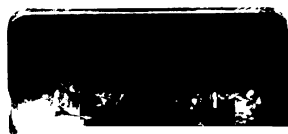


THE ECONOMIC FEASIBILITY OF
SUPPLEMENTING BROOD COWS AND
YEARLING STEERS WITH PROTEIN,
MINERALS AND VITAMINS WHILE
GRAZING FROSTED WINTER PASTURES

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
CHARLES KELLER ALLEN
1972

1000000



ABSTRACT

THE ECONOMIC FEASIBILITY OF SUPPLEMENTING BROOD COWS AND YEARLING STEERS WITH PROTEIN, MINERALS AND VITAMINS WHILE GRAZING FROSTED WINTER PASTURES

By

Charles Keller Allen

Three grazing trials and two nitrogen balance trials were conducted concurrently to test the value of two commercially available liquid supplements for supplementing cows and steers while grazing winter pastures in Argentina. Two types of pasture, Agropirum elongatum (agropero) and leoti red (sorghum), were used. Two supplements, one containing 35% crude protein equivalent having 80% derived from urea and 20% pre-formed protein sources, "Pro-Lix", and one containing 30% crude protein equivalent having 100% derived from urea, "Rico-30", were compared to a control (no protein supplement).

A total of 250 yearling steers were assigned to five treatment groups. Three of the five groups were assigned to sorghum pastures and the other two groups assigned to agropero pastures. "Pro-Lix", "Rico-30" and a no supplement control were fed to the steers grazing sorghum while only "Pro-Lix" and the control treatments were used with agropero pastures.

Almost all of the yearling steers grazing sorghum lost weight during the experiment. The "Pro-Lix" steers lost the

least weight and the control steers had the greatest losses. All of the differences among treatments in total weight loss were significant ($P < 0.05$).

The agropero steers gained weight during the experiment. The control steers outgained the "Pro-Lix" steers during the first half of the experiment but this advantage was more than offset by the significantly higher ($P < 0.05$) weight gains of the "Pro-Lix" steers during the last half of the experiment.

Thirty lactating Angus cows and 20 non-lactating Angus cows were assigned to each of the three supplements ("Pro-Lix", "Rico-30" and control) and grazed on adjacent sorghum pastures. There was virtually no difference in weight changes of the non-lactating and lactating cows regardless of whether they were supplemented or not. However, the calves nursing cows receiving "Pro-Lix" supplement gained significantly more weight ($P < 0.05$) than the calves in either the "Rico-30" or control groups.

The plasma carotene and vitamin A levels were used to predict the vitamin status of a random sample of animals in each group. The mid-experiment and final blood collections were taken from the same animals selected at the beginning of the experiment. There were no significant differences among the different supplemental groups for any of the plasma vitamin A analysis. The plasma carotene concentration of the agropero control steers was significantly ($P < 0.05$) higher than "Pro-Lix" steers on the same pasture. Although not

significant, there was a trend for the plasma carotene concentration of the controls to exceed the carotene level of the supplemented animals in all experiments.

The nitrogen balance of the control treatment was negative for both the agropuro and sorghum forages. The dry-matter intake was greater for the supplemented steers on both forages, but only the differences on agropuro were statistically significant ($P < 0.05$). There were no significant differences among any of the supplements for dry-matter digestibility.

THE ECONOMIC FEASIBILITY OF SUPPLEMENTING
BROOD COWS AND YEARLING STEERS
WITH PROTEIN, MINERALS AND VITAMINS
WHILE GRAZING FROSTED WINTER PASTURES

by

Charles Keller Allen

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Animal Husbandry

1972

G75405

Charles Keller Allen
candidate for the degree of
Master of Science

DISSERTATION: The Economic Feasibility of Supplementing
Brood Cows and Yearling Steers with Protein,
Minerals and Vitamins while Grazing Frosted
Winter Pastures

OUTLINE OF STUDIES:

Major Area: Animal Husbandry (Ruminant Nutrition)

Minor Subject: Biochemistry

BIOGRAPHICAL ITEMS:

Born: December 15, 1942; Independence, Virginia

Undergraduate Studies: Virginia Polytechnic Institute,
1965-1969

Graduate Studies: Michigan State University, 1969-1972

MEMBER: American Society of Animal Science

ACKNOWLEDGMENTS

The author extends his deep appreciation to Dr. Hugh E. Henderson for his valued guidance and counsel during his graduate program.

