.0058 pound) of phosphorus as monosodium phosphate was still evident 24 hours after supplementation. At zero hours the level of phosphorus in centrifuged rumen liquor of unsupplemented sheep was less than 15 milligrams per 100 milliliters, whereas, the phosphorous supplemented sheep had levels of about 30 milligrams per 100 milliliters. Anderson *et al.* (1956) reported that 40 to 80 micrograms of available phosphorus per milliliter of fermenta-

tion medium met the requirements for *in vitro* cellulose digestion by rumen microorganisms, whereas, Hubbert *et al.* (1958), reported that additions of as much as 100 milligrams of phosphorus per milliliter did not depress *in vitro* cellulose digestion. Since both the control and supplemented sheep had rumen phosphorus levels in the range of these two reported values, it would be expected that phosphorus supplementation as practiced in this experiment would neither be beneficial nor deleterious to cellulose digestion.

The lower response in weight gain in sheep reported by Harris *et al.* (1956), when given 17 grams (0.038 pound) as compared to 13 grams (0.029 pound) of monosodium phosphate, was probably not caused by an excess phosphorus concentration which depressed cellulose digestion.

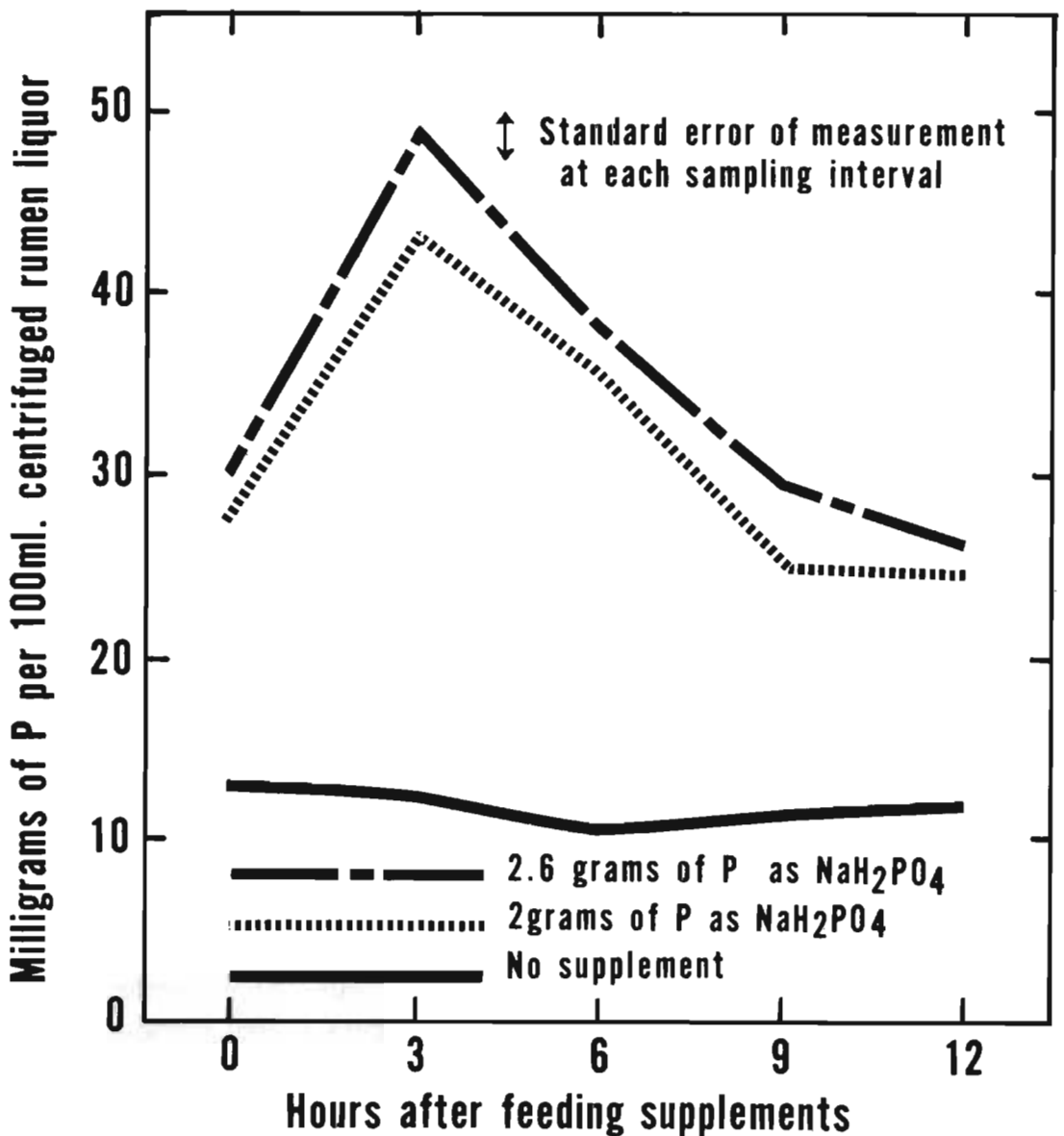


Figure 15. Changes in the total phosphorus of centrifuged rumen liquor from sheep on desert range forage with time.

Except for the effect of the gluten supplement on valeric acid concentration, neither the individual concentrations of the other acids, the molar percent of all acids, nor the level of total volatile fatty acids were influenced by nitrogen supplementation (table 12). The increase in valeric concentration was almost certainly a result of deamination of amino acid residues from the wheat gluten. El-Shazly (1952 a,b) and Annison (1954, 1956) demonstrated that proteins favor the formation of higher volatile fatty acids in the rumen. The enhancement of cellulose digestion *in vitro* by the addition of straight and branched chain volatile fatty acids has been demonstrated by Bentley *et al.* (1954, 1955), Bryant and Doetsch (1955), and Johnson *et al.* (1958).

The rumen-ammonia concentration curves for sheep fed the three levels of nitrogen supplementation paralleled each other and exhibited maximum concentration 9 hours after the beginning of grazing. Phosphorus supplementation did not affect rumen-ammonia concentration.

Neither phosphorus nor nitrogen supplements influenced the rate of cellulose digestion (as measured by the cotton thread technique), the apparent digestibility coefficient of cellulose, or gross energy.

It was shown earlier that the metabolizable energy was lower in range shrubs containing high amounts of volatile oils. In a recent report, Nagy *et al.* (1964) obtained volatile oils from the current annual growth of leaves, twigs, flowers, and shoots of big sagebrush, bud sage (*Artemisia spinescens*) and fringed sage (*Artemisia frigida*). In general, the

Table 12. The mean† liquor concentration and molar percent of steam volatile fatty acids

Acid	Hours after administration of supplement					Standard error
	0	3	6	9	12	
	rumen concentration, mmoles/l					
Valeric	0.9	1.2	1.1	1.2	1.0	0.018
Butyric	5.2	5.1	5.5	6.7	6.4	0.060
Propionic	16.6	15.2	16.1	20.1	19.7	0.149
Acetic	66.7	63.9	69.1	86.2	84.0	0.482
Total	89.4	85.4	91.8	114.2	111.1	0.668
	molar percent‡					
Valeric	1.1	1.4	1.2	1.1	0.9	0.018
Butyric	5.9	6.0	6.0	5.9	5.8	0.042
Propionic	18.6	17.9	17.6	17.6	17.8	0.072
Acetic	74.4	74.7	75.2	75.2	75.2	0.082

†Data derived from replications I and II, period I; and replications II and III, period II (n = 540)

‡Means for all acids differ significantly (P < .01) among hours

highest oil content was found in big sagebrush leaves and twigs (approximately 2 to 5 percent on a dry matter basis), followed by bud sage (1 to 2 percent).

The antibacterial action of the oils of big sagebrush was investigated on aerobic bacteria species as well as on rumen bacteria obtained from wild and domestic deer. Bacterial response varied significantly according to species of bacteria. There were significant differences in response to the oils of wild deer rumen microorganisms as compared with captive deer. This finding suggests that volatile oils in range plants may affect the way the microorganisms digest cellulose.

The mean daily forage dry matter and metabolizable energy intakes were 985 grams (2.17 pounds) and 1,223 kilocalories, respectively. Phosphorus supplementation significantly reduced the metabolizable energy intake from 1,303 kilocalories for control sheep to 1,086 kilocalories for sheep receiving 2.65 grams (0.0058 pound) of phosphorus per day.

Since this experiment did not demonstrate beneficial effects in improving the utilization of range forage, we are currently doing *in vitro* and *in vivo* experiments to determine how to nourish the microorganisms so the sheep can better utilize range forage.

Influence of Nitrogen Intake upon Rumen Function

Although nitrogen and phosphorus are required by the rumen microorganisms, it is difficult to study the effects of dietary additions of these nutrients because of the phenomenon of recycling. Ruminants secrete a large volume of saliva which contains considerable amounts of urea and phosphate salts. There is also appreciable diffusion into the rumen of these nutrients through the rumen wall. Thus materials are recycled into the rumen and augment the dietary supply of nutrients to the rumen microorganisms. This process has very direct bearing in studies on the nutritional adequacy of range plants and on the effects of supplementation.

Experimental plan

Since the host animal depends on the symbiotic relationship with the microorganisms, it is difficult to study the effects of nutrient deficiencies in the rumen without finding a way to nourish the host animal and the microorganisms separately. To accomplish this, we fed the host animal through a duodenal fistula (figure 16) and varied the diet to nourish the microorganisms in the rumen.

In one experiment to study the above principles we used Columbia wethers. They were housed in our metabolism building and confined in individual pens with slatted hardwood floors, feed mangers and water bucket. Water was supplied *ad libitum*. Canvas bags were attached to the sheep by light leather harnesses to catch the feces so digestion coefficients could be determined.

During March, April and May, the temperature within our metabolism building ranged from 7 to 15 C (45 to 59 F), then increased

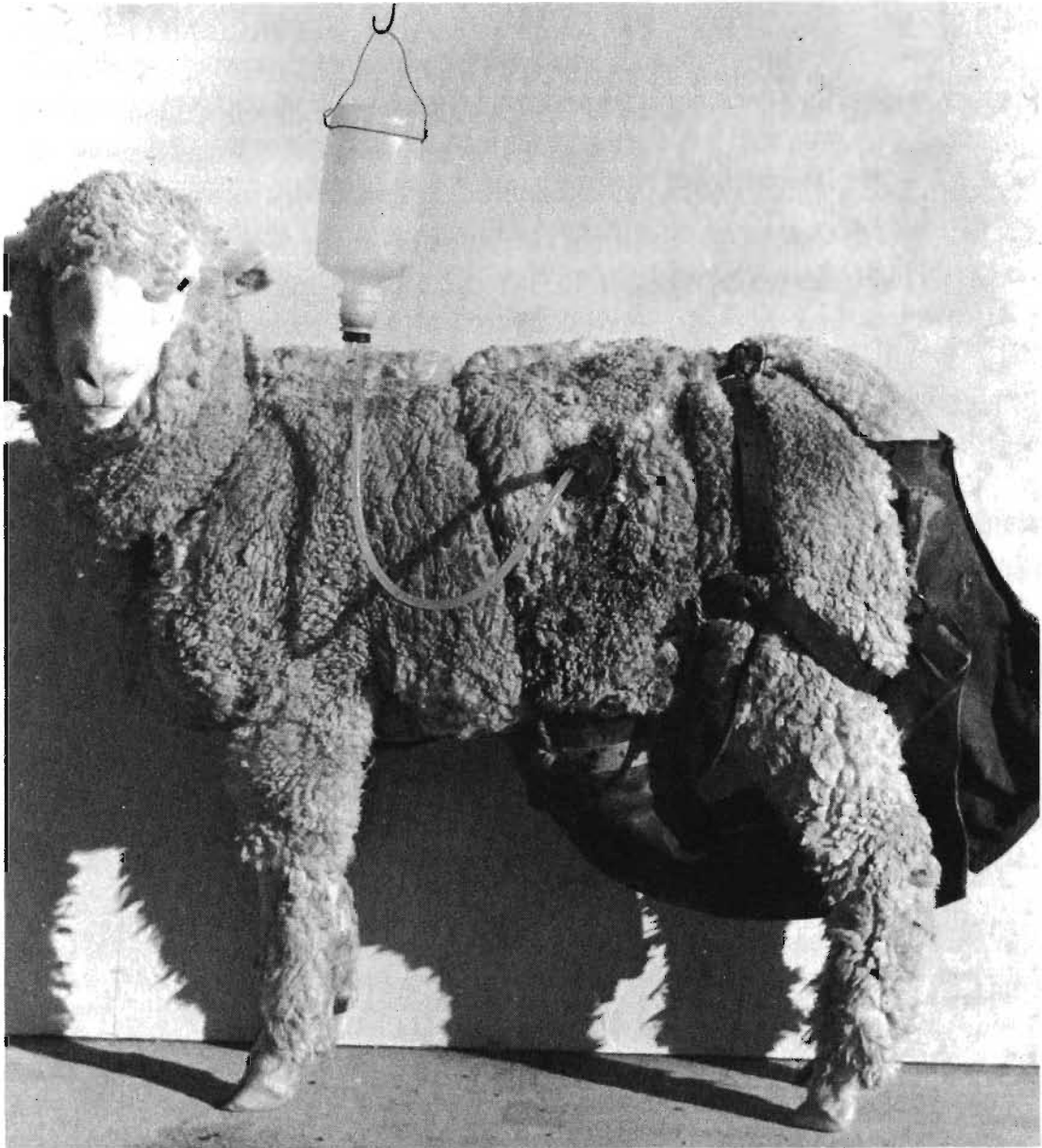


Figure 16. This sheep is equipped with a duodenal fistula, a urinal, and a feces bag. Casein is being introduced through the duodenal fistula. This makes it possible to nourish the host animal through the duodenum. The diet may then be varied so the nutrient requirements of the rumen microorganisms may be determined. When the feces and urine are collected, digestion coefficients and metabolizable energy may be determined.

gradually to 25 C (77 F) at the end of the experiment in August. There was little temperature variation in the semi-basement during the winter months.

The basal diet is shown in table 13. The nitrogen content of this ration was varied by adding casein (15 percent nitrogen) and urea (42.6 percent nitrogen), each supplying one-half the added nitrogen. The initial ration contained a total of 12.2 grams of nitrogen and thereafter the nitrogen intake was reduced each second week by decreasing each nitrogen source by 10 percent. The other constituents remained constant, but the dry matter intake was slightly reduced (range 824 to 797 grams per day). The starch, sugar, molasses, casein, and urea were dissolved or suspended in water, then mixed with the straw and minerals in a dough mixer. This mixture was then put into a polyethylene dish and presented to the sheep each morning at 9 a.m. It was eaten avidly.

Prior to the commencement of the experiment, the sheep were fed a ration containing 12.2 grams of nitrogen for approximately 1 month. The pre-feeding periods started March 8 and collections commenced March 17. Each of the following periods consisted of 2 weeks. Collections for digestion data were made over the last 7 days.

Table 13. Basal ration used in the experiment. The nitrogen was varied by replacing cornstarch with casein and urea

Constituents	Dry weight	Dry matter	Nitrogen	Crude fiber
	g/day	%	%	%
Oat straw, alkali-treated †	550	87.8- 94.1	0.41-0.54	55.5-59.1
Cornstarch	125	88.4- 91.0	0.02-0.09	-
Sugar (sucrose)	100	99.8-100.0	-	-
Sugarcane molasses	50	70.2- 76.3	0.66-0.69	-
Mineral mix†	30	100.0	-	-
Water‡				

†Bales of oat straw (*Avena sativa*) were placed on wire sling and totally immersed in cold 1.5 percent (weight per volume) sodium hydroxide. The straw was then lifted out, drained for a few minutes, placed in another tank and washed thoroughly using an automatic siphon which gave 5 to 6 changes of washing water per hour. Alkali free conditions were obtained in 18 to 20 hours. The straw was then drained, dried for 48 hours in a forced draft at 55 C and put through a chaff cutter.

‡The mineral mix consisted of the following: (in percent) NaCl, 40; CaCO₃, 17; Ca₂HPO₄, 20; MgSO₄.7H₂O, 12; KCl, 8; and trace elements, 3. The trace element mixture consisted of: (in grams) FeC₆H₅O₇.3H₂O, 150; CuSO₄.5H₂O, 60; MnSO₄, 9; KI, 1.5; CoCl₂.6H₂O, 6; ZnCO₃, 15; Na₂SO₄, 1008.5; Na₂SeO₄.10H₂O, 1.35. The trace element mixture supplied the following amounts in the daily ration: (in milligrams) Fe, 20; Cu, 10; Mn, 2; I, one; Co, one; Zn, 10; S, 166; and Se, 0.2.

‡The constituents were mixed with 400 ml of water.

Supplementation of the diet by supplying the sheep with casein through the duodenal fistula commenced after the third period. The purpose of this supplementation was to bypass the rumen and supply the host animal with nitrogen. As the nitrogen supplementation through the duodenal fistula was increased the nitrogen fed in the diet was decreased. This in effect produced a nitrogen deficiency in the rumen so that the symbiotic relationship of the microorganisms in the host animal could be studied.

The cotton thread technique was used to study the digestion of cellulose in the rumen. Rumen samples were taken before feeding at 9 a.m. then at 11 a.m., 1, 5 and 9 p.m. on Wednesdays and Thursdays of the collection week. These samples were taken from directly below the rumen fistula by means of a 15-millimeter bore glass tubing using gentle suction. Approximately 75 milliliters were collected on each occasion. The animals became so accustomed to sampling that they did not stand up if they were lying down or cease ruminating during the process.

Results and conclusions

The dry matter intake and rate of eating of the sheep supplemented by the duodenum remained almost constant throughout the range of diets fed, in which the nitrogen varied stepwise from 12.2 to 2.5 grams per day. The dry matter intake and the rate of eating of the unsupplemented sheep, in contrast, were both greatly reduced when the nitrogen intake was decreased by 6 grams per day.

On the basis of differences in data between the supplemented and unsupplemented sheep, it was estimated that at least 3.5 grams of nitrogen per day were recycled to the rumen.

As the amount of nitrogen in the diet decreased the rate of cotton thread digestion in the rumen decreased. In figure 17 is shown the relationship of the percentage of cotton thread remaining (z), against nitrogen intake (y), and days in the rumen (x) for sheep 474, 454 and 455. The regression $(z) = 114.9 - 0.494x^2 - 1.8xy$, relating these three factors, is highly significant ($P < .001$).

The concentration of ruminal bacteria, as shown by direct count, was positively ($P < .001$) correlated with the nitrogen intake, both before and 8 hours after feeding; more than a tenfold decrease occurred within the range of nitrogen intake fed.

The changes in bacterial concentration were correlated significantly with cotton thread cellulose digestion (figure 18). It is concluded that

within the system examined, where close control was attained over recycled nitrogen and total intake, and hence substrate concentrations, the direct count of ruminal microorganisms reflects the functional capacity of the rumen.

This experiment outlines a classic technique for feeding the host animal through the duodenum while various other supplements may be administered to study how to best nourish the microorganisms. We believe this technique and modifications of it might be used to do basic research on how to nourish the microorganisms so sheep or cattle may utilize more of the range forage they consume.