The author is also indebted to Dr. William T. Magee and Dr. Richard W. Luecke, as members of his graduate committee, for their sound advice and participation in his graduate program.

The author also wishes to thank Dr. Ronald H. Nelson and Dr. J. A. Hoefer for making the facilities of Michigan State University and the Michigan Agricultural Experiment Station available for this research.

Appreciation is extended to all members of the Department of Animal Husbandry for their kindness and hospitality.

The author is indebted to ProRico Industries of Mobile, Alabama, for providing the materials used and for providing the author's expenses during the course of this research.

The author is also indebted to Dr. Raul Haumüller of Rosario, Argentina and Sr. Raul Firpo of Buenos Aires for their assistance in conducting this research and for providing the cattle and facilities used.

TABLE OF CONTENTS

	<u>Page</u>
List of Tables	vi
List of Figures	vii
I. Introduction	1
II. Literature Review	4
Use of Frosted Winter Pastures	4
Urea as a Protein Supplement	5
Self-Feeding	10
Vitamin A	11
Summary	14
III. Materials and Methods	15
<u>Experiment 1 - Supplementation of Steers</u>	
<u>Grazing Sorghum (leoti red) Pastures</u>	17
Design	17
Method of Supplementation	17
Pasture	20
Management	20
Carotene and Vitamin A Determination	20
<u>Experiment 2 - Supplementation of Steers</u>	
<u>Grazing Agropero (Agropirum elongatum)</u>	
Pastures	21
Design	21
Method of Supplementation	22
Pasture	22
Management	23
<u>Experiment 3 - Cows and Calves Grazing</u>	
<u>Sorghum Pastures</u>	23
Design	23
Method of Supplementation	23
Pasture	23
Management	24
<u>Experiments 4 and 5 - Nitrogen Balance</u>	
<u>Studies</u>	25
Design	25
Facilities	25
Feeding Regime and Sample Collections	26
Laboratory Analysis	27
<u>Statistical Analysis</u>	27

Table of Contents (Cont.)

	<u>Page</u>
IV. Results and Discussion	28
<u>Experiment 1 - Steers Grazing Sorghum</u>	
<u>Pastures</u>	28
Supplement and Feed Intake	28
Weight Changes	32
Plasma Carotene and Vitamin A	
Concentrates	35
<u>Experiment 2 - Steers Grazing Agropero</u>	
<u>Pastures</u>	38
Supplement and Feed Intake	39
Weight Changes	40
Carotene and Vitamin A	43
<u>Experiment 3 - Cows and Calves Grazing</u>	
<u>Sorghum Pastures</u>	46
Supplement and Feed Intake	47
Weight Changes of Non-Lactating Cows	48
Weight Changes of Lactating Cows	50
Weight Changes of Calves	52
Carotene and Vitamin A of Cows	54
<u>Experiments 4 and 5 - Nitrogen Balance</u>	
<u>Studies</u>	56
Feed and Supplement Analysis	56
Drymatter Intake and Digestibility	58
Nitrogen Balance	58
V. Summary	61
Bibliography	65

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1 Analysis of Supplements Used	16
2 Ingredients of the Supplements Used	16
3 Analysis of Pro-Lix Mineral	18
4 Number of Animals Starting and Finishing Experiment and Reasons for Removal from Experiment	29
5 Crude Protein Levels Found in Representative Samples of Experimental Pastures	30
6 Supplement Consumption of Animals in Experiments 1 through 3	31
7 Weight Changes of Steers on Sorghum Pasture	33
8 Cost of Supplement Necessary to Make Supple- mentation Profitable for Steers Wintered on Sorghum	35
9 Plasma Carotene and Vitamin A Concentrations of Sorghum Steers	36
10 Weight Changes of Steers on Agropero Pasture	41
11 Cost of Supplement Necessary to Make Supple- mentation Profitable for Steers Wintered on Agropero	43
12 Plasma Carotene and Vitamin A Concentration of Agropero Steers	44
13 Weight Changes of Non-Lactating Cows	49
14 Weight Changes of Lactating Cows	51
15 Weight Changes of Calves	53
16 Carotene and Vitamin A of Cows	55
17 Drymatter and Crude Protein Levels of Forage and Supplements Offered and Forage not Con- sumed by Cattle on Nitrogen Balance Studies	57
18 Actual Treatment Means for Metabolic Study	59

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Supplement Feeder Used for Sorghum Steers and Cows	19
2	Wheel Type Feeder Initially Used for Agro-pero Steers	22
3	One of the 6 Collection Stalls Used in the Metabolic Studies	25

I. INTRODUCTION

Argentina is one of the great agricultural producers and exporters of the world. It is the world's leading supplier of beef and accounts for approximately 7.5% of the beef exports. Argentina is also a strong competitor in international markets for meat products, hides and animal fats. During the ten years from 1956 to 1965, the export of beef, cattle hides and live cattle accounted for 24.9% of the average annual value of total Argentine exports.