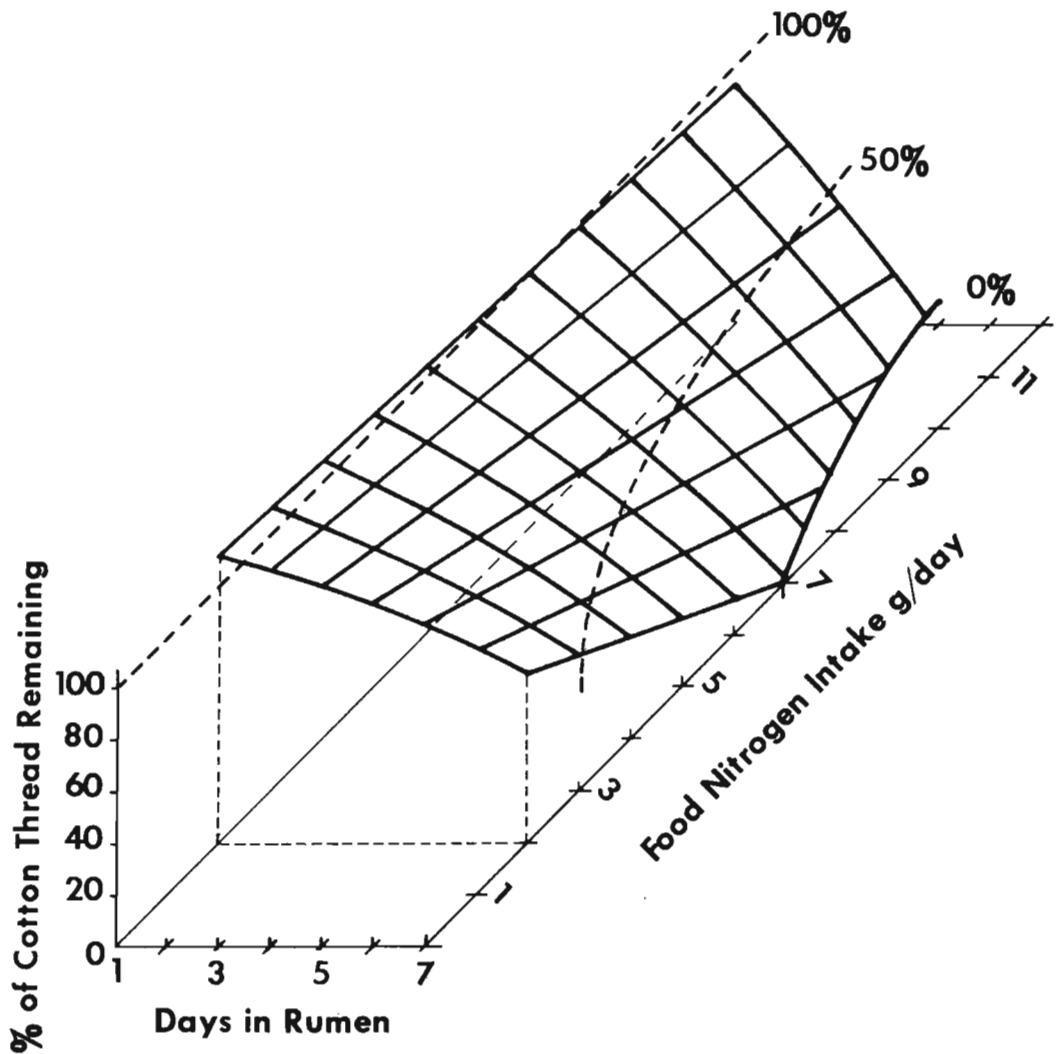


Figure 17. The relationship between loss of cotton thread cellulose and the nitrogen intake (see text for regression).

UTILIZATION OF RESEEDED GRASSES IN AN ARID REGION

Grazing Reseeded Grasses in the Spring

Winter grazing areas or supplies of hay are often depleted before native range areas are ready to graze in the spring. Because of this, late winter and early spring are the most critical times for livestock feed in the Intermountain region. Often cattle and sheep are in thin condition this time of year. Because of these facts, early spring range is needed. To develop this kind of range, we conducted an 11-year study (1948-1958) of grazing crested wheatgrass by cattle at Benmore, Utah (Frischknecht and Harris, 1968).

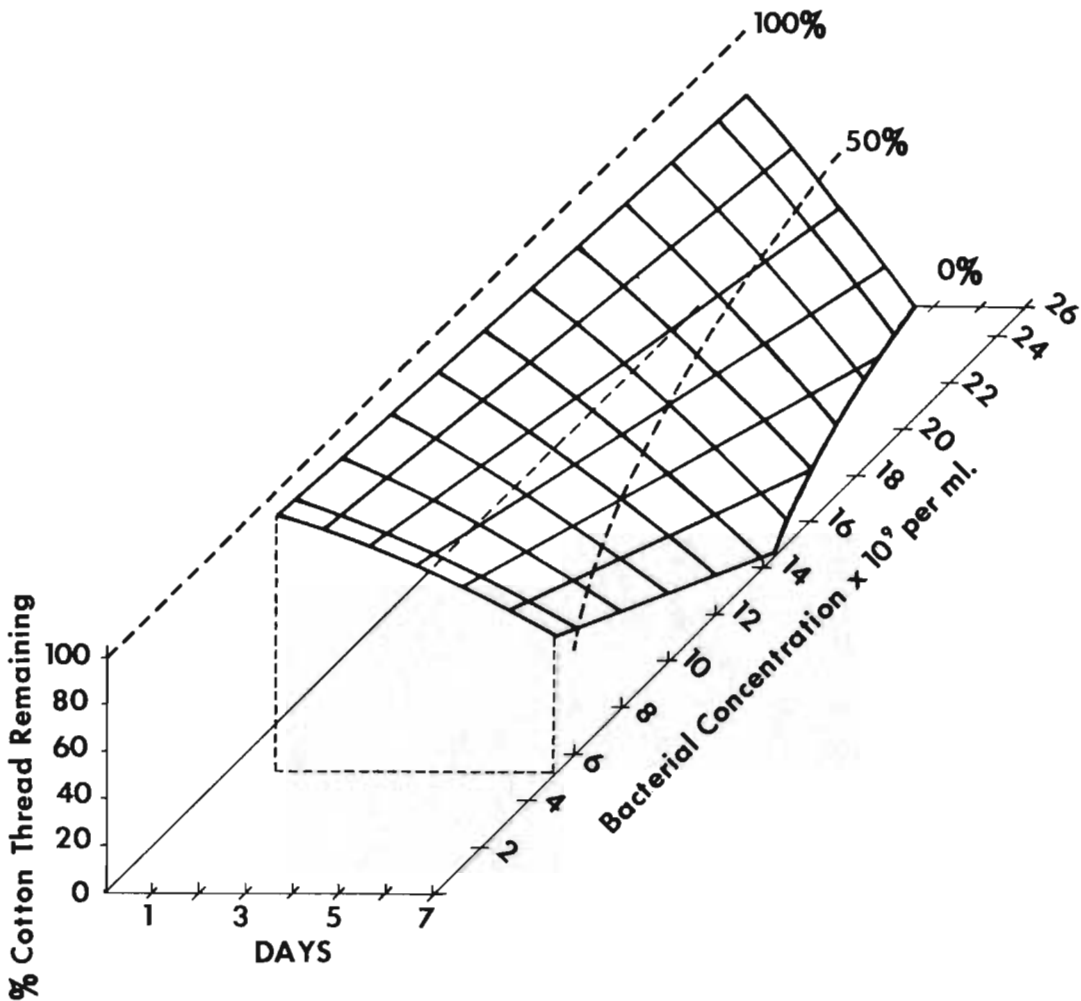


Figure 18. The regression of cotton thread remaining (z) on days (x) x bacterial concentration y , $z = 113.46 - 0.47x^2 - 0.88xy$, showing the quantitative relationship between bacterial concentrations and the digestion of cotton thread cellulose.

Experimental area

The Benmore area was named for two early Utah families, the Bennions and the Skidmores. They and other pioneers in the valley, impressed by the abundance of native grasses, grazed their stock on the range the year around when snow conditions permitted. The area was later planted to dryland wheat. After several years, it was found that this was unprofitable and in 1934, the land was purchased by the Federal Government. Twelve hundred ninety-six hectares (3,200 acres) were set aside as an experimental area in the late 1930's. Twenty-eight 40.5-hectare (100-acre) pastures were fenced, seeded to grass, and water piped to each.

The area is considered to be a spring and fall range. It is bounded on the north by salt desert winter range and on the south by the mountainous summer range of the Sheep Rock Mountains. The south end of Rush Valley, where the range is located, is gently sloping though broken by shallow, intermittent stream channels. The elevation is approximately 1,768 meters (5,800 feet), and the average annual precipitation is about 300 millimeters (12 inches). Soils are mainly clay loams with generally small amounts of gravel in some locations.

At the start of the experiment, the grass stands were about 12 years old. Crested wheatgrass comprised about 95 percent of the forage, with minor amounts of western wheatgrass, bulbous bluegrass (*Poa bulbosa*), cheatgrass, squirreltail grass, and several forbs. Big sagebrush and rubber rabbitbrush were present in varying amounts but were seldom eaten by cattle in the experimental pastures.

Experimental plan

We used three intensities and four methods of grazing in two treatment replications (table 14) to determine the best management practices to graze this reseeded crested wheatgrass range. The intensities of grazing are shown in figure 19.

The classes of cattle used to graze the pastures were: yearlings, dry cows and steers over 1 year of age, pregnant cows calving in the pasture (for calculating gain of this class the gain in weight of the calf was added to the gain in weight of the cow), lactating cows, and calves entering the pasture with the mother cow. These cattle were furnished by about a dozen ranchers of the Vernon Cattlemen's Association. The cattle were put in the corral overnight, then weighed at random, and put into each pasture. Before each weighing, they were put in the corral and shrunk overnight.

They were identified with a number on a chain which was put around their necks. We like this method of identification because the number on the chain can be read in the pastures.

Changes in the vegetation were observed and recorded on 40 permanent plots per pasture. These plots were 0.89 square meters (9.6



Figure 19. Crested wheatgrass being grazed at three intensities for approximately 60 days during the spring grazing season: (A) light (53%), (B) moderate (65%), and (C) heavy (80%)

Table 14. Experimental design to compare three intensities of grazing and four methods of grazing

Method of grazing	Intensity of grazing			Total number pastures to compare
	Light 53%	Moderate 65%	Heavy 80%	
Total I and II †	total number pastures			
Rotation	2	2	2	6
Continuous	2	2	2	6
Delayed 10 days	2	2	2	6
Removed 10 days early	2	2	2	6
Total pasture compared	8	8	8	24

†The twelve pastures with the highest carrying capacity were assigned at random to replication I and the remaining 12 pastures were assigned at random to replication II. Approximately 250 head of cattle were assigned at random to each block of pastures. Each pasture contained 100 acres.

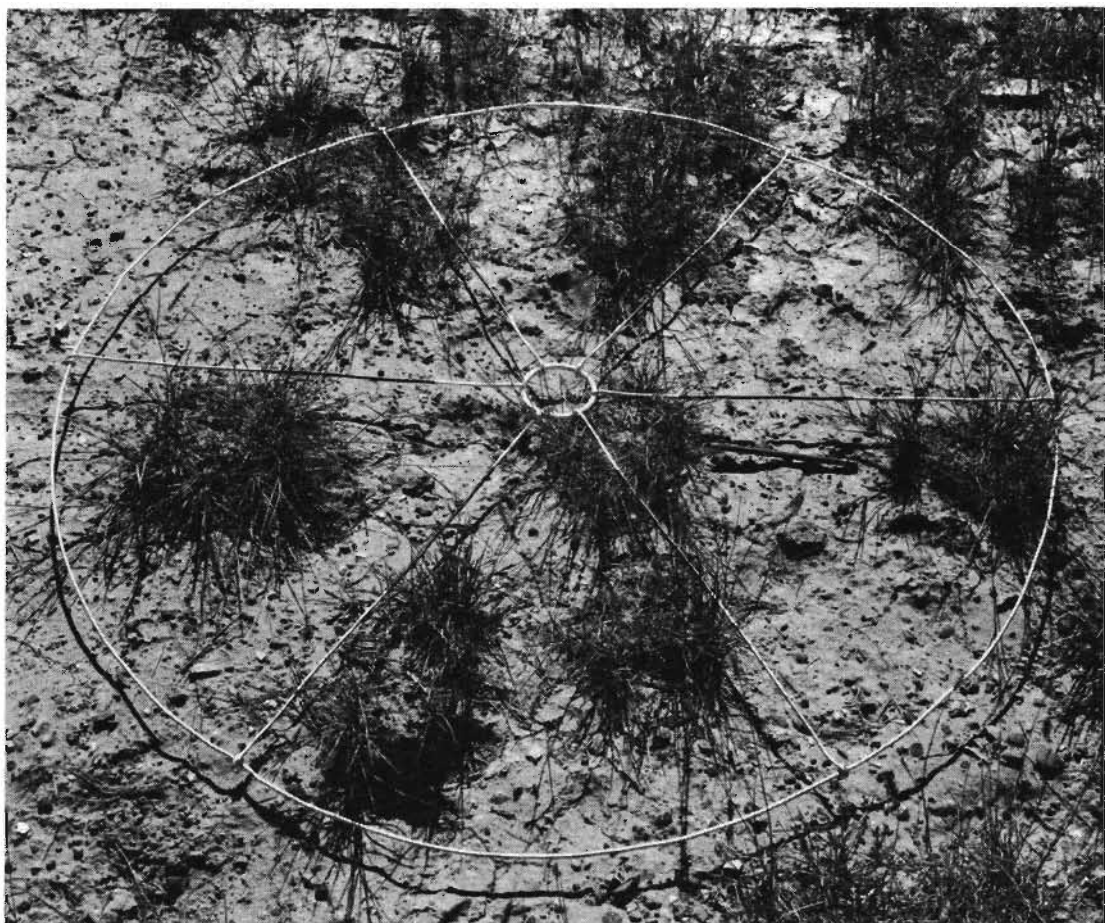


Figure 20. Wire hoop encircling 0.89 square meter (9.6 square feet) was divided into sixths by crosswires to facilitate the recording of data on crested wheatgrass and other herbaceous species. Colored tape on crosswires, corresponding to subdivisions of 93 square centimeters (0.1 square feet), 465 square centimeters (0.5 square feet), and 930 square centimeters (1.0 square feet) within each 1488 square centimeter (1.6 square foot) section, facilitated estimating grass basal area to the nearest 93 square centimeters. Inner ring maintained accurate centering over plot markers.

square feet) in area. Wire hoops segmented radially into sixths (figure 20) facilitated taking the following kinds of data on herbaceous species: (1) basal area to the nearest 93 square centimeters (0.1 square foot), an adaptation of the "square foot" method described by Stewart and Hutchings (1936); (2) numbers of plants by two sizes — less than 2.54 centimeters (1 inch) crown diameter and 2.54 centimeters and larger; (3) numbers of ungrazed or lightly grazed "wolf" plants. These data were recorded after grazing in the even numbered years from 1948 through 1958.

Every year a record of forage utilization on the permanent plots was taken after the final spring grazing by using the ocular estimate-by-plot method (Pechanec and Pickford, 1937). These data included the amount of remaining herbage, percentage of utilization, and stubble height. Yields of grass on each plot were calculated from estimates with amount left in percentage utilization. About 200 wire cages, each covering an area slightly more than 0.89 square meters (9.6 square feet) were distributed over the 24 pastures as guides in estimating utilization (figure 21). Some caged and some grazed plots were clipped during the grazing season to determine the progress of growth and utilization. Others were clipped at the end of the season prior to making the utilization survey of each pasture. In the even numbered years, the invasion of big sagebrush and rubber rabbitbrush was recorded. At the beginning of the

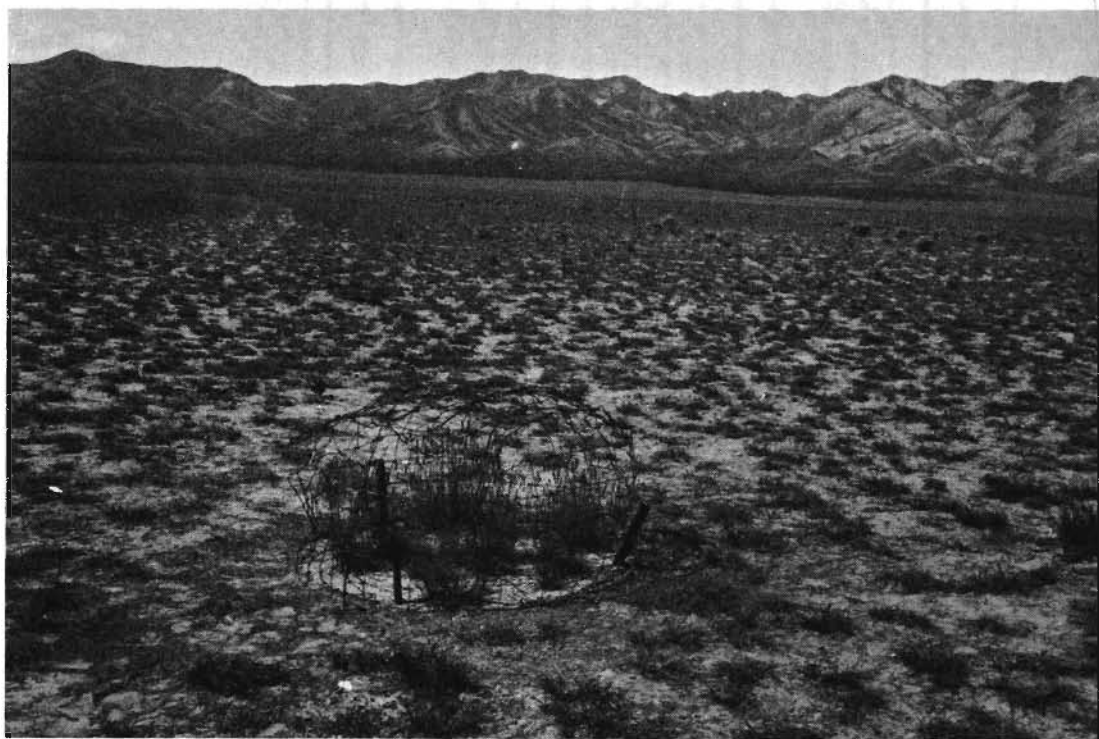


Figure 21. Wire cage encompasses an area slightly larger than 0.89 square meters (9.6 square feet) to protect samples of ungrazed vegetation for comparison with grazed plots.

studies in 1948 wherever either of these species occurred on a permanent 0.89 square meter (9.6 square feet) plot, a 9.29 square meter (100 square feet) circular plot was superimposed for taking brush data. The data included (1) the counting of plants in two size classes — less than 10.2 centimeters (4 inches) high and 10.2 centimeters or more in height, and (2) estimating herbage yields in kilograms per acre.

In 1947 the pastures were all grazed at a uniform rate to establish the carrying capacity. These data were later used in covariance analyses to correct for differences in grazing capacity when calculating the total cattle gain per acre. The correcting of the data greatly reduced the experimental error (Harris, 1959).

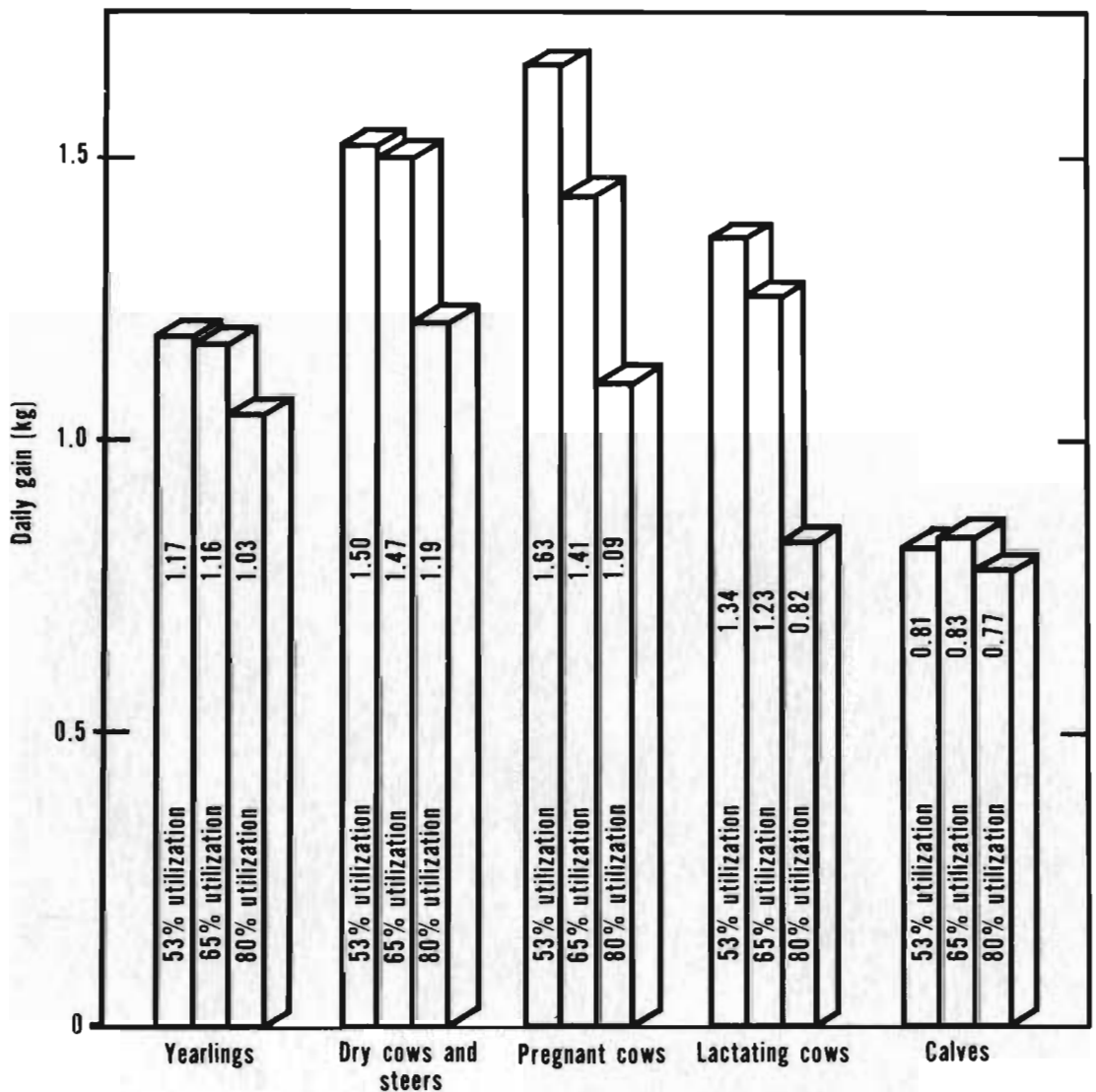


Figure 22. Heavy grazing (80% utilization of grass) produced lowest daily gains for all classes of animals. Differences between light (53%) and moderate (65%) grazing were important only for lactating and pregnant cows.

Results and conclusions

Differences in daily gains of cattle were much greater between the 80 and 65 percent intensities of grass utilization than they were between the 65 and 53 percent intensities. Average daily gains for the three utilizations for the 11 years were:

Percent Utilization	Gains
53	1.29 kilograms (2.84 Pounds)
65	1.22 kilograms (2.69 Pounds)
80	0.98 kilogram (2.16 Pounds)

All five classes of animals showed significantly reduced daily gains when spring utilization increased from 65 to 80 percent (figure 22.)

Per acre gains under heavy grazing were initially high but dropped below those for moderate grazing after the second year because it was necessary to reduce the number of grazing animals as forage yields declined (figure 23). After 6 years per acre gains for heavy grazing declined below those of light grazing. Moderate grazing provided the best long term production (19.7 kilograms or 43.4 pounds) per acre for the season compared to 18.0 kilograms (39.7 pounds) and 16.7 kilograms (36.8 pounds) for heavy and light grazing, respectively. Heavy

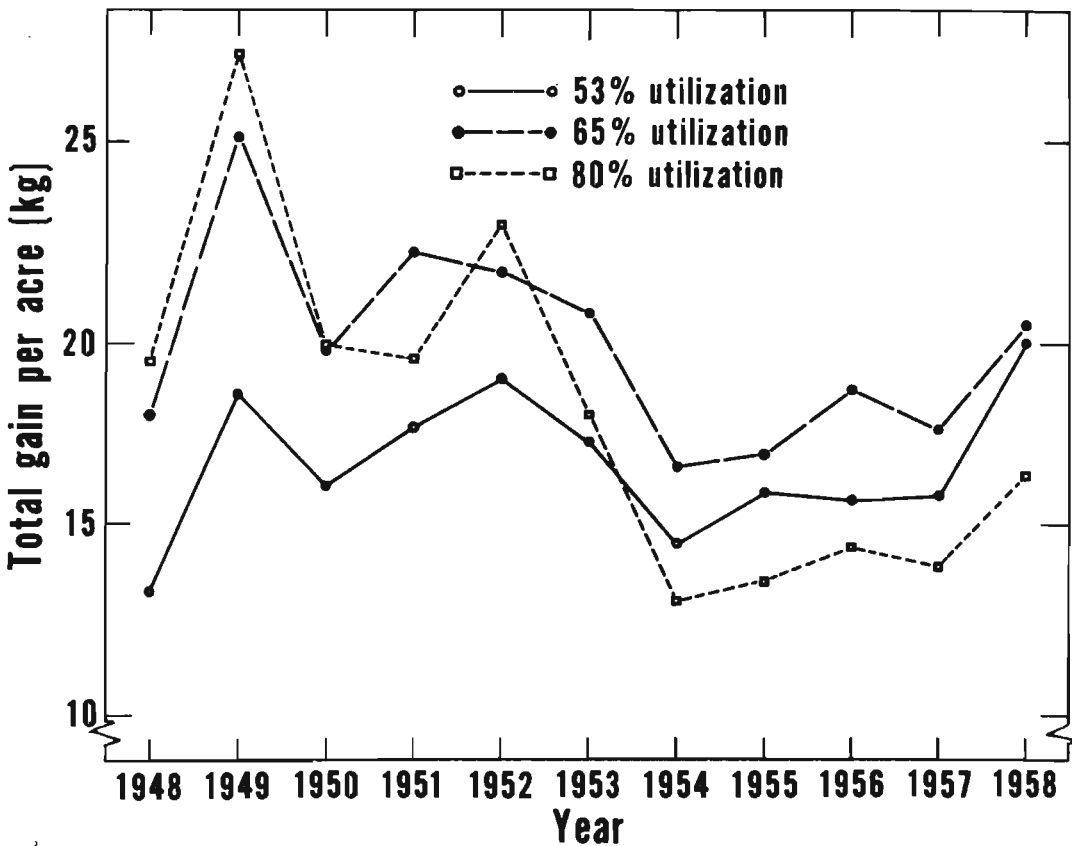


Figure 23. Continued heavy grazing resulted in decreased forage yields, hence decreased per acre gains of animals. Over the years moderate grazing produced the most gain.

utilization produced the lowest daily weight gains for all five classes of cattle — lactating cows, pregnant cows, dry cows and steers, yearlings and calves. Dry cows and steers, yearlings and calves gained as well under moderate utilization (65 percent) as they did under light (50 percent) utilization. However, pregnant cows which calved after grazing began, gained 13.6 kilograms (30.0 pounds) more on lightly grazed range than on moderately grazed range, and cows that already had a calf when grazing began, gained 6.4 kilograms (14.0 pounds) more on lightly grazed range than on moderately grazed range.

This shows that gain of lactating cows was the most sensitive indicator of grazing intensity, but since there were no important differences in gain of calves between light and moderate grazing, we concluded that crested wheatgrass may be grazed year after year in the spring by all classes of cattle at 65 percent utilization.

The grazing system shortened at the end provided the heaviest average daily gains for all classes of cattle. Highest gains per acre resulted from either rotation or delayed grazing. Rotation was superior 7 out of the 11 years of the test. Average gains per acre for the 11-years were as follows:

Methods of grazing	Gains
Rotation	19.5 kilograms (42.9 pounds)
Delayed-10-days	18.4 kilograms (40.6 pounds)
Continuous	17.7 kilograms (39.0 pounds)
Removed-10-days-early	16.9 kilograms (37.3 pound)

The above experiment shows that crested wheatgrass can fill an important need for early spring grazing in the Intermountain region. Under conditions at Benmore, elevation 1,829 meters (6,000 feet), rainfall 330 millimeters (13 inches), crested wheatgrass may be grazed from about April 20 to June 20 at an intensity that allows utilization of approximately 65 percent of herbage by weight. This intensity of use will give optimum cattle gains per acre and maintain grass production.

Two important principles brought out in this study are: (1) delaying the start of grazing in the spring will contribute toward maximum basal area and yields of grass; (2) shortening the grazing season toward the end of the spring growing season will contribute toward maximum plant numbers. Combinations of these principles can mitigate adverse effects of heavy grazing.

Although shrub invasion increased with intensity of grazing, in “wet” years some sagebrush and rabbitbrush will invade crested wheat-

grass even under no grazing, if a seed source is present. Sagebrush depresses grass yields more than rabbitbrush. It is likely that brush control will be required when sagebrush seriously limits grass production.

The following daily gains may be expected at 65-percent utilization for the various classes of cattle:

Class of cattle	Gains
Yearlings	1.18 kilograms (2.60 pounds)
Dry cows and steers	1.45 kilograms (3.20 pounds)
Pregnant cows calving in pasture	1.41 kilograms (3.10 pounds)
Lactating cows	1.22 kilograms (2.70 pounds)
Calves	0.82 kilograms (1.80 pounds)

Cows having suckling calves were the most sensitive animals to intensity of spring grazing.

The total gain per acre that may be expected at 65-percent utilization is approximately 19.5 kilograms (43 pounds). The rotation treatment produced the highest animal gain per acre in 7 out of 11 years; the delayed-10-days treatment produced the highest gains in the other 4 years. All systems of grazing, however, permitted sufficient gains on the cattle for efficient beef production providing the pastures were grazed at 65-percent utilization or less.

It takes about 2 hectares (5 acres) to graze a cow and a calf for the 60 day spring grazing season.

Grazing Reseeded Grasses from April to December

Because numbers of livestock permitted on the higher summer ranges have been reduced, it is important to obtain new sources of feed supply for the summer months. Crested wheatgrass has been used extensively for spring and fall grazing although it has been considered inferior to other grasses during the summer (Sarvis, 1941; Williams and Post, 1945; Barnes and Nelson, 1950; Cook *et al.*, 1956). This experiment was designed to determine the merits of feeding a protein supplement to cattle grazing crested wheatgrass during summer and fall, combined with regular spring grazing (Harris *et al.*, 1965).

We conducted our experiment on the Benmore experimental area already described. The purpose of our experiment was to determine if crested wheatgrass was a dependable source of forage for cattle from April to December. The experiment covered a 4-year period from 1961 to 1964.

Experimental plan

Ten treatments were used: early spring plus early fall; late spring; early summer; late summer; early fall; and late fall. All of the summer and fall treatments included grazing with supplement and without supplement. The treatments were assigned at random to three replications of ten 50-acre pastures. The early spring and late spring treatments were about 30 days in length while the summer and fall treatments were about 40 days in length.

Two yearlings and 8 to 12 cow-and-calf pairs were allotted at random to each pasture. Animals were shifted to new pastures at the beginning of each season, excepting that the three pastures grazed in early spring were also grazed in early fall.

Some shifting of animals was necessary to achieve the desired grass utilization of 60 to 70 percent. All animals were weighed individually after an overnight shrink in the corral before being placed in, or following removal from, a pasture. Cattle of Hereford breeding were provided by the Vernon Cattlemen's Association.

During summer and fall, half of the yearlings and lactating cows received in portable mangers the equivalent of 0.34 kilogram (0.75 pound) per day of a protein supplement on Monday, Wednesday, and Friday. The other half received no supplement. The supplement had the following percentage composition:

Soybean meal, solvent extracted, 44 percent protein	88.2%
Dicalcium phosphate	10.8%
Trace mineral salt	1.0%

Each 0.34 kilogram of supplement supplied 75 percent of the daily requirement of phosphorus.

All animals received rock salt during the spring periods, while during the summer and fall periods they received crushed salt in one side of a self feeder and one part trace mineral salt and one part dicalcium phosphate in the other half of the feeder.

Bulls were admitted to the pastures at the beginning of the late spring period. At the end of this period, part of the cattle were moved to the mountainous summer range (National Forest) south of the pastures. These cattle were rounded up and weighed at the beginning of the early fall period to provide data for comparison of pasture gains made on the higher summer range (National Forest).

Results and conclusions

Average daily gains for each season and precipitation data for the corresponding periods are shown in figure 24.

The gains of cows varied as a function of available green forage, this in turn being affected by the precipitation, except during late fall which was beyond the growing season. Calf gains did not change with available green grass since their gains depended on the milk supply of the cow.

Pastures which were grazed in early spring and again in early fall provided slight additional gains upon second grazing in 1962 and 1964 compared to pastures grazed only in early fall. In fact, gains for second grazing without supplement equalled or exceeded gains for single grazing with supplement. These years were dry and no summer or fall regrowth was produced. On the other hand, during the years of regrowth (1961 and 1963), early fall gains were higher for single grazing.

Gain per acre averaged highest for late spring and all spring grazing (figure 25). This corresponds to the period of maximum green forage. Substantial gains were also made during early summer. Average gains were slightly over 4.5 kilograms (9.9 pounds) per acre during late summer and early fall for cattle receiving supplement, while cattle without supplement gained only about half this amount. These differences were significant ($P < .05$). Late fall losses are attributed to the last two years, as explained under average daily gains.

Yearlings made substantial gains in all seasons except during late fall when they lost weight slightly (figure 26). They finished the entire

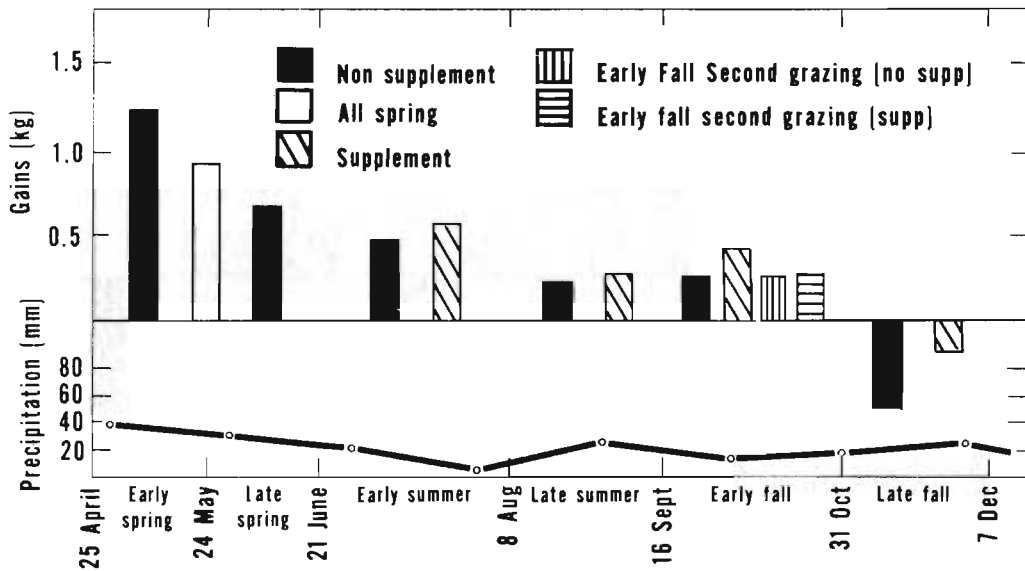


Figure 24. Average daily gains of all classes of cattle grazing crested wheatgrass at various seasons of the years 1962-64. The average precipitation for these same years is shown at the bottom of the figure.

grazing period with an average gain of 102 kilograms (225 pounds). Calves gained at a steady rate, finishing in October with an average gain of 113 kilograms (249 pounds). It may be concluded that yearlings and calves did as well on crested wheatgrass as on the National Forest, and supplementation provided no additional gain.

Of the three classes of cattle, only cows showed significant response to the supplement, making an average gain of 57 kilograms (126 pounds) as compared to about 23 kilograms (51 pounds) for non-supplemented cows. Cows on the higher range (National Forest) made comparable gains to cows receiving supplement on crested wheatgrass (figure 27).

In pastures where the grazing capacity was not reduced by big sagebrush, the stocking level in early spring averaged about 2 hectares (5 acres) per cow (with a calf) month. At this rate, cows with sucking calves ate the grass as fast as it grew. Again, in early fall the stocking level on pastures that had been grazed previously in early spring averaged about 2 hectares (5 acres) per cow month. Thus, the total grazing capacity of these pastures was about 1 hectare (2.5 acres) per cow month which was about equal to that of pastures in the other treatments. The only difference was that half the capacity was taken in early spring and the other half in early fall, rather than in one period.