There was approximately 47 million cattle in Argentina in 1966. These cattle provided beef and dairy products for a population of 22.85 million and contributed approximately 25% of the total exports. Total food production in Argentina increased 20% from the 1952-56 average until 1966, but the per capita food production actually declined 2% during that same period.

The agricultural resources of Argentina are extensive and varied. The country extends south from a latitude of $21^{\circ} 46' 55''$. It is 2,300 miles long and 884 miles wide at the widest point. The total land area of continental Argentina is 279.2 million hectares, of which 175 million hectares or 63% is in farms. Average annual rainfall and seasonal temperatures are extremely varied among different areas. The mean annual rainfall ranges from 10 cm at San Juan in the northwest to 165 cm at Posadas in the northeast.

The mean July and January temperatures for different regions range from 25° to 62° F. and from 49° to 83° F., respectively. Only 24% of the land area is classified as humid, while 15% is considered semi-arid and 61% arid.

The most productive agricultural area in Argentina is the Pampa. This is the predominant crop area and also contains over 80% of the country's cattle. The Pampa corresponds to a rough semicircle with a radius of about 550 kilometers around the city of Buenos Aires. The Pampa is naturally divided into two parts, humid and semiarid, accounting respectively for 63 and 37% of the regional area.

Beef production is very extensive and Argentina's beef potential is much greater than present production. Sixty-three percent of the land in farms consist of natural pasture with only 6% of the farmland comprised of improved pastures. Presently, almost all slaughter cattle are finished on grass and go to market between two and three years of age.

On a typical estancia or ranch in the Pampa, the brood cows and yearling steers are wintered on low quality frosted grass pastures without supplementation. The yearling cattle usually lose weight during the winter. The average calving percentage of the cows is approximately 60% or in herds that breed cows all year, the average calving interval is about 15 months.

It was hypothesized that economic production traits could be greatly enhanced if cattle grazing frosted winter

pastures had access to a supplement formulated to correct the nutritional deficiencies of the winter pasture.

Therefore, the objectives of this study were:

- 1) To test the above stated hypothesis;
- 2) To determine the nutritive value of frosted grass pastures;
- 3) To compare the relative value of two different sources of supplemental protein -- one having 100% of its crude protein equivalent derived from urea and the other, 80% from urea and 20% from organic sources of protein; and
- 4) To determine changes occurring in blood serum levels of vitamin A and carotene.

II. LITERATURE REVIEW

The use of frosted winter pastures as a source of winter feed in the United States has been limited primarily to the western states and to native bluestem pastures. Pinney et al. (1962c) reported that samples of native grasses consistently showed that the forage produced during the winter period is deficient in energy, protein and phosphorus. They found that by December, native grass in Oklahoma had lost 80% or more of the protein and phosphorus it contained during early growth. A study during 1942 and 1943 showed that the percent protein in the drymatter of native bluestem grass declined from a high of 9% in May to a low of 2.6% in February (Hobbs et al. 1945). Wallace et al. (1970) found that the diets of cattle grazing pastures in the sand hills of Colorado were deficient in digestible protein and marginal in metabolizable energy in September. By December, the diet was grossly deficient in both energy and protein.

In contrast to Argentina, protein supplementation of cattle on winter pasture is a common practice in the United States. Hobbs et al. (1945) reported that supplements of cottonseed cake not only provided adequate protein but also increased the digestibility of the forage. Campbell et al. (1969), in a nitrogen balance study, found that the digestibility of the organic matter, crude protein, nitrogen free extract and gross energy in the total ration increased with

higher levels of natural protein. Several other workers have observed an increase in digestibility following a more liberal feeding of protein supplements to ruminants (Swift et al., 1947; Gallup and Briggs, 1948; Burroughs et al., 1949).