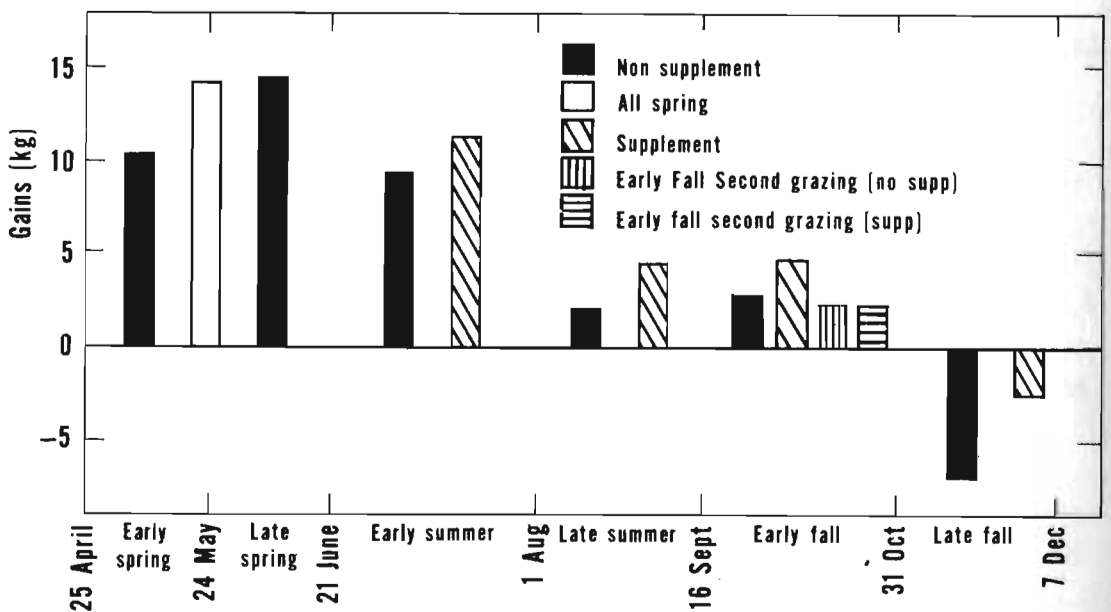


Figure 25. Total gain per acre for the cattle grazing crested wheatgrass at various seasons of the year.

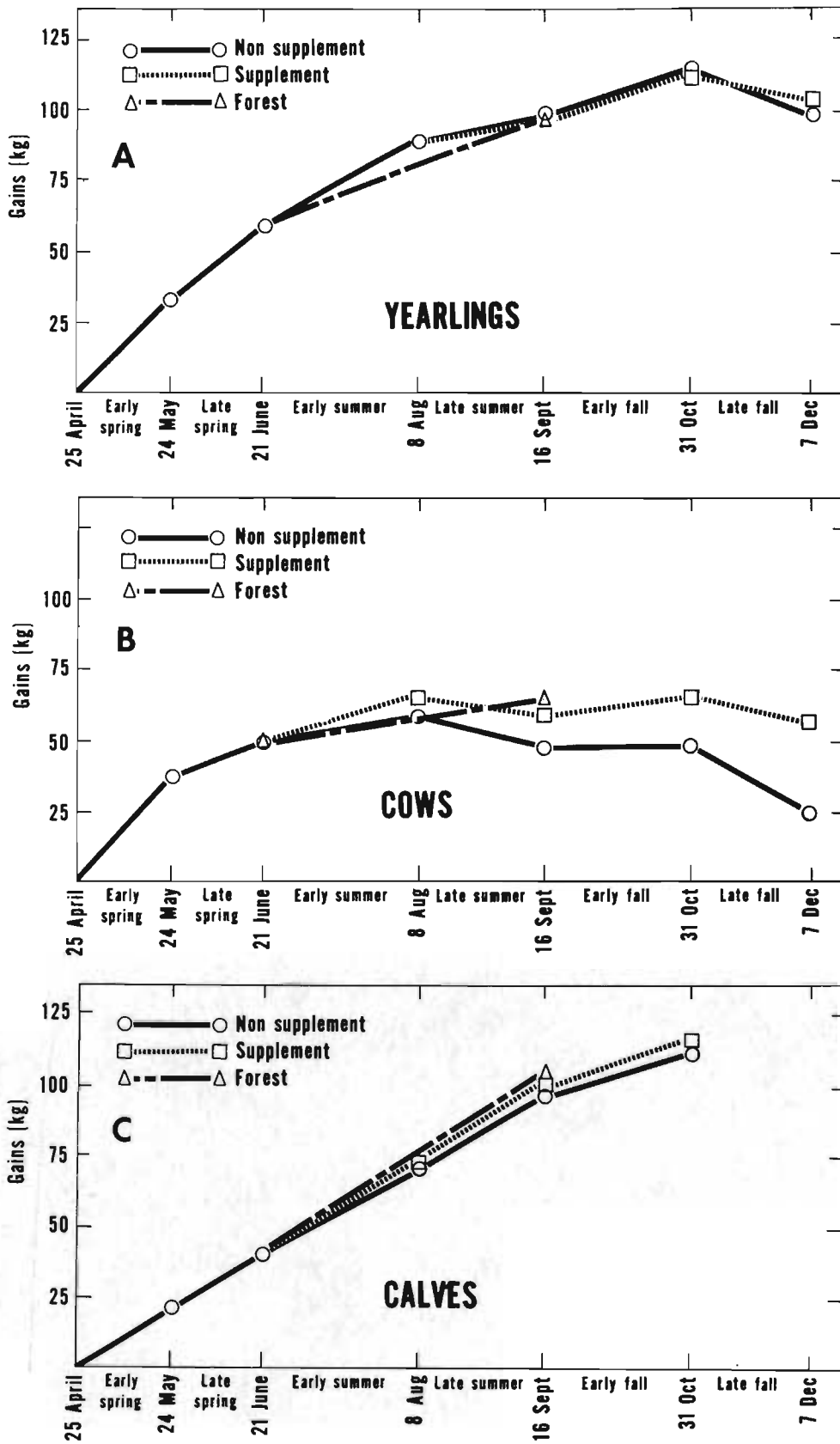


Figure 26. Cumulative gain per animal for yearlings, cows and calves when grazing crested wheatgrass at various seasons of the year.

As the grass matured, cows became more selective of the areas grazed and the plant parts which they desired. In the spring, utilization of grass in swales and depressions averaged about 5 percent heavier than on ridges and flat areas. Utilization continued equally heavy in the swales in all seasons, but it became lighter on ridges and flats as the seasons progressed. By late fall, utilization of grass in swales and depressions was about 15 percent heavier than that on the ridges and flats.

In late summer and fall, cows ate the seedheads mainly on the dry grass on ridges and flats. The nutritive quality of seedheads was undoubtedly superior to that of the dry stems.

Control of Invading Sagebrush in Reseeded Range Grasses

Reinvasion of big sagebrush in crested wheatgrass stands is a major problem even if light grazing is practiced (Frischknecht *et al.*, 1958). This reinvasion, however, can be controlled by sheep grazing in late fall.⁵ For most effective control, this practice should be inaugurated before brush becomes dense. Early results showed that brush declined most where there were approximately 22 sagebrush plants of varying ages per 100 square meters (2 sagebrush plants per 100 square feet) of area.

⁵ Frischknecht and Harris, unpublished data.



Figure 27. When cows are fed a protein supplement they are in good condition at the end of the summer season. Their grains also compare favorably with cows grazing on the high range (National Forest).

Table 15. Changes in yields of big sagebrush during years of treatment

Grazing treatment	Percent change
Cattle early spring plus sheep early fall	+ 2
Cattle early spring	+ 56
Sheep early fall	+ 6
Cattle early spring plus sheep late fall	+ 16
Sheep late fall	- 52
No grazing	+ 51

Of the six treatments applied on the Benmore range (table 15), grazing in late fall by sheep gave the greatest percentage reduction in volume of big sagebrush. Brush increased most where cattle grazed in early spring.

On other units having a greater amount of brush, late fall sheep grazing reduced brush only slightly where there were 43 brush plants per 100 square meters (four brush plants per 100 square feet), but brush continued to increase where there were 108 plants per 100 square meters (10 plants per 100 square feet), of area. Of course, the alternative to grazing by sheep is periodic spraying of brush to help keep ranges productive. Sheep utilize brush forage that would otherwise be wasted, but there is a limit to the amount they will eat.

FULFILLMENT

Some Ideas for the Rancher

Supplements for sheep on the winter range

On some well-managed ranges with mixed species of vegetation, it may not pay dividends to feed a supplement. However, most of the winter ranges do not furnish sufficient protein, phosphorus, or energy to satisfy the animals' requirements. If good management is practiced and the nutrient requirements are satisfied by feeding a small amount of supplement, we have found that the wool may be increased 1 pound per animal and the lamb crop increased 15 to 30 percent (figure 28).

The basis of formulating a supplement for range ewes is to determine the composition of the grazing sheep's diet and then supply sufficient nutrients to meet any deficiency. In preparing the supplement, the following steps should be followed:

1. Determine how much supplement is to be fed and the form in which it is to be fed. In general, it will not be economical to feed supple-

ments at a level to keep ewes gaining or to maintain their weight throughout the winter months because they are usually in good condition when they go on winter range. The objective is to maximize the use of range and to supplement only at a level to prevent production losses. Supplements should, therefore, be the minimum amount that will insure sufficient and uniform intake of specific nutrients.

2. Add phosphorus to the supplement at a level to meet the recommended requirements for a 59-kilogram (130 pound) ewe.

3. Do the same with protein.

4. Under conditions in which carotene is likely to be deficient, supply sufficient vitamin A to meet the requirement. However, under Intermountain range conditions, animals will probably not be deficient in vitamin A.

5. Add 1 percent salt, preferably trace mineralized salt.

6. Make up the balance of the supplement with an energy feed so that the intended amount of supplement will supply the above nutrients uniformly to the whole herd.

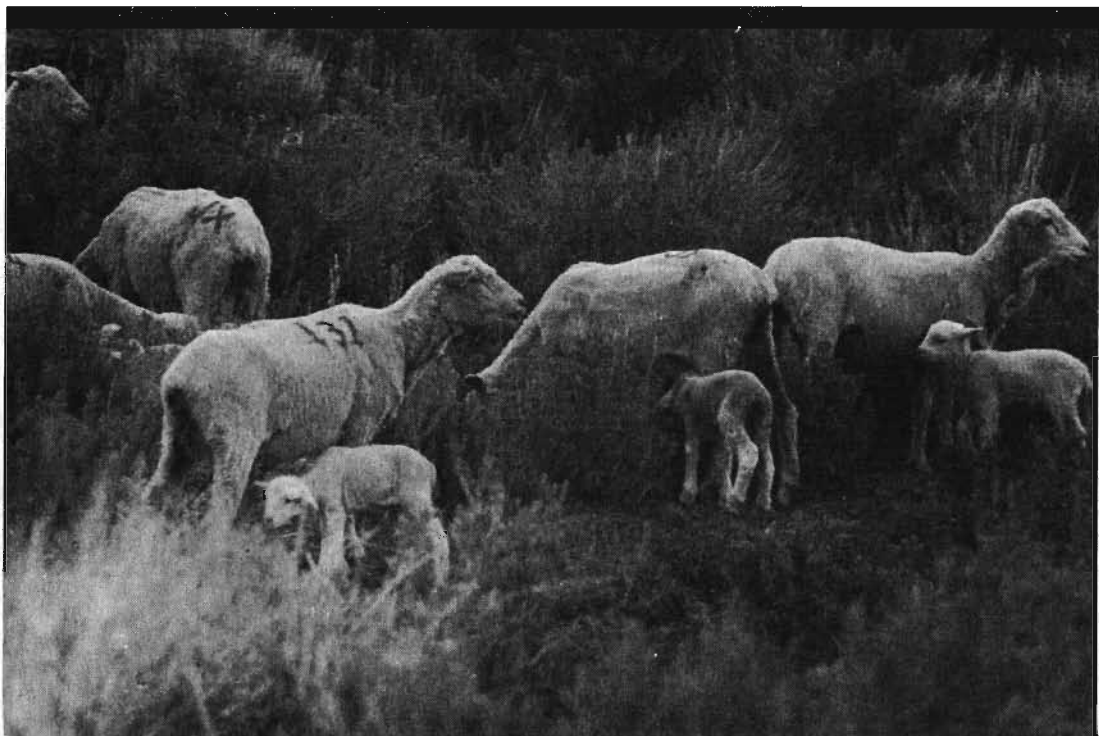


Figure 28. These ewes were fed a balanced supplement with the correct amounts of protein, phosphorus and energy. By supplying such supplements, it is possible to increase wool production by about 1 pound and the lamb crop by about 15 to 30 percent. This practice has a potential of increasing wool production in Utah by 544,316 kilograms (1,200,000 pounds) and the number of lambs weaned by 120,000.

For the various types of range, this means that the general recommendations for supplements are as follows:

1. A 12-percent protein supplement in pellet or block form or a cereal grain of corn or barley should be used on sagebrush range types since the diets of sheep grazing on these areas are usually high in protein. Feed from 0.11 to 0.45 kilogram (0.25 to 1.0 pound) per day, depending on range and climatic conditions and the condition of the animals (table 16). These feeds can also be fed during deep snow emergencies along with alfalfa hay.

2. A 24-percent protein pellet or block fed at 0.11 to 0.23 kilogram (0.25 to 0.5 pound) per day is better adapted for feeding on mixed browse-grass types.

3. A 36-percent protein pellet or block or solvent extracted cottonseed meal fed at 0.11 to 0.15 kilogram (0.25 to 0.33 pound) per day should be used with saltbush types or where there is an abundance of grass or wherever grass predominates.

Salt is being used to regulate the consumption of supplements. This

Table 16. Formulas for range supplements for sheep

Feed	Recommended amount of protein		
	High	Medium	Low
	%	%	%
Barley, grain, ground	.....	32.25	57.0
Corn, grain, ground	5.0	10.0	15.0
Sugarcane, molasses, or beet, molasses	5.0	5.0	10.0
Beet, pulp, dried	.....	.....	10.0
Cottonseed meal, solv. extd.	62.5	32.5	5.0
Soybean meal, solv. extd.	10.0	10.0	.....
Dicalcium phosphate	4.0	3.0	2.0
Salt or trace mineralized salt	1.0	1.0	1.0
Alfalfa, dehydrated or sun-cured meal	12.5	6.25	.....
Total	100.0	100.0	100.0
Suggested composition			
Protein (N x 6.25) %	36.0	24.0	12.0
Phosphorus %	1.5	1.0	0.5
Carotene mg/kg	7.1	3.5	.....
Rate of feeding (kg per day)	0.11	0.15 to 0.23	0.09 to 0.45
Rate of feeding (lb per day)	0.25	0.33 to 0.50	0.20 to 1.00

method of feeding saves labor and is recommended where it is not possible to hand feed the animals — that is, where range sheep are handled under fence. It should be kept in mind, however, that salt is used to regulate the amount of meal consumed and it should not be used if the intake of supplement can be controlled by hand feeding.

Salt-meal mixtures greatly increase water consumption. If this method of feeding is followed, the animals should have access to water every day since the extra salt must be excreted through the urine. If sufficient water is not available, the animals dehydrate.

The choice of whether to hand feed pellets, feed a supplement with salt or to use a protein block should be decided by whichever method is cheaper. If pellets are used they may be fed every second day.

The animals should have free access to salt or trace mineralized salt in one side of a self feeder and a mixture of 1 part salt and 1 part dicalcium phosphate in the other side. If a commercial supplement is fed, it should contain at least 10 percent phosphorus.

Grazing scheme for spring and fall

Spring forage is woefully short in the Intermountain region. Proper grazing of crested wheatgrass can overcome this problem (figure 28). For early spring grazing there should be some growth remaining from the previous fall, since new growth is more rapid where there is some material left from the previous year. Of course, the animals prefer the young, tender grass, but in utilizing it they will also consume some of the dry growth from the previous year.

Fall regrowth occurs about one-half the time. Where there is no fall regrowth, any fall grazing must depend upon grass left from spring.

To perpetuate grass vigor pastures should not be grazed every year in the spring. Rotation grazing where the pastures are divided into three sections by electric fences, and each section grazed twice in regular order each spring, beginning with a different section each year, may fill this need.

Water should be provided. In late fall provision should be made to cope with freezing conditions. As on winter range, salt should be available at all times. In addition, during the fall cattle should have free access to a mixture of 1 part salt or trace mineralized salt and 1 part dicalcium phosphate or a commercial phosphorus supplement containing at least 10 percent phosphorus.

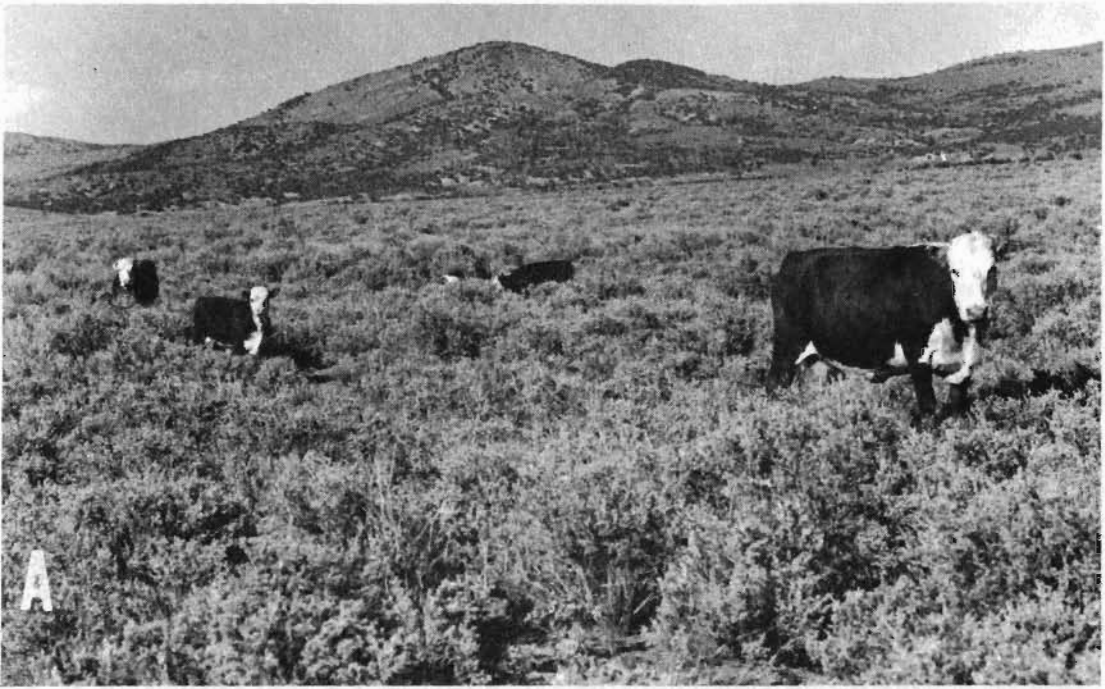


Figure 29. (A) There are about 20 million hectares (50 million acres) in the Intermountain region, and 2 million hectares (5 million acres) in Utah of spring and fall sagebrush and depleted dry farm land which would benefit from reseeding to drought-resistant grasses, such as crested, intermediate, or tall wheatgrass, or Russian wildrye.

On sagebrush land it takes 2.02 to 10.1 hectares (5 to 25 acres) to maintain a cow and a calf for 60 days in the spring. While on this range the cows gain about 0.5 kilogram (1.10 pounds) and calves gain about 0.67 kilogram (1.47 pounds).

(B) When sagebrush land is reseeded to crested wheatgrass and grazed to a utilization of 65 percent, it takes about 2 hectares (5 acres) for a cow and a calf for a 60-day grazing season. While on this type of spring range, cows gain from 1.13 to 1.39 kilograms (2.49 to 3.06 pounds), and calves gain about 0.80 kilogram (1.77 pounds). Reseeding this type of range is the best way to increase cattle production in the Intermountain West.

In the spring the following daily gains may be expected at 65 percent utilization for the various classes of cattle (assuming they are thin when put in the pastures):

Class of cattle	Gains
Yearlings	1.18 kilograms (2.60 pounds)
Dry cows and steers	1.45 kilograms (3.20 pounds)
Pregnant cows calving in pasture	1.41 kilograms (3.10 pounds)
Lactating cows	1.22 kilograms (2.70 pounds)
Calves	0.82 kilogram (1.80 pounds)

In the fall cows will about maintain their weight on a crested wheat-grass pasture. If there is some rain and some regrowth they will gain slightly. For a 60-day grazing season in the spring, it takes about 2 hectares (5 acres) for a cow and a calf.

The grazing of sheep in late fall will control big sagebrush if the grazing is started when there are not more than 22 sagebrush plants of varying ages per 100 square meters (two sagebrush plants per 100 square feet).

Grazing scheme from April to December

When a rancher has limited permits for cattle on the National Forest range, or does not have meadows or irrigated pastures for summer grazing, it may be desirable to develop a system to graze grass from April to December on the spring and fall zone where there is a rainfall of 279 to 356 millimeters (11 to 14 inches).

1. *Early spring.* Cattle may be started to graze about April 10. The pasture used for this grazing should have been one that was grazed in such a manner the previous year that there is some old growth left.

2. *Late spring.* The pasture used for this grazing should have been one that was grazed in early fall or late fall the previous year.

3. *Early summer.* Use a pasture seeded to intermediate wheat-grass, because it stays green longer (Cook, 1966). Intermediate wheat-grass requires 305 millimeters (13 inches) of rainfall. If there is not this much rainfall, use crested wheatgrass or Russian wildrye.

Graze the same cows on this area every second year and on the higher land (National Forest) the other years. Feed the cows the equivalent of 0.34 kilogram (0.75 pound) of cottonseed meal daily in three

feedings per week or give them access to a protein block or access to a mixture of protein supplement and salt to control intake while on crested wheatgrass.

4. *Late summer.* Follow the same practices as outlined for early summer.

5. *Early fall.* Use a crested wheatgrass, Russian wildrye or intermediate wheatgrass pasture.

6. *Late fall.* Use a crested wheatgrass, Russian wildrye or intermediate wheatgrass pasture.

In the spring cattle may be grazed for about 60 days in a pasture, but in the summer and fall they should be moved to a new pasture about every 30 to 45 days. The pastures may be utilized to about 65 percent. The grazing capacity is the same as described above for spring and fall.

Water should be available. Feed minerals as recommended above for spring and fall ranges.

When big sagebrush invades it may be controlled as outlined above.

A Glimpse into the Future

As the questions we ask through our research become more exacting, the techniques at our disposal must become more accurate and reliable. Hence, part of our work, as in the past, must be concerned with the development of better techniques.

We need better methods to indicate the nutritive status of an animal by making measurements directly on the animal.

The apparatus we use to collect urine from grazing animals is cumbersome and difficult for the animal to carry. Some work has been done to devise an indicator for estimating urine output similar to estimating feces output by the use of chromic oxide. This work involves the use of creatinine (Butcher and Harris, 1957). Future research may show that a sustained release capsule implanted under the skin may be able to release a small amount of some substance so that total urine

output may be predicted from grab samples. If such a method is developed, digestion and balance trials could be carried out on the range without a harness on the animal.

As suggested before, we still do not have a completely satisfactory internal indicator for digestibility studies. The search for a chemically definable, indigestible substance should continue which, if successful, would open a whole new area of research.

Both rumen and esophageal samples are obtained contaminated with saliva. This makes some analyses such as for phosphorus somewhat difficult. Methods of accurately estimating saliva contamination or of sample collection without this contamination should be investigated and developed.

Under range conditions it is impractical to supplement often yet a sustained supply of nutrients may be necessary for optimum performance. The future should see satisfactory means of long-term supplementation with a minimum of handling of the livestock. For example, sustained released pellets are now being used to supply cobalt to sheep in deficient areas in Australia. A vitamin A supply for feedlot cattle sufficient for 90 days or more has been administered in one injection. These methods may be adapted for use in supplementation on our ranges. We are even now considering projects to develop nitrogen supplements containing biuret and other slowly soluble materials for a more sustained nitrogen supply to rumen microorganisms.

The symbiotic relationship between the microorganisms in the rumen and the host animal presents challenging problems. Perhaps we may be able to create an environment in the rumen which will permit a more rapid or more complete utilization of the polysaccharide energy present in range forage. Proper supplementation and even bacterial population manipulation with inoculation and antibiotics may improve the efficiency of rumen microorganisms in converting some of the indigestible fiber to human food.

Our increasing population continues to utilize more and more of our protein feeds such as soybean meal. At present, this valuable protein is being converted to substitute forms for meat, chicken, and milk. If we expect to continue eating beefsteak and lamb and drinking milk, we must find a more efficient way for ruminants to utilize poor range forage or corn stalks by utilizing nonprotein sources.

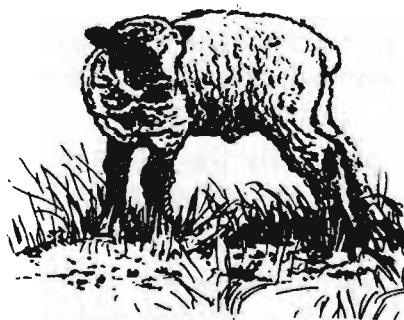
It has been shown that the amounts and proportions of volatile fatty acids can be altered in the rumen and that this alteration affects the effi-

ciency with which certain physiological functions occur. High levels of acetic acid promote increased heat production and milk-fat levels while an increase in propionic acid depresses milk-fat levels but improves efficiency of weight gain and protects against acetonemia. The manipulation of these factors could greatly improve the productivity of a given range.

Range cattle and sheep in the Intermountain region gain weight during the summer even though they are nursing a calf or lamb. In the winter they lose weight. The NRC nutrient requirements for these animals are based on farm conditions where they are fed to gain weight in the winter and lose weight in the summer. With the above thoughts in mind a separate set of nutrient requirements should be developed for range cattle and sheep.

The nutritionist cannot ignore the effects of environment on the animal, its nutrient requirements, and its diet. Our ranges have a varied, heterogeneous, rigorous environment. If we are to make good the nutrient deficiencies that may occur under these varied environmental conditions, then specific research must be conducted under controlled environments. For example, it has recently been shown that animals in a hot environment need higher levels of vitamin A. The effects of extremes of heat and cold, altitude, water supply, and other environmental factors should be studied and their relationship to the nutrition of the animal should be established.

Whether the world situation is viewed from the most pessimistic Malthusian or from the most optimistic affirmative standpoint, it is obvious that any improvement in the efficiency with which the vegetation of the Intermountain rangelands can be converted to food and fiber will be of value to society. The economic benefit can be partially estimated but the humanitarian and sociological benefits cannot. An arid region is not necessarily an unproductive region, it merely presents a greater challenge to human ingenuity. The nutritional scientists have met and are meeting that challenge.



REFERENCES CITED

- Allen, N. N. Variations in the live weight of dairy cattle. Vt. Agr. Expt. Sta. Bul. 534. 1946.
- Anderson, R., E. Cheng and W. Burroughs. A laboratory technique for measuring phosphorus availability of feed supplements fed to ruminants. J. Animal Sci. 15:489. 1956.
- Annison, E. F. Some observations on volatile fatty acids in the sheep's rumen. Biochem. J. 57:400. 1954.
- Annison, E. F. Nitrogen metabolism in the sheep. Protein digestion in the rumen. Biochem. J. 64:705. 1956.
- Baker, A. L., R. W. Phillips and W. H. Black. The relative accuracy of one-day and three-day weaning weights of calves. J. Animal Sci. 6:56. 1947.
- Balch, C. C. and C. Line. Weight changes in grazing cows. J. Dairy Res. 24:11. 1957.
- Barnes, O. L. and A. L. Nelson. Dryland pastures for the Great Plains. Wyo. Agr. Expt. Sta. Bul. 302. 1950.
- Bath, D. L., W. C. Weir and D. T. Torell. The use of the esophageal fistula for the determination of consumption and digestibility of pasture forage by sheep. J. Animal Sci. 15:1166. 1956.
- Bean, H. W. Single weight versus a three-day-average weight for sheep. J. Animal Sci. 7:50. 1948.
- Bentley, O. G., R. R. Johnson, T. V. Hershberger, J. H. Cline and A. L. Moxon. Cellulolytic-factor activity of certain short chain fatty acids from rumen microorganisms *in vitro*. J. Nutrition 57:389. 1955.
- Bentley, O. G., A. Lehmkuhl, R. R. Johnson, T. V. Hershberger and A. L. Moxon. The "cellulolytic factor" activity of certain short chain fatty acids. J. Am. Chem. Soc. 76:5000. 1954.
- Binns, W. and L. F. James. A plastic rumen fistula apparatus for sheep — its insertion and use. J. Am. Vet. Med. Assoc. 135:603. 1959.
- Blaxter, Kenneth Lyon. The Energy Metabolism of Ruminants. Hutchinson and Co., London, p. 200. 1962.
- Bohman, V. R., L. E. Harris, G. P. Lofgreen, C. J. Kercher and R. J. Raleigh. Techniques for range livestock nutrition research. Ut. Agr. Expt. Sta. Bul. 471. 1967.
- Border, Jerry R., Lorin E. Harris and John E. Butcher. Study of the quantitative fecal recovery of chromic oxide when administered to sheep as a component of paper. J. Animal Sci. 22:1117. 1963a.
- Border, Jerry R., Lorin E. Harris and John E. Butcher. Apparatus for obtaining sustained quantitative collections of urine from male cattle grazing pasture or range. J. Animal Sci. 22:521. 1963b.
- Brannon, W. R., J. T. Reid and J. I. Miller. The influence of certain factors upon the digestibility and intake of pasture herbage by beef steers. J. Animal Sci. 13:535. 1954.

- Brisson, German J., W. J. Angus, P. E. Sylvestre and W. J. Pigden. The chromogen content of herbage as an index of its digestibility. Proc. 8th Pacific Sci. Congress of the Pacific Sci. Assoc. Vol. IV B:537. 1953.
- Brisson, G. J., W. J. Pigden and P. E. Sylvestre. Effect of frequency of administration of chromic oxide on its fecal excretion pattern by grazing cattle. Can. J. Animal Sci. 37:90. 1957.
- Bryant, M. P and R. N. Doetsch. Factors necessary for the growth of *Bacteriodes succinogenes* in the volatile fatty acid fraction of rumen fluid. J. Dairy Sci. 38:340. 1955.
- Butcher, John E. and Lorin E. Harris. Creatinine as an index material for evaluating ruminant nutrition. J. Animal Sci. 16:1020. 1957.
- Butcher, J. E. and L. E. Harris. The relationship of climate and water to feed utilization by cattle and sheep. Am. Soc. Range Mgmt. Proc. 1962.
- Clanton, D. C., L. E. Harris and J. E. Butcher. Effect of nutrition on the productivity of range sheep. J. Animal Sci. 18:1416. 1959.
- Connor, J. M., V. R. Bohman, A. L. Lesperance and F. E. Kinsinger. Nutritive evaluation of summer range forage with cattle. J. Animal Sci. 22:961. 1963.
- Cook, C. Wayne. Development and use of foothill ranges in Utah. Ut. Agr. Expt. Sta. Bul. 461. 1966.
- Cook, C. W. and L. E. Harris. The nutritive value of range forage as affected by vegetation type, site, and stage of maturity. Ut. Agr. Expt. Sta. Bul. 344. 1950a.
- Cook, C. W. and L. E. Harris. The nutritive content of the grazing sheep's diet on summer and winter ranges of Utah. Ut. Agr. Expt. Sta. Bul. 342. 1950b.
- Cook, C. W. and L. E. Harris. A comparison of the lignin ratio technique and the chromogen method of determining digestibility and forage consumption of desert range plants by sheep. J. Animal Sci. 10:565. 1951.
- Cook, C. W., L. E. Harris and L. A. Stoddart. Measuring the nutritive content of a foraging sheep's diet under range conditions. J. Animal Sci. 7:170. 1948.
- Cook, C. Wayne, Lorin E. Harris and Melvin C. Young. Botanical and nutritive content of diets of cattle and sheep under single and common use on mountain range. J. Animal Sci. 26:1169. 1967.
- Cook, C. W., M. Kothmann and L. E. Harris. Effect of range condition and utilization on nutritive intake of sheep on summer ranges. J. Range Mgmt. 18:69. 1965.
- Cook, C. W., L. A. Stoddart and L. E. Harris. Measuring consumption and digestibility of winter range plants by sheep. J. Range Mgmt. 4:335. 1951.
- Cook, C. W., L. A. Stoddart and L. E. Harris. Determining the digestibility and metabolizable energy of winter range plants by sheep. J. Animal Sci. 11:578. 1952.

- Cook, C. W., L. A. Stoddart and L. E. Harris. The nutritive value of winter range plants in the Great Basin. *Ut. Agr. Expt. Sta. Bul.* 372. 1954.
- Cook, C. Wayne, L. A. Stoddart and Lorin E. Harris. Comparative nutritive value and palatability of some introduced and native forage plants for spring and summer grazing. *Ut. Agr. Expt. Sta. Bul.* 385. 1956.
- Cook, C. W., J. L. Thorne, J. T. Blake and James Edlefsen. Use of an esophageal-fistula cannula for collecting forage samples by grazing sheep. *J. Animal Sci.* 17:189. 1958.
- Corbett, J. L., J. F. D. Greenhalgh, I. McDonald and E. Florence. Excretion of chromium sesquioxide administered as a component of paper to sheep. *Brit. J. Nutrition* 14:289. 1960.
- Crampton, E. W. and Lorin E. Harris. Joint United States-Canadian Tables of Feed Composition. *Natl. Acad. Sci., Natl. Res. Council. Pub.* 1232. 1964.
- Crampton, E. W. and L. E. Lloyd. Studies with sheep on the use of chromic oxide as an index of digestibility of ruminant rations. *J. Nutrition* 45:319. 1951.
- Crampton, E. W., L. E. Lloyd, and V. G. MacKay. The calorie value of TDN. *J. Animal Sci.* 16:541. 1957.
- Cresswell, E. and L. E. Harris. An improved rangemeter for sheep. *J. Animal Sci.* 18:1447. 1959.
- Dann, William J. and Kenneth A. Evelyn. CXXXVI. The determination of vitamin A with the protoelectric colorimeter. *Biochem. J.* 32:1008. 1938.
- Edin, H., G. Kihlen and S. Nordfeldt. A summarized description of "Edin's indicator method" for the determination of the digestibility of feeds and feed mixtures. *Lantbrukshogskolans Annaler.* 12:166. 1944.
- El-Shazly, L. Degradation of protein in the rumen of the sheep. 1. Some volatile fatty acids including branched-chain isomers found *in vivo*. *Biochem. J.* 51:640. 1952a.
- El-Shazly, L. Degradation of protein in the rumen of the sheep. 2. The action of rumen microorganisms on amino acids. *Biochem. J.* 51:647. 1952b.
- Frischknecht, Neil C. and Lorin E. Harris. Vegetation and cattle responses to grazing crested wheatgrass in central Utah. *U.S.D.A. Tech Bul.* 1388. 1968.
- Frischknecht, N. C., L. E. Harris and H. K. Woodward. Cattle gains and vegetal changes as influenced by grazing treatments on crested wheatgrass. *J. Range Mgmt.* 6:151. 1958.
- Gaines, W. L., H. P. Davis and R. F. Morgan. Estimation of initial live weight at each lactation of dairy cows. *J. Dairy Sci.* 24:983. 1941.
- Guilbert, H. R., R. F. Miller and E. H. Hughes. The minimum vitamin A and carotene requirement of cattle, sheep, and swine. *J. Nutrition* 13:543. 1937.
- Hamilton, T. S., H. H. Mitchell, C. H. Kick and G. G. Carman. New method tested in digestion trials. 41st Ann. Rep., *Ill. Agr. Expt. Sta.* 1927-1928.

- Harris, Lorin E. Glossary of definitions of energy terms. Committee on Animal Nutrition, Natl. Acad. Sci., Natl. Res. Council. Pub. 1940. 1962.
- Harris, Lorin E. Biological energy interrelationships and glossary of energy terms. Natl. Acad. Sci., Natl. Res. Council Pub. 1411. First revised edition. 1966.
- Harris, Lorin E., C. Wayne Cook and John E. Butcher. Symposium on forage evaluation: V. Intake and digestibility techniques and supplemental feeding in range forage evaluation. *J. Agronomy* 51:226. 1959.
- Harris, L. E., C. W. Cook and L. A. Stoddart. Range nutrition techniques. *J. Animal Sci.* 11:181. 1952.
- Harris, L. E., C. W. Cook and L. A. Stoddart. Feeding phosphorus, protein and energy supplements to ewes on winter ranges of Utah. *Ut. Agr. Expt., Sta. Bul.* 398. 1956.
- Harris, Lorin E., Neil C. Frischknecht and Earl M. Sudweeks. Extended grazing of crested wheatgrass by cattle. *Farm and Home Sci.* 26:14. 1965.
- Harris, L. E., J. C. James and C. W. Cook. A method of feeding supplements to individual cattle on winter range. *J. Animal Sci.* 16:872. 1957.
- Hawk, Phillip B., Bernard C. Oser and William H. Summerson. *Practical Physiological Chemistry*. 12th ed. Philadelphia, The Blakiston Co. 1937.
- Hubbert, J. E. Cheng and W. Burroughs. The influence of potassium, sodium, rubidium, lithium and cesium on the *in vitro* cellulose digestion by rumen microorganisms with observations on sodium potassium influences in lamb fattening rations. *J. Animal Sci.* 17:576. 1958.
- Johnson, R. R., B. A. Dehority and O. G. Bentley. Studies in the *in vitro* rumen procedure: Improved inoculum preparation and the effects of volatile fatty acids on cellulose digestion. *J. Animal Sci.* 17:841. 1958.
- Kane, E. A., W. C. Jacobsen and L. A. Moore. A comparison of techniques used in conducting digestibility studies on dairy cattle. 41st Ann. Meeting, Am. Soc. Animal Prod. 1949.
- Kendrick, J. T. and J. B. Parker. Estimating the weight of dairy cows from heart girth measurements. U.S.D.A. Bureau Dairy Industry. BDIM 695 (Mimeograph). 1936.
- Kennedy, W. K., A. H. Carter and R. J. Lancaster. Comparison of faecal pigments and faecal nitrogen as digestibility indicators in grazing cattle studies. *New Zealand J. Agr. Res.* 2:627. 1959.
- Koch, R. M., E. W. Schleicher and V. H. Arthaud. The accuracy of weights and gains of beef cattle. *J. Animal Sci.* 17:604. 1958.
- Kock, Frederick C. *Practical Methods in Biological Chemistry*. 1st ed. Baltimore, Maryland, The Williams and Wilkin Co. 1935.
- Lancaster, R. J. Measurement of feed intake of grazing cattle and sheep. *New Zealand J. Sci. and Tech.* 36:15. 1954.