Wintering pregnant or lactating cows on native grasses and very low levels of supplement has been shown to increase cow weight losses, decrease weaning weights, delay the average calving date and decrease the percent calf crop (Pinney et al., 1962a; Nelson et al., 1962; Speth et al., 1962; and Ludwig et al., 1967). Nelson et al. (1962) also found that cows wintered in a trap on prairie hay performed better than cows grazing dry grass. In addition, Pinney and associates (1962b) reported that the producer who feeds out his own calves (as is common in Argentina) would profit by not wintering their dams on an extremely low level.

Meyer et al. (1965) reported that compensatory gain offset some of the disadvantages incurred by wintering steers on a low energy level immediately after weaning. However, the total energy requirement was higher and the total days required to slaughter was greater for the low level group. Steers in this study wintered on the low level diet did not lose weight as is common with steers wintered in Argentina.

Urea as a Protein Supplement

Feeding trials with cattle (Bartlett and Cotton, 1938; Hart et al., 1939; Rupel et al., 1943; Willet et al., 1946; Briggs et al., 1947; Dinning et al., 1949; and Brown et al.,

1956] have demonstrated the usefulness of urea as a nitrogenous supplement for partially meeting the protein needs of ruminants. Nitrogen balance experiments (Harris and Mitchell, 1941; Johnson et al., 1942; Harris et al., 1943; Hamilton et al., 1948 and Arias et al., 1951) have added further information showing that limited amounts of urea can be converted into useful protein. Urea is particularly suited as a feed ingredient since it is economical, odorless material of high nitrogen content and biological availability (Belasco, 1954).

Numerous studies at the Michigan Station (Henderson et al., 1960; 1968a; 1968b and 1970) have shown that urea can not only replace part of the supplemental protein but also substantially reduce the total feed cost for feedlot steers. Other workers (Ewing and Burroughs, 1963 and Martin et al., 1968) have shown that urea can also be used in the rations of breeding cattle to reduce feed cost without sacrificing optimal performance.

In contrast, experiments in Oklahoma have shown that urea is not as efficiently utilized as natural proteins for wintering cattle on native grass. This was true for both steers (Nelson et al., 1961) and lactating cows (Miller et al., 1958; Williams et al., 1968). Williams and co-workers (1968) thought that the reason that previous Oklahoma work had failed to show good urea utilization was due to the low level of energy in the ration. Newland et al. (1961) reported a slight depression in gains and feed

efficiency when urea made up 100% of supplemental protein.

In order to make the most efficient use of urea as a nitrogen supplement to poor quality roughages, a readily available source of carbohydrate appears necessary (McKnaught and Smith, 1947; Bell et al., 1953; Reid, 1953; and Belasco, 1956). Arias et al. (1951) reported that increasing the energy content of the fermentation mixture resulted in an increased urea utilization with all sources of energy tested. This was true regardless of whether the energy source was a soluble carbohydrate such as dextrose or sucrose, or whether the carbohydrate was more complex such as the cellulose of a high fiber feed. It was observed that small amounts of a readily available carbohydrate aided cellulose digestion, which in turn increased urea utilization, whereas large amounts of readily available carbohydrate, inhibited cellulose digestion.

Burroughs et al. (1950) found cane molasses to exert a favorable effect on the digestion of cellulose in an artificial rumen. Willet and et al. (1946) found that when cane molasses constituted 25% of the concentrates in the ration of the dairy cow, urea was utilized very efficiently. Bowstead and Freedon (1948) reported that molasses was essential for the utilization of urea included in the rations of their dairy cows. Tillman et al. (1951) reported that animals receiving liquid molasses made satisfactory gains while those receiving dehydrated molasses did not make satisfactory gains. However, Mills and associates (1942, 1944)

reported that starch and the cereal grains were more desirable than sugar (molasses) as a source of carbohydrates in urea containing rations.

Gallup et al. (1954) compared the additions of urea and soybean meal to a high molasses ration and found that both additions improved digestibility and nitrogen retention. However, the soybean meal addition had the greatest effect. Blackstrap molasses fed at the level of 10% of drymatter intake to fattening cattle was efficiently utilized, but increasing the level of molasses to 20% or above caused a marked depression on feed consumption, weight gains and net energy values (Lofgreen and Otagaki, 1960; and Lofgreen, 1965).