- Lesperance, A. L., V. R. Bohman and D. W. Marble. Development of techniques for evaluating grazed forage. *J. Dairy Sci.* 43:682. 1960.
- Lucas, H. L. Algebraic relationships between digestion coefficients determined by the conventional method and by indicator methods. *Sci.* 116:301. 1952.
- Lush, J. L., F. W. Christensen, C. V. Wilson and W. H. Black. The accuracy of cattle weights. *J. Agr. Res.* 36:551. 1928.
- Morris, J. G., L. E. Harris, J. E. Butcher and C. W. Cook. Indices of efficiency for rumen fermentation of sheep grazing desert range forage as influenced by supplements of nitrogen and phosphorus. *J. Animal Sci.* 24:1152. 1965.
- Nagy, J. G., G. H. Steinhoff and J. M. Ward. Effects of essential oils on sagebrush over rumen microbial function. *J. Wildlife Mgmt.* 28:785. 1964.
- National Research Council. Recommended nutrient allowances for domestic animals. No. V. Recommended nutrient allowances of sheep. A report of the Committee on Animal Nutrition. Natl. Res. Council, Revised. 1949.
- National Research Council. Nutrient requirements of domestic animals. No. V. Nutrient requirements of sheep. A report of the Committee on Animal Nutrition. Natl. Acad. Sci., Natl. Res. Council. Pub. 1193. Revised. 1964.
- Patterson, R. E. The comparative efficiency of single versus three-day average weights of steers. *J. Animal Sci.* 6:237. 1947.
- Pechanec, Joseph F. and G. D. Pickford. A comparison of some methods used in determining percentage utilization of range grasses. *J. Agr. Res.* 54:753. 1937.
- Raymond, W. F., D. J. Minson and C. E. Harris. The effect of management on herbage consumption and selective grazing. Proc. 7th International Grasslands Congress. Massey Agr. College, New Zealand. 1956.
- Reid, J. T., P. G. Woolfolk, W. A. Hardison, C. M. Martin, A. L. Brundage and R. W. Kaufmann. A procedure for measuring the digestibility of pasture forage under grazing conditions. *J. Nutrition* 46:255. 1952.
- Reid, J. Thomas and W. Keith Kennedy. Measurement of forage intake by grazing animals. Proc. 7th International Grasslands Congress. 1956.
- Ridley, J. R., A. L. Lesperance, E. H. Jensen and V. R. Bohman. Pasture evaluation with fistulated and intact cattle. Proc. Western Sec. Am. Soc. Animal Sci. Western Sec. Proc. 14:XXXV. 1963.
- Sarvis, J. T. Grazing investigations on the Northern Great Plains. N. Dak. Agr. Expt. Sta. Bul. 308. 1941.
- Schneider, B. H. Feeds of the World; Their Digestibility and Composition. W. Va. Agr. Expt. Sta. Morgantown, W. Va. 1947.
- Schneider, B. H., B. K. Soni and W. E. Ham. Methods for determining consumption and digestibility of pasture forages by sheep. Wash. Agr. Expt. Sta. Bul. 16. 1955.

- Schurch, A. F., L. E. Lloyd and E. W. Crampton. The use of chromic oxide as an index for determining the digestibility of a diet. *J. Nutrition* 41:629. 1950.
- Stare, F. J., J. B. Allison, G. Arroyave, M. Behar, R. Bressani, B. S. Burke, J. Cravioto, N. W. Flodin, S. Frenk, F. Gomer, A. E. Harper, J. M. Hundley, P. C. Jeans, J. A. Johnston, J. B. McKinley, K. J. Newman, R. Ramos-Galvan, R. B. Reed, N. W. Scrimshaw, J. Senecal, R. L. Squibb, G. Stearns, H. C. Stuart, I. Valadian, F. Viteri, A. R. F. Walker and D. M. Watkins. Protein nutrition. *Annals. New York Academy Sci.* 69 (Article 5):885. 1958.
- Stewart, George and S. S. Hutchings. The point-observation-plot (square-foot density) method of vegetation survey. *J. Am. Soc. Agronomy* 28:714. 1936.
- Swift, R. W. The caloric value of TDN. *J. Animal Sci.* 16:753. 1957.
- Swift, R. W., J. W. Bratzler, W. H. James, A. D. Tillman and D. C. Meek. The effect of dietary fat on utilization of the energy and protein of rations by sheep. *J. Animal Sci.* 7:475. 1948.
- Torell, D. T. An esophageal fistula for animal nutrition studies. *J. Animal Sci.* 13:878. 1954.
- Vallentine, J. F. Use of indicator methods in range digestion trails: A review. *J. Range Mgmt.* 9:235. 1956.
- Van Dyne, George M. and D. T. Torell. Development and use of the esophageal fistula: A review. *J. Range Mgmt.* 17:7. 1964.
- Van Horn, J. L., O. O. Thomas, G. F. Payne, J. Drummond, A. S. Roversland and F. S. Willson. Nutritional requirements of ewes wintered under range conditions. *Mont. Agr. Expt. Sta. Mimeo Cir.* 68. 1952.
- Wheeler, R. R. Evaluation of various indicator techniques in estimating forage intake and digestibility by range cattle. Ph.D. Thesis, Ore. State Univ. 1962.
- Whiteman, J. V., P. F. Loggins, D. Chambers, L. S. Pope and D. F. Stephens. Some sources of error in weighing steers off grass. *J. Animal Sci.* 13:832. 1954.
- Williams, Ralph M. and A. H. Post. Dryland pasture experiments at the central Montana Branch Station, Moccasin, Montana. *Mont. Agr. Expt. Sta. Bul.* 431. 1945.

PUBLICATIONS

by Lorin E. Harris

UNIVERSITY OF ILLINOIS

1. The quantitative utilization of urea nitrogen by mature and growing sheep. Ill. Univ. Ph.D. Thesis. 1940.
2. The quantitative utilization of urea nitrogen by mature and growing sheep. Ill. Univ. abstr. Ph.D. Thesis. 1940.
3. The value of urea in the synthesis of protein in the paunch of the ruminant. I. In maintenance (with H. H. Mitchell) *J. Nutrition* 22:167-172. 1941.
4. The value of urea in the synthesis of protein in the paunch of the ruminant. II. In growth (with H. H. Mitchell) *J. Nutrition* 22:183-196. 1941.

UNIVERSITY OF HAWAII

5. The utilization of urea and soybean oil meal nitrogen by steers (with S. H. Work and L. A. Henke) *J. Animal Sci.* 2:328-335. 1942.
6. A note of the effect on the kidneys and livers of feeding urea to steers fattening in dry lot and on pasture (with S. H. Work, C. J. Hamre and L. A. Henke) *J. Animal Sci.* 2:166-169. 1943.

CORNELL UNIVERSITY

7. Fox carcasses as a possible source of protein (with John K. Loosli) *Fur J.* Nov. 1943, 16-18; *Am. Natl. Fur Market J.*, Dec. 1943, 7-8; *Am. Fur Breeder* 38-40. 1943.
8. The calcium requirement of growing foxes (with Charles F. Bassett, Sedgwick E. Smith and Eldon D. Yoeman) *Cornell Vet.* 35:9-22. 1945.
9. Methionine increases the value of urea for lambs (with J. K. Loosli) *J. Animal Sci.* 4:435-437. 1945.
10. Urinary calculi associated with vitamin A deficiency in the fox (with Charles F. Bassett, Sedgwick E. Smith and Eldon D. Yoeman) *Cornell Vet.* 36:5-16. 1946.
11. A comparison of carotene and vitamin A utilization by the fox (with Charles F. Bassett and C. Ford Wilke) *Cornell Vet.* 36:16-24. 1946.
12. How to meet the calcium needs of growing foxes (with Charles F. Bassett) *Canadian Silver Fox and Fur* 14:7, 8, 10. *Natl. Fur News* 20:10, 26, 28, 30, 31. 1948.

UTAH STATE AGRICULTURAL COLLEGE

13. Utilization of northern Utah summer range plants by sheep (with Clyde J. Cook and C. Wayne Cook) *J. Forestry* 46:416-425. 1948.
14. Measuring the nutritive content of a foraging sheep's diet under range conditions (with C. Wayne Cook and L. A. Stoddart) *J. Animal Sci.* 7:170-180. 1948.
15. Supplementary feeding of sheep on the winter range (with Lloyd E. Meldrum, Lee A. Sharp, C. Wayne Cook, Laurence A. Stoddart and Louis L. Madsen) *Ut. Agr. Expt. Sta. Farm Home Sci.* 9:8-11. 1948.

16. The concentration of DDT in the blood and tissues of sheep fed varying levels of DDT (with J. R. Harris, C. Biddulph, D. A. Greenwood, M. J. Bryson, M. L. Miner, W. Binns and L. L. Madsen) *Ut. Agr. Expt. Sta. Farm Home Sci.* 9:13-14. 1948.
17. The thiamine requirement of mature silver foxes (with John K. Loosli) *Cornell Vet.* 39:277-281. 1949.
18. Concentration of DDT in the blood and tissues of sheep fed varying levels of DDT (with Joseph R. Harris, Clyde Biddulph, D. A. Greenwood, Melvin J. Bryson, Wayne Binns, M. L. Miner and L. L. Madsen) *Arch. Biochem.* 21:370-376. 1949.
19. Should range heifers be bred as yearlings (with J. A. Bennett and L. A. Stoddart) *Ut. Agr. Expt. Sta. Farm Home Sci.* 10:3, 9. 1949.
20. Mineral supplements for farm animals. *Ut. Agr. Expt. Sta. Farm Home Sci.* 10:5, 12, 13. 1949.
21. DDT in eggs and tissues of chickens fed varying levels of DDT (with Melvin J. Bryson, C. I. Draper, J. R. Harris, Clyde Biddulph, D. A. Greenwood, Wayne Binns, M. L. Miner and L. L. Madsen) *Advances Chem. Series No. 1:232-236.* 1950.
22. DDT in milk and tissues of dairy cows fed DDT-dusted alfalfa hay (with Clyde Biddulph, G. Q. Bateman, M. J. Bryson, J. R. Harris, D. A. Greenwood, Wayne Binns, M. L. Miner and L. L. Madsen) *Advances Chem. Series No. 1:237-243.* 1950.
23. Appraising desert range forage for sheep (with C. Wayne Cook, David O. Williamson, L. A. Stoddart and L. L. Madsen) *Ut. Agr. Expt. Sta. Farm Home Sci.* 11:32, 42. 1950.
24. Minerals will not cure or prevent brucellosis (with Wayne Binns) *Ut. Agr. Expt. Sta. Farm Home Sci.* 11:47, 48. 1950.
25. Crested wheatgrass provides excellent spring pasture for beef cattle (with Neil Frischknecht, George Stewart, James A. Bennett and Harry K. Woodward) *Ut. Agr. Expt. Sta. Farm Home Sci.* 11:70, 71, 94. 1950.
26. Range nutrition techniques (with C. Wayne Cook and L. A. Stoddart) *Ut. Acad. Sci. Arts, Letters Proc.* 1950.
27. The nutritive content of the grazing sheep's diet on summer and winter ranges of Utah (with C. Wayne Cook) *Ut. Agr. Expt. Sta. Bul.* 342:1-66. 1950.
28. The nutritive value of range forage as affected by vegetation type, site, and stage of maturity (with C. Wayne Cook) *Ut. Agr. Expt. Sta. Bul.* 344:1-45. 1950.
29. Effect of various levels of calcium, phosphorus, and vitamin D intake on bone growth. I. Foxes (with Charles F. Bassett and C. Ford Wilke) *J. Nutrition* 43:153-165. 1951.
30. The protein requirement of growing foxes (with Charles F. Bassett, Leonard M. Llewellyn and John K. Loosli) *J. Nutrition* 43:167-180. 1951.
31. Utilization of winter range forage by sheep (with Lisle R. Green, Lee A. Sharp and C. Wayne Cook) *J. Range Mgmt.* 4:233-241. 1951.
32. Effect of feeding DDT-dusted alfalfa hay to fattening lambs (with T. Myint, C. Biddulph, D. A. Greenwood, W. Binns, M. L. Miner and L. L. Madsen) *J. Animal Sci.* 10:581-591. 1951.

33. A comparison of the lignin ratio technique and the chromogen method of determining digestibility and forage consumption of desert range plants by sheep (with C. Wayne Cook) *J. Animal Sci.* 10:565-573. 1951.
34. Effect of various levels of calcium, phosphorus, and vitamin D intake on bone growth. II. Minks (with Charles F. Bassett and C. Ford Wilke) *J. Nutrition* 44:433-442. 1951.
35. Supplementary feeding of range sheep pays dividends (with Ernest H. Whitcomb, C. Wayne Cook and David O. Williamson) *Ut. Agr. Expt. Sta. Farm Home Sci.* 12:48, 49, 63. 1951.
36. Determining the digestibility and metabolizable energy of winter range plants by sheep (with C. Wayne Cook and L. A. Stoddart) *J. Animal Sci.* 10:1069. 1951.
37. Effect of feeding various levels of phosphorus, protein, and energy to range ewes by the use of a factorial design (with C. Wayne Cook) *J. Animal Sci.* 10:1070. 1951.
38. Measuring consumption and digestibility of winter range plants by sheep (with C. Wayne Cook and L. A. Stoddart) *J. Range Mgmt.* 4:335-346. 1951.
39. Studies give answers to some of the questions on the toxicity of DDT and methoxychlor (with Clyde Biddulph, D. A. Greenwood, C. I. Draper, G. Q. Bateman, L. L. Madsen, Wayne Binns, M. L. Miner, C. L. Sorenson and F. V. Lieberman) *Ut. Agr. Expt. Sta. Farm Home Sci.* 12:45, 55, 56, 64. 1951.
40. Brisket disease investigated in southeastern Utah (with Wayne Binns and La Zone Bagley) *Ut. Agr. Expt. Sta. Farm Home Sci.* 12:46-47. 1951.
41. Nutritive value of cheatgrass and crested wheatgrass on spring ranges of Utah (with C. Wayne Cook) *J. Range Mgmt.* 5:331-339. 1952.
42. The calcium, phosphorus, vitamin D, and protein requirements of growing foxes and minks. *Am. Chem. Soc. meeting Milwaukee, Wis.* March, 1952.
43. Determining the digestibility and metabolizable energy of winter range plants by sheep (with C. Wayne Cook and L. A. Stoddart) *J. Animal Sci.* 11:578-590. 1952.
44. The transfer of DDT from the feed to eggs and body tissues of White Leghorn hens (with Carroll I. Draper, Joseph R. Harris, Delbert A. Greenwood, Clyde Biddulph, Ferron Mangelson, Wayne Binns and Merthyr R. Miner) *Poultry Sci.* 31:388-393. 1952.
45. Range nutrition techniques (with C. Wayne Cook and L. A. Stoddart) *J. Animal Sci.* 11:181-190. 1952.
46. The effect of DDT upon the digestion and utilization of certain nutrients by dairy calves (with Verle R. Bohman, I-lun Allen Chi, Wayne Binns and Louis L. Madsen) *J. Dairy Sci.* 35:6-12. 1952.
47. Recommended practices to reduce fluorosis in livestock and poultry (with Glenn T. Baird, George Q. Bateman, Wayne Binns, Carroll I. Draper, Delbert A. Greenwood, George R. Henderson, Woodrow R. Jenkins, Lyman H. Rich, D. Wynne Thorne and Frank B. Wann) *Ut. Agr. Expt. Sta. and Ut. Agr. Ext. Service Circ.* 130:1-16. 1952.

48. Research on effects of fluorine compounds on plants and animals being conducted by station (with D. A. Greenwood, M. C. Cannon, H. M. Nielsen, F. B. Wann, B. L. Richards, W. Binns, M. L. Miner, G. Q. Bateman and D. W. Thorne) *Ut. Agr. Expt. Sta. Farm Home Sci.* 13:54, 55, 69. 1952.
49. Meat quality and dressing percentage increased by feeding sugar to livestock prior to slaughter (with E. B. Wilcox, D. A. Greenwood, L. S. Galloway, M. B. Merkley, W. Binns and J. A. Bennett) *Ut. Agr. Expt. Sta. Farm Home Sci.* 13:32, 33, 47. 1952.
50. Is there a better way to organize research, teaching and extension work? *Am. Soc. Animal Prod., Western Sec. Proc.* 3:1-13. 1952.
51. Effects of grazing intensity upon the nutritive value of range forage (with C. Wayne Cook and L. A. Stoddart) *J. Range Mgmt.* 6:51-54. 1953.
52. Wool growth of weanling lambs fed various levels of urea, methionine, and sulfur (with Edward A. Nelson and Milton A. Madsen) *Ut. Acad. Sci. Arts, Letters Proc.* 30:112. 1952-53.
53. Wool growth of weanling lambs fed various levels of urea, methionine, and sulfur (with Milton A. Madsen and Edward A. Nelson) *Am. Soc. Animal Prod., Western Sec. Proc.* 4(xxxii):1-8. 1953.
54. Transmission studies of milk of dairy cows fed toxaphene-treated hay (with G. Q. Bateman, Clyde Biddulph, J. R. Harris and D. A. Greenwood) *Agr. Food Chem.* 1:322-324. 1953.
55. Effect of feeding DDT-treated alfalfa hay to swine and of feeding the swine tissues to rats (with Joseph R. Harris, Ferron L. Mangelson, Delbert A. Greenwood, Clyde Biddulph, Wayne Binns and Merthyr L. Miner) *J. Nutrition* 51:491-505. 1953.
56. Cattle gains and vegetal changes as influenced by grazing treatments on crested wheatgrass (with Neil C. Frischknecht and Harry K. Woodward) *J. Range Mgmt.* 6:151-158. 1953.
57. Feeding rats tissues from lambs and butterfat from cows that consumed DDT-dusted alfalfa hay (with D. A. Greenwood, C. Biddulph, G. Q. Bateman, W. Binns, M. L. Miner, J. R. Harris, F. Mangelson and L. L. Madsen) *Soc. Expt. Biol. Med. Proc.* 83:458-460. 1953.
58. The effect of feeding sucrose to beef cattle and swine on the dressing percentage and quality of meat (with E. B. Wilcox, M. B. Merkley, L. S. Galloway, D. A. Greenwood, W. Binns and J. A. Bennett) *J. Animal Sci.* 12:24-32. 1953.
59. Nutrient requirements of domestic animals number VII. Nutrient requirements of foxes and minks. A report of the Committee on Animal Nutrition (with C. A. Cabell, J. K. Loosli, C. A. Elvehjem and H. C. Schaefer) *Natl. Acad. Sci., Natl. Res. Council. Pub.* 296. 1953.
60. The effect of fluorides on plants and animals (with Carl Frischknecht, Wayne Binns, D. A. Greenwood, M. L. Miner, B. L. Richards and F. B. Wann) *Ut. Agr. Ext. Service Circ.* 179. 1953.
61. Is methionine here to stay? *Feed Age* 3:41-42. 1953.

62. How harmful are the newer insecticides to domestic animals and human beings (with Clyde Biddulph, D. A. Greenwood, C. I. Draper, G. Q. Bateman, George E. Stoddard, Wayne Binns, M. L. Miner, C. J. Sorenson and F. V. Lieberman) *Ut. Agr. Expt. Sta. Farm Home Sci.* 15:38-41. 1954.
63. Studies on a cattle disease of unknown origin in southeastern Utah (with Robert J. Raleigh, Wayne Binns, J. LeGrande Shupe and Louis L. Madsen) *Ut. Acad. Sci. Arts, Letters Proc.* 31:163. 1954.
64. The nutritive value of winter range plants in the Great Basin (with C. W. Cook and L. A. Stoddart) *Ut. Agr. Expt. Sta. Bul.* 372:1-56. 1954.
65. Effects of intake of various amounts of sodium fluoride on dairy heifers — A progress report (with George E. Stoddard, D. A. Greenwood, Wayne Binns, J. L. Shupe and G. Q. Bateman) *Am. Dairy Sci. Assoc. Western Div. Proc.* July, 1954.
66. How well do cattle eat on the range (with Milton A. Madsen and C. Wayne Cook) *Ut. Agr. Expt. Sta. Farm Home Sci.* 15:66-67. 1954.
67. A plan for the distribution of references on nutrition literature. *Ut. State Univ., Logan, Ut.* 1954.
68. Effects of feeding dieldrin- and heptachlor-treated alfalfa hay to dairy cows — A progress report (with G. E. Stoddard, G. Q. Bateman, J. L. Shupe, J. L. Harris, T. H. Bahler and D. A. Greenwood) *Am. Dairy Sci. Assoc. Western Div. Proc.* July, 1954.
69. Effects of various levels and sources of flourine in the fattening ration of Rambouillet, Targhee, and Columbia lambs (with Milton A. Madsen, Ibrahim J. Alkahalisi, LeGrande Shupe, D. A. Greenwood and Wayne Binns) *Am. Soc. Animal Prod., Western Sec. Proc.* 25(LXXXV):1-19. 1954.
70. Studies on a cattle disease of unknown origin in southeastern Utah (with Robert J. Raleigh, Wayne Binns, J. LeGrande Shupe and Louis L. Madsen) *J. Animal Sci.* 14:951-963. 1955.
71. Effect of feeding various levels of fluorine, calcium, phosphorus and grain to dairy heifers from four months of age to thirty-two months of age (with G. E. Stoddard, J. L. Shupe, M. L. Miner, D. A. Greenwood, W. Binns, G. Q. Bateman, H. M. Nielsen and D. C. Strong) *J. Dairy Sci.* 38:626. 1955.
72. Pathology of chronic bovine fluorosis (with J. L. Shupe, M. L. Miner, W. Binns, D. A. Greenwood, H. M. Nielsen, G. E. Stoddard and G. Q. Bateman) *Am. Vet. Med. Assoc. Proc.* 195-201. 1955.
73. Committee on Animal Nutrition, Subcommittee on Fluorosis Problems. P. H. Phillips, D. A. Greenwood, C. A. Hobbs and C. F. Huffman. Committee on Animal Nutrition, L. C. Norris, W. M. Beeson, H. R. Bird, H. M. Briggs, E. W. Crampton, G. K. Davis, T. S. Hamilton, L. E. Harris and J. K. Loosli. The fluorosis problem in livestock production. *Natl. Acad. Sci., Natl. Res. Council. Pub.* 381. 1955.
74. Comparative nutritive value and palatability of some introduced and native forage plants for spring and summer grazing (with C. Wayne Cook and L. A. Stoddart) *Ut. Agr. Expt. Sta. Bul.* 385:1-39. 1956.

75. Composition of concentrate by-product feeding stuffs (with Feed Composition Committee Agricultural Board, Donald F. Miller, H. E. Bechtel, K. C. Beeson, R. V. Boucher, C. F. Huffman, H. L. Lucas, F. B. Morrison, E. M. Nelson and B. H. Schneider) *Natl. Acad. Sci., Natl. Res. Council. Pub.* 449. 1956.
76. Effects of feeding dieldrin- and heptachlor-treated alfalfa hay to dairy cows (with Joseph R. Harris, George E. Stoddard, George Q. Bateman, J. Le-Grande Shupe, Delbert A. Greenwood, Thomas L. Bahler and Frank V. Lieberman) *J. Agr. Food Chem.* 4:694-696. 1956.
77. Serum alkaline phosphatase levels, weight changes, and mortality rates of rats fed endrin (with S. C. Nelson, T. L. Bahler, W. V. Hartwell and D. A. Greenwood) *J. Agr. Food Chem.* 4:696-700. 1956.
78. Stilbestrol increases rate of gain and feed utilization in lambs (with M. A. Madsen and R. J. Raleigh) *Ut. Agr. Expt. Sta. Farm Home Sci.* 17:20, 25, 26. 1956.
79. Terramycin in the fattening ration of lambs (with R. J. Raleigh and M. A. Madsen) *Ut. Agr. Expt. Sta. Farm Home Sci.* 17:67-68. 1956.
80. Feeding phosphorus, protein, and energy supplements to ewes on winter ranges of Utah (with C. Wayne Cook and L. A. Stoddart) *Ut. Agr. Expt. Sta. Bul.* 398:1-28. 1956.
81. Chromic oxide and creatinine as index materials for evaluating ruminant nutrition (with John E. Butcher) *Am. Soc. Animal Prod. Western Sec. Proc.* 7(xxv):1-5. 1956.
82. The effect of the level of nutrition on the pathology and productivity of range sheep (with Donald C. Clanton, Wendall E. Brooksby and Max E. Robinson) *Am. Soc. Animal Prod. Western Sec. Proc.* 7(xLviii):1-10. 1956.
83. Supplementing cattle with protein and phosphorus on desert ranges (with Lynn F. James, John E. Butcher and Laurence A. Stoddart) *Am. Soc. Animal Prod. Western Sec. Proc.* 7(xxxvii):1-7. 1956.
84. A metabolism stall with mechanical separation of feces and urine adjustable to accommodate various size animals (with Robert J. Raleigh and John E. Butcher) *Am. Soc. Animal Prod., Western Sec. Proc.* 7(xxii):1-7. 1956.
85. The effect of feeding various levels of stilbestrol, terramycin, and concentrates to three breeds of fattening lambs (with Don L. Steele, Robert J. Raleigh and Milton A. Madsen) *Am. Soc. Animal Prod., Western Sec. Proc.* 7(xxvii):1-7. 1956.
86. Fluorosis studies with dairy cows — A progress report (with G. E. Stoddard, J. L. Shupe, D. A. Greenwood, M. L. Miner, G. Q. Bateman, H. M. Nielsen and T. V. Bishop) *Am. Dairy Sci. Assoc. Western Div. Proc.* July, 1956.
87. Feeding sweet corn and pea by-products (their value with comparisons) (with Milton E. Andersen) *Ut. Agr. Ext. Service, Fact Sheet* 17. 1956.

UTAH STATE UNIVERSITY

88. Committee on Animal Nutrition, Subcommittee on Dairy Cattle Nutrition, J. K. Loosli, R. B. Becker, C. F. Huffman, P. H. Phillips and J. C. Shaw. Committee on Animal Nutrition, L. C. Norris, W. M. Beeson, H. R. Bird, H. M. Briggs, E. W. Crampton, G. K. Davis, T. S. Hamilton, L. E. Harris and J. K. Loosli. Nutrient requirements of domestic animals number III. Nutrient requirements of dairy cattle. Natl. Acad. Sci., Natl. Res. Council Pub. 604. Revised 1956.
89. Supplementing livestock on desert ranges (with C. Wayne Cook and L. A. Stoddart) *Ut. Agr. Expt. Sta. Farm Home Sci.* 18:36, 37, 45, 47, 56. 1957.
90. Committee on Animal Nutrition, Subcommittee on Sheep Nutrition, A. L. Pope, C. W. Cook, W. E. Dinusson, W. S. Garrigus and W. C. Weir. Committee on Animal Nutrition, L. C. Norris, W. M. Beeson, H. R. Bird, H. M. Briggs, E. W. Briggs, E. W. Crampton, G. K. Davis, T. S. Hamilton, L. E. Harris and J. K. Loosli. Nutrient requirements of domestic animals number V. Nutrient requirements of sheep. Natl. Acad. Sci., Natl. Res. Council. Pub. 504. Revised 1957.
91. Creatinine as an index material for evaluating ruminant nutrition (with John E. Butcher) *J. Animal Sci.* 16:1020. 1957.
92. Influence of protein and phosphorus supplements on range cattle production (with John E. Butcher, Lynn F. James and C. Wayne Cook) *J. Animal Sci.* 16:1059. 1957.
93. Roughage in rations of feeder lambs (with R. J. Raleigh and J. E. Butcher) *Ut. Agr. Expt. Sta. Farm Home Sci.* 18:64-65. 1957.
94. Cattle gains and vegetal changes as influenced by grazing treatments on crested wheatgrass (with R. J. Raleigh, N. C. Frischknecht and J. A. Bennett) *Am. Soc. Animal Prod., Western Sec. Proc.* 8(xLVii):1-6. 1957.
95. A method of feeding supplements to individual cattle on winter range (with J. Carl James and C. Wayne Cook) *J. Animal Sci.* 16:872-876. 1957.
96. Committee on Animal Nutrition, Subcommittee on Beef Cattle Nutrition, Wise Burroughs, Marvel L. Baker, W. P. Garrigus, T. B. Keith, G. P. Lofgreen, A. L. Neumann. Committee on Animal Nutrition, L. C. Norris, W. M. Beeson, H. R. Bird, E. W. Crampton, George K. Davis, Tom S. Hamilton, Lorin E. Harris and J. K. Loosli. Nutrient requirements of domestic animals number IV. Nutrient requirements of beef cattle. Natl. Acad. Sci., Natl. Res. Council Pub. 579. Revised 1958.
97. Effect of various levels and sources of fluorine in the fattening ration of Columbia, Rambouillet and Targhee lambs (with Milton A. Madsen, Delbert A Greenwood, J. LeGrande Shupe and Robert J. Raleigh) *Agr. Food Chem.* 6:365-368. 1958.
98. Feeding dehydrated alfalfa to sheep. *Am. Dehydrators Assoc. Alfalfa Feeding Forum Proc.* Kansas City, Mo. 1958.
99. Availability of the nitrogen of ammoniated beet pulp, urea-phosphoric-acid molasses and cottonseed meal when fed to fattening lambs (with Robert J. Raleigh and John E. Butcher) *Am. Soc. Animal Prod., Western Sec. Proc.* 9(xii):1-6. 1958.

100. Cattle gains and vegetal changes as influenced by grazing treatments on crested wheatgrass over a ten-year period (Neil C. Frischknecht and Robert J. Raleigh) *J. Animal Sci.* 17:156. 1958.
101. Techniques for the determination of energy metabolism in the grazing animal (with Eric Cresswell) *J. Animal Sci.* 17:156. 1958.
102. Composition of cereal grains and forages (with Feed Composition Committee Agricultural Board, Donald F. Miller, H. E. Bechtel, K. C. Beeson, C. F. Huffman, H. L. Lucas, F. B. Morrison, E. M. Nelson and B. H. Schneider) *Natl. Acad. Sci., Natl. Res. Council. Pub.* 585. 1958.
103. Irrigated pastures — a way to maintain beef production (with Milo L. Dew and George Q. Bateman) *Ut. Agr. Expt. Sta. Farm Home Sci.* 19:76, 77, 80. 1958.
104. Committee on Animal Nutrition, Subcommittee on Dairy Cattle Nutrition, J. K. Loosli, R. B. Becker, C. F. Huffman, P. H. Phillips and J. C. Shaw. Committee on Animal Nutrition, L. C. Norris, W. M. Beeson, H. R. Bird, H. M. Briggs, E. W. Crampton, G. K. Davis, T. S. Hamilton, L. E. Harris and J. K. Loosli. Nutrient requirements of domestic animals number III. Nutrient requirements of dairy cattle. *Natl. Acad. Sci., Natl. Res. Council. Pub.* 464. Revised 1958.
105. The effect of intensity of grazing upon nutritive content of the diet (with Rex Pieper and C. Wayne Cook) *J. Animal Sci.* 18:1031-1037. 1959.
106. Symposium on forage evaluation: V. Intake and digestibility techniques and supplemental feeding in range forage evaluation (with C. Wayne Cook and John E. Butcher) *J. Agronomy* 51:226-234. 1959.
107. An improved rangemeter for sheep (with Eric Cresswell) *J. Animal Sci.* 18:1447-1451. 1959.
108. Effect of nutrition on the productivity of range sheep (with D. C. Clanton and J. E. Butcher) *J. Animal Sci.* 18:1416-1429. 1959.
109. A metabolism building for large animals (with John E. Butcher and Robert J. Raleigh) *J. Animal Sci.* 18:1535. 1959.
110. The chemical content in various portions of the current growth of salt-desert shrubs and grasses during winter (with C. Wayne Cook and L. A. Stoddart) *Ecology* 40:644-651. 1959.
111. Water requirements for beef cattle (with J. E. Butcher and Robert J. Raleigh) *Ut. Agr. Expt. Sta. Farm Home Sci.* 18:72-73. 1959.
112. Forage intake, energy measures, and supplementary feeding on the arid ranges of the Great Basin. 8th International Grasslands Congress Proc. Univ. Reading, Berkshire, England. 574-578. July, 1960.
113. Economical water trough and mineral box (with M. L. Dew) *Ut. Agr. Expt. Sta. Farm Home Sci.* 21:82-83. 1960.
114. Committee on Animal Nutrition, Subcommittee on Poultry Nutrition, H. R. Bird, H. J. Almquist, D. R. Clandinin, W. W. Cravens, F. W. Hill and James McGinnis. Committee on Animal Nutrition, L. C. Norris, W. M. Beeson, O. G. Bentley, H. R. Bird, E. W. Crampton, G. K. Davis, R. M. Forbes, L. E. Hanson, L. E. Harris and J. K. Loosli. Nutrient requirements

- of domestic animals number I. Nutrient requirements of poultry. Natl. Acad. Sci., Natl. Res. Council, Pub. 827. Revised 1960.
115. Performance of Hereford steers on irrigated pastures (with Milo L. Dew and George Q. Bateman) *J. Animal Sci.* 19:1305. 1960.
 116. Design of experimental facilities for feeding cattle. *J. Animal Sci.* 20:981. 1961.
 117. A new system for naming and compiling data on the composition of feed-stuffs (with Donald F. Miller) *Am. Soc. Animal Prod., Western Sec. Proc.* 12(LXiii):1-7. 1961.
 118. A new system for naming and compiling data on the composition of feed-stuffs (with Donald F. Miller) *J. Animal Sci.* 20:684. 1961.
 119. Technique for naming and summarizing feedstuffs and the use of such information for calculating diets. *J. Animal Sci.* 20:935. 1961.
 120. Alternatives for soil bank lands in Utah (with N. K. Roberts) *Ut. Agr. Expt. Sta. Farm Home Sci.* 22:68-69, 83-84. 1961.
 121. Dieldrin residue on vegetation in an irrigated pasture (with J. V. Smith, J. C. Street and G. R. Shultz) *J. Econ. Ent.* 54:1091-1096. 1961.
 122. Comparative daily consumption and digestibility of summer range forage by wet and dry ewes (with C. Wayne Cook and James Mattox) *J. Animal Sci.* 20:866-870. 1961.
 123. Improved tracheal cannula for use in indirect calorimetry and other studies (with Eric Cresswell) *Brit. Vet. Rec.* 73:343-344. 1961.
 124. Technique for naming and summarizing feedstuffs and the use of such information in calculating diets. Record Forty-Second Annual Meeting Am. Dairy Sci. Assoc. Western Div. Proc., Moscow, Idaho. 15 pp. July, 1961.
 125. The influence of energy and protein levels on feed utilization by pregnant ewes (with Milo L. Dew and J. E. Butcher) *Am. Soc. Animal Prod., Western Sec. Proc.* 12(xxxv):1-5. 1961.
 126. The influence of energy and protein levels on feed utilization by pregnant ewes (with Milo L. Dew and J. E. Butcher) *J. Animal Sci.* 20:676. 1961.
 127. The influence of various levels of protein and phosphorus on the volatile fatty acid composition of the rumen of sheep (with Paul V. Fannesbeck) *Am. Soc. Animal Prod., Western Sec. Proc.* 12(LXXXIX):1-6. 1961.
 128. The influence of various levels of protein and phosphorus on the volatile fatty acid composition of the rumen of sheep (with Paul V. Fannesbeck) *J. Animal Sci.* 20:680. 1961.
 129. The effect of range condition and intensity of grazing upon daily intake and nutritive value of the diet on desert ranges (with C. Wayne Cook and Kent Taylor) *J. Range Mgmt.* 15:1-6. 1962.
 130. Effect of feeding various levels of fluorine, calcium-phosphorus mineral, and concentrate mix to dairy females from weaning to mature age. I. Growth and feed consumption (with G. E. Stoddard, G. Q. Bateman, J. L. Shupe and D. A. Greenwood) *J. Dairy Sci.* 45:676. 1962.

131. Effect of feeding various levels of fluorine, calcium-phosphorus mineral, and concentrate mix to dairy females from weaning to mature age. II. Milk production (with G. E. Stoddard, G. Q. Bateman, J. L. Shupe and D. A. Greenwood) *J. Dairy Sci.* 45:676. 1962.
132. Ruminal flora studies in the sheep: X. The influence of nitrogen intake upon ruminal function (with R. J. Moir) *J. Nutrition* 77:285-298. 1962.
133. Relative effects of feeding hay atmospherically contaminated by fluoride residue, normal hay plus calcium fluoride, and normal hay plus sodium fluoride to dairy heifers (with James L. Shupe, M. L. Miner and Delbert A. Greenwood) *J. Vet. Res.* 23:777-787. 1962.
134. Measurement of the energy values of pasture and range forage. Chap. 17 in *Pasture and Range Research Techniques*. Comstock Pub. Assoc., Ithaca, New York. 1962.
135. Committee on Animal Nutrition, Subcommittee on Laboratory Animal Nutrition, Paul L. Day, J. Milton Bell, Stanley N. Gershoff, Mary E. Reid, H. C. Schaefer, B. S. Schweigert and Richard G. Warner. Committee on Animal Nutrition, W. M. Beeson, O. G. Bentley, H. R. Bird, E. W. Crampton, George W. Davis, R. M. Forbes, L. E. Hanson, L. E. Harris, J. K. Loosli and L. C. Norris. Nutrient requirements of domestic animals number 10. Nutrient requirements of laboratory animals. *Natl. Acad. Sci., Natl. Res. Council. Pub.* 990. 1962.
136. Committee on Animal Nutrition, Subcommittee on Canine Nutrition, E. E. Rice, James B. Allicon, J. W. Corbin, R. W. Engel and Victor Heiman. Committee on Animal Nutrition, W. M. Beeson, O. G. Bentley, H. R. Bird, E. W. Crampton, G. K. Davis, L. E. Hanson, J. K. Loosli, R. M. Forbes, L. E. Harris and L. C. Norris. Nutrient requirements of domestic animals number 8. Nutrient requirements of dogs. *Natl. Acad. Sci., Natl. Res. Council. Pub.* 909. Revised 1962.
137. Management including feeding of sheep. Chap. 34 in *Introduction to Livestock Production Including Dairy and Poultry*. W. H. Freeman and Co., San Francisco, California. 1962.
138. The measurement of the flow of food in the duodenum of sheep (with A. T. Phillipson) *Brit. J. Animal Prod.* 4:97-116. 1962.
139. Glossary of definitions of energy terms. Committee on Animal Nutrition, *Natl. Acad. Sci., Natl. Res. Council. Pub.* 1040. 1962.
140. The relationship of climate and water to feed utilization by cattle and sheep (with J. E. Butcher) *Am. Soc. Range Mgmt. Proc.* 1962.
141. Effects of fluorine on dairy cattle. II. Clinical and pathological effects (with James L. Shupe, Merthyr L. Miner, Delbert A. Greenwood and George E. Stoddard) *Am. J. Vet. Res.* 24:964-979. 1963.
142. Effects of fluorine on dairy cattle. I. Growth and feed consumption (with G. E. Stoddard, G. Q. Bateman, J. L. Shupe and D. A. Greenwood) *J. Dairy Sci.* 46:1094-1102. 1963.
143. Effects of fluorine on dairy cattle. IV. Milk production (with G. E. Stoddard, G. Q. Bateman, J. L. Shupe and D. A. Greenwood) *J. Dairy Sci.* 46:720-726. 1963.

144. An apparatus for obtaining sustained quantitative collections of urine from male cattle grazing pasture or range (with Jerry R. Border and John E. Butcher) *J. Animal Sci.* 22:521-525. 1963.
145. Symposium on feeds and meats terminology. III. A system for naming and describing feedstuffs, energy terminology and the use of such information in calculating diets. *J. Animal Sci.* 22:535-547. 1963.
146. Effects of fluorine on dairy cattle. V. Fluorine in the urine as an estimator of fluorine intake (with James L. Shupe, Delbert A. Greenwood, John E. Butcher and Harold M. Nielsen) *Am. J. Vet. Res.* 24:300-306. 1963.
147. Effect of various levels of fluorine, stilbestrol, and oxytetracycline in the fattening ration of lambs (with R. J. Raleigh, M. A. Madsen, J. L. Shupe, J. E. Butcher and D. A. Greenwood) *J. Animal Sci.* 22:51-55. 1963.
148. Estimating urine energy from urine nitrogen (with Joseph C. Street and John E. Butcher) *Am. Soc. Animal Sci., Western Sec. Proc.* 1963.
149. A new system for naming feeds and describing energy terminology (with Earle W. Crampton) *Proc. 6th International Congress of Nutrition.* 1963.
150. Committee on Animal Nutrition, Subcommittee on Beef Cattle Nutrition, Wise Burroughs, W. P. Garrigus, T. B. Keith, G. P. Lofgreen and A. L. Neumann. Committee on Animal Nutrition, W. M. Beeson, O. G. Bentley, H. R. Bird, E. W. Crampton, G. K. Davis, R. M. Forbes, L. E. Hanson, L. E. Harris, J. K. Loosli and L. C. Norris. Nutrient requirements of domestic animals number IV. Nutrient requirements of beef cattle. *Natl. Acad. Sci., Natl. Res. Council. Pub. 1137.* Revised 1963.
151. Study of the quantitative fecal recovery of chromic oxide when administered to sheep as a component of paper (with Jerry R. Border and John E. Butcher) *J. Animal Sci.* 22:1117. 1963.
152. Biochemical aspect on the use of para-aminohippuric acid and inulin as a means of assessing renal activity in animals (with F. L. Mangelson, D. A. Greenwood and J. L. Shupe) *Ut. Acad. Sci., Arts, Letters Proc.* 1964.
153. The proposed National Research Council Feed nomenclature system and the Association of American Feed Control Officials definitions. Official Publication, Assoc. Am. Feed Control Officials. p. 104-115. 1964.
154. Fluorosis in cattle (with Delbert A. Greenwood, James L. Shupe, George E. Stoddard, Harold M. Nielsen and L. Elmer Olson) *Ut. Agr. Expt. Sta. Special Report 17.* 1964.
155. Effects of fluorine on dairy cattle. III. Digestion and metabolism trials (with Robert J. Raleigh, George E. Stoddard, Delbert A. Greenwood, J. LeGrande Shupe and Harold M. Nielsen) *J. Animal Sci.* 23:537-546. 1964.
156. Estimating urine energy from urine nitrogen (with Joseph C. Street and John E. Butcher) *J. Animal Sci.* 23:1039-1041. 1964.
157. Committee on Animal Nutrition, Subcommittee on Swine Nutrition, W. M. Beeson, D. E. Becker, E. W. Crampton, T. J. Cunha, N. R. Ellis and R. W. Leucke. Committee on Animal Nutrition, W. M. Beeson, O. G. Bentley, H. R. Bird, E. W. Crampton, G. K. Davis, R. M. Forbes, L. E. Hanson, L. E. Harris, J. K. Loosli and J. H. Meyer. Nutrient requirements of domestic

- animals number II. Nutrient requirements of swine. Natl. Acad. Sci., Natl. Res. Council. Pub. 1192. Revised 1964.
158. Committee on Animal Nutrition, Subcommittee on Sheep Nutrition, A. L. Pope, C. W. Cook, W. E. Dinusson, U. S. Garrigus and W. C. Weir. Committee on Animal Nutrition, W. M. Beeson, O. G. Bentley, H. R. Bird, E. W. Crampton, G. K. Davis, R. M. Forbes, L. E. Hanson, L. E. Harris, J. K. Loosli and J. H. Meyer. Nutrient requirements of domestic animals number V. Nutrient requirements of sheep. Natl. Acad. Sci., Natl. Res. Council. Pub. 1193. Revised 1964.
 159. Joint United States-Canadian Tables of Feed Composition (with E. W. Crampton) Natl. Acad. Sci., Natl. Res. Council. Pub. 1232. 1964.
 160. Extended grazing of crested wheatgrass by cattle (with Neil C. Frischknecht and Earl M. Sudweeks) *Farm and Home Sci.* 26:14-17. 1965.
 161. Effect of range conditions and utilization on nutritive intake of sheep on summer ranges (with C. W. Cook and M. Kothmann) *J. Range Mgmt.* 18:69-73. 1965.
 162. Association of American Feed Control Officials Incorporated. Feed control, Official Publication. Agricultural Laboratories, Capitol Building, Charleston, West Virginia, 1965. NOTE: Dictionary of Feed Terms pp. 32-40 were developed by the Feed Production School Terminology Committee of which Lorin E. Harris was chairman, in collaboration with the Feed Control Officials.
 163. Collection and summarization of feed composition data. I. The NRC feed nomenclature system (with Earle W. Crampton, Arlin D. Knight and Alice Denney) *J. Animal Sci.* 24:884. 1965.
 164. Collection and summarization of feed composition data. II. A proposed source form for collection of feed composition data (with Earle W. Crampton, Arlin D. Knight and Alice Denney) *J. Dairy Sci.* 48:1136. 1965.
 165. Collection and summarization of feed composition data. III. Coding of the source form for compiling feed composition data (with Arlin D. Knight, Earle W. Crampton and Alice Denney) *J. Dairy Sci.* 48:1136. 1965.
 166. Collection and summarization of feed composition data. IV. Computer summarization of feed composition data (with Arlin D. Knight and Earle W. Crampton) *J. Animal Sci.* 24:891-892. 1965.
 167. Effects of protein and shelter on finishing cattle (with L. C. Kearl and J. E. Butcher) *J. Animal Sci.* 24:856. 1965.
 168. The NRC system for naming feeds, energy terminology, and the use of such information when calculating diets (with Earle W. Crampton, Arlin D. Knight and Alice Denney) *Proc. 25th Annual Meeting Nutrition Council. Am. Feed Mfgs. Assoc., Chicago.* p. 26-30. 1965.
 169. Indices of the efficiency of rumen fermentation of sheep grazing desert range forage as influenced by supplements of nitrogen and phosphorus (with J. G. Morris, J. E. Butcher and C. W. Cook) *J. Animal Sci.* 24:1152-1158. 1965.

170. Seasonal grazing of crested wheatgrass by cattle (with Earl M. Sudweeks and Neil C. Frischknecht) *Am. Soc. Animal Sci., Western Sec. Proc.* 16(Lxxix):1-6. 1965.
171. Energy and protein terminology. *Proc. 16th Annual School for Feed Men*, sponsored by Univ. of Wisconsin and Wisconsin Feed, Seed and Farm Supply Assoc. p. 66-83. 1965.
172. Names of feeds (with E. W. Crampton) *Feed Age* 15:30-34. 1965.
173. Committee on Animal Nutrition, Subcommittee on Rabbit Nutrition, S. E. Smith, R. B. Casady and E. E. Donefer. Committee on Animal Nutrition, W. M. Beeson, O. G. Bentley, H. R. Bird, E. W. Crampton, G. K. Davis, R. M. Forbes, L. E. Hanson, L. E. Harris, J. K. Loosli and J. H. Meyer. Nutrient requirements of domestic animals number IX. Nutrient requirements of rabbits. *Natl. Acad. Sci., Natl. Res. Council. Pub. 1194.* Revised 1966.
174. Committee on Animal Nutrition, Subcommittee on Dairy Cattle Nutrition, J. K. Loosli, R. B. Becker, C. F. Huffman, N. L. Jacobson and J. C. Shaw. Committee on Animal Nutrition, W. M. Beeson, O. G. Bentley, H. R. Bird, E. W. Crampton, G. K. Davis, R. M. Forbes, L. E. Hanson, L. E. Harris, J. K. Loosli and J. H. Meyer. Nutrient requirements of domestic animals number III. Nutrient requirements of dairy cattle. *Natl. Acad. Sci., Natl. Res. Council. Pub. 1349.* Revised 1966.
175. Committee on Animal Nutrition, Subcommittee on Poultry Nutrition, H. R. Bird, H. J. Almquist, D. R. Clandinin, W. W. Cravens, F. W. Hill and James McGinnis. Committee on Animal Nutrition, W. M. Beeson, O. G. Bentley, H. R. Bird, E. W. Crampton, G. K. Davis, R. M. Forbes, L. E. Hanson, L. E. Harris, J. K. Loosli and J. H. Meyer. Nutrient requirements of domestic animals number I. Nutrient requirements of poultry. *Pub. 1345.* Revised 1966.
176. Digestible protein estimation for NRC feed composition tables (with Arlin D. Knight) *Am. Soc. Animal Prod., Western Sec. Proc.* 17:283-288. 1966.
177. Mineral supplementation on crested wheatgrass (with Earl M. Sudweeks and Neil C. Frischknecht) *Am. Soc. Animal Prod., Western Sec. Proc.* 17: 421-426. 1966.
178. Digestible protein estimation for NRC feed composition tables (with Arlin D. Knight) *J. Animal Sci.* 25:593. 1966.
179. Mineral supplementation on crested wheatgrass (with Earl M. Sudweeks and Neil C. Frischknecht) *J. Animal Sci.* 25:599. 1966.
180. Biological energy interrelationships and glossary of energy terms. *Natl. Acad. Sci., Natl. Res. Council. Pub. 1411.* First revised edition, p. 1-35. 1966.
181. Committee on Animal Nutrition, Subcommittee on Horse Nutrition, R. M. Forbes, J. E. Corbin, G. P. Lofgreen, W. H. Pfander, L. E. Washburn. Committee on Animal Nutrition, W. M. Beeson, O. G. Bentley, H. R. Bird, E. W. Crampton, G. K. Davis, R. M. Forbes, L. E. Hanson, L. E. Harris, J. K. Loosli, J. H. Meyer. Nutrient requirements of domestic animals number vi. Nutrient requirements of horses. *Pub. 1401.* Revised 1966.

182. Committee on Animal Nutrition, Subcommittee on Hormones, M. T. Clegg, P. J. Dziuk, Joseph Meites, Martin Stob and M. X. Zarrow. Committee on Animal Nutrition, W. M. Beeson, O. G. Bentley, H. R. Bird, E. W. Crampton G. K. Davis, R. M. Forbes, L. E. Hanson, L. E. Harris, J. K. Loosli and J. H. Meyer. Hormonal relationships and application in the production of meats, milk, and eggs. Natl. Acad. Sci., Natl. Res. Council. Pub. 1415. Supplement 1966.
183. Collection and summarization of feed composition data. III. Coding of a source form for compiling feed composition data (with Arlin D. Knight, Earle W. Crampton and Alice Denney) J. Dairy Sci. 49:1548-1556. 1966.
184. Botanical and nutritive content of diets of cattle and sheep under single and common use on mountain range (with C. Wayne Cook and Melvin C. Young) J. Animal Sci. 26:1169-1174. 1967.
185. Collection and summarization of feed composition data. II. A proposed source form for collection of feed composition data (with Earle W. Crampton, Arlin D. Knight and Alice Denney) J. Animal Sci. 26:97-105. 1967.
186. Biuret digestion in sheep (with D. C. Tomlin and J. E. Butcher) Am. Soc. Animal Sci., Western Sec. Proc. 18:207-211. 1967.
187. Refinements in the *in vivo* bag rumen technique (with D. C. Tomlin and M. J. Anderson) Am. Soc. Animal Prod., Western Sec. Proc. 18:291-296. 1967.
188. Effect of supplements on nutrient intake of range forage (with C. Wayne Cook) J. Animal Sci. 26:934. 1967.
189. Techniques for range livestock nutrition research (with V. R. Bohman, G. P. Lofgreen, C. J. Kercher and R. J. Raleigh) Ut. Agr. Expt. Sta. Bul. 471. 1967.

THIRTY-SIXTH FACULTY HONOR LECTURE DELIVERED AT THE UNIVERSITY

JANUARY 17, 1968

A basic objective of The Faculty Association of the Utah State University, in the words of its constitution, is:

to encourage intellectual growth and development of its members by sponsoring and arranging for the publication of two annual faculty research lectures in the fields, or (1) the biological and exact sciences, including engineering, called the Annual Faculty Honor Lecture in the Natural Sciences; and (2) the humanities and social sciences, including education and business administration, called the Annual Faculty Honor Lecture in the Humanities.

The administration of the University is sympathetic with these aims and shares the costs of publishing and distributing these lectures.

Lecturers are chosen by a standing committee of the Faculty Association. Among the factors considered by the committee in choosing lecturers are, in the words of the constitution:

(1) creative activity in the field of the proposed lecture; (2) publication of research through recognized channels in the field of the proposed lecture; (3) outstanding teaching over an extended period of years; (4) personal influence in developing the character of the students.

Dr. Harris was selected by the committee to deliver the Annual Faculty Honor Lecture in the Natural Sciences. On behalf of the members of the Association we are happy to present Doctor Harris' paper:

RANGE NUTRITION IN AN ARID REGION

Committee on Faculty Honor Lecture

OTHER LECTURES IN THE SERIES

THE SCIENTIST'S CONCEPT OF THE PHYSICAL WORLD
by Willard Gardner

IRRIGATION SCIENCE: THE FOUNDATION OF
PERMANENT AGRICULTURE IN ARID REGIONS
by Orson W. Israelson

NUTRITIONAL STATUS OF SOME UTAH
POPULATION GROUPS
by Almeda Perry Brown

RANGE LAND OF AMERICA AND SOME RESEARCH
ON ITS MANAGEMENT
by Laurence A. Stoddart

MIRID-BUG INJURY AS A FACTOR IN DECLINING
ALFALFA-SEED YIELDS
by Charles J. Sorenson

THE FUTURE OF UTAH'S AGRICULTURE
by W. Preston Thomas

GEOLOGICAL STUDIES IN UTAH
by J. Stewart Williams

INSTITUTION BUILDING IN UTAH
by Joseph A. Geddes

THE BUNT PROBLEM IN RELATION TO
WINTER WHEAT BREEDING
by Delmar C. Tingey

THE DESERT SHALL BLOSSOM AS THE ROSE
by D. Wynne Thorne

THE TEACHING OF SCIENCE
by Sherwin Maeser

THE BEGINNINGS OF SETTLEMENT IN CACHE VALLEY
by Joel Edward Ricks

GENETICS OF CANCER
AND OTHER ABNORMAL GROWTHS
by Eldon J. Gardner

OBLIGATIONS OF HIGHER EDUCATION TO THE
SOCIAL ORDER
by Ernest A. Jacobsen

SOME EFFECTS OF FLUORIDES ON PLANTS,
ANIMALS, AND MAN
by Delbert A. Greenwood

THE POLITICAL PROCESS
by M. R. Merrill

RANGE LIVESTOCK NUTRITION AND ITS IMPORTANCE
IN THE INTERMOUNTAIN REGION
by C. Wayne Cook

SOME ECONOMIC FALLACIES AND THE CITIZEN
by Evan B. Murray

UTAH'S FUTURE WATER PROBLEMS
by Wayne D. Criddle

MOTIVATION IN LEARNING
by Arden N. Frandsen
(not published in this series)

GOOD NUTRITION FOR THE FAMILY
by Ethelwyn B. Wilcox

ZION IN PARADISE — EARLY MORMONS
IN THE SOUTH SEAS
by S. George Ellsworth

STUDIES IN EXPERIMENTAL EVOLUTION
by William Sidney Boyle

WATER FOR MAN
by Sterling A. Taylor

THE SEMANTICS OF STRESS AND PITCH IN ENGLISH
by George A. Meyer

THE PRICE OF PREJUDICE

by Leonard J. Arrington

BEAR LAKE AND ITS FUTURE

by William F. Sigler

THE RESPONSIBLE EXERCISE OF CREATIVE POWER

by Carlton Culmsee

THE SECRETS OF VIRAL REPRODUCTION

by George W. Cochran

THE SEARCH FOR CONSENSUS

by M. Judd Harmon

COCCIDIOSIS OF CATTLE — SOME UNSOLVED PROBLEMS

by Datus M. Hammond

COMMITMENTS IN MARRIAGE

by Don C. Carter

MAN AND HIS WATER RESOURCE

by Dean F. Peterson

JACK LONDON: MASTER CRAFTSMAN OF THE
SHORT STORY

by King Hendricks

A MODERN PHILOSOPHER'S STONE

by Grant Gill Smith

NATIONAL GOALS AND
HUMAN RESOURCES DEVELOPMENT

by Vernon L. Israelsen



*Sir, I am a true laborer: I earn that I eat, get that I wear,
owe no man hate, envy no man's happiness, glad of other
men's good, content with my harm, and the greatest of
my pride is to see my ewes graze and my lambs suck.*

SHAKESPEARE — *As You Like It*