The superiority of starch over molasses in vivo may mean that simple sugars tend to be washed out of the rumen or to be absorbed more rapidly than the less soluble polysaccharides, resulting in less exposure to the micro-organisms. On the other hand cellulose (an insoluble polysaccharide) is probably attacked too slowly to make it a ready source of energy for microbial multiplication (McKnaught and Smith, 1947).

The relative cost of different grains and other high energy sources must be considered when formulating a practical supplement. Molasses is a very inexpensive (2 to 3 cents per kilogram) source of energy in Argentina (Haumüller, 1969). Detailed discussions of the carbohydrate component of urea rations can be found in comprehensive reviews by

McKnaught and Smith (1947), Owen (1951) and Arias (1951). Johnson et al. (1942) reported that supplements containing corn molasses depressed the digestibility of the ration but enhanced the utilization of urea. Bell et al. (1953) reported the efficiency of urea utilization was lowest when fed with molasses and was approximately equal when fed with the various cereal grains and sweet potatoes.

Tillman et al. (1951) combined urea with liquid molasses and reported that urea did not alter the palatability of the molasses. The urea-molasses treatment group had gains and feed efficiencies that were slightly below the corn-cottonseed meal control group. However, the differences were not significant ($P < 0.05$).

Commercial liquid supplements composed of molasses, urea, phosphorus, trace minerals and vitamins were first introduced to the United States in 1951 (Beeson and Perry, 1970). Feedlot test with beef steers by Perry et al. (1967), Gay and Vetter (1967) and Kercher and Paulus (1967) have shown no significant difference in the nutritive value (as measured by cattle response) to high-urea solid or liquid supplements when the supplements and/or rations contain the same essential nutrients in the proper balance.

Beeson et al. (1964a and 1964b), Beeson and Perry (1969) and Perry and Beeson (1968) reported the existence of unidentified urea protein factors (UPF). The addition of both dehydrated alfalfa meal and distillers grain solubles increased nitrogen retention, feed efficiency and average

daily gain (Beeson and Perry, 1969; Beeson et al., 1968 and 1969; and Perry et al., 1969). In other work, Beeson and Perry (1969 and 1970) verified the effectiveness of dehydrated alfalfa meal on increasing urea utilization in liquid supplements.

Perry et al. (1969) found a slight but non-significant increase average daily gain by adding fish solubles to a high urea liquid supplement. Burroughs et al. (1969) also reported improved performance when fish solubles were added to high urea liquid supplements, but found no advantage to adding fish solubles to high urea dry supplements.

Self-Feeding

Labor requirements and cost can be decreased if the intake of supplements can be regulated so they may be self fed. Weir and Miller (1953) compared a self-fed mixture of 25% salt and 75% cottonseed meal to an equal amount of cottonseed meal fed to ewes under drylot conditions. There was no difference in the performance of the ewes or their lambs and no evidence of salt toxicity. A later trial conducted under range conditions and utilizing the same supplements (Weir and Torrell, 1953) gave similar results. Riggs et al. (1953) reported that salt-cottonseed meal mixtures for beef cows had no adverse effects and that a higher salt intake may have a beneficial effect upon the digestibility of all nutrients.

Currently, many of the liquid supplements available

commercially use phosphoric acid both as a source of phosphorus and to regulate intake. Phosphoric acid was first introduced into liquid supplements in 1896 when Goldby, a British scientist, obtained a patent on a liquid feed containing a combination of beet molasses and phosphoric acid (Beeson and Perry, 1970).

Menzies et al. (1955) conducted studies with steers using a mixture of molasses and phosphoric acid to supply small amounts of energy and phosphorus. Their studies indicate that phosphoric acid has a high biological availability for cattle. Bhattacharga and Warner (1967) demonstrated the ability of phosphoric acid to significantly reduce the intake of supplemental feed.

Vitamin A

The importance of vitamin A as a nutrient in all classes of livestock has been reported by many research workers. Watkins et al. (1950) stated that vitamin A deficiency will develop in range cows on typical western ranges only after periods of prolonged drought. However, Riggs (1940), working with young cattle on diets devoid of carotene and vitamin A, reported depletion of vitamin A stores in as little as 46 days. It has long been recognized that aging, weathering and bleaching of forages destroys the carotene and/or vitamin A (Flora, et al., 1939).

Some of the most obvious vitamin A deficiency symptoms, from an economic point of view, are blindness, reproductive

impairment and decreased rate of gain. Numerous studies (Guilbert and Hart, 1935; Flora et al., 1939; Sutton et al., 1940; and Hodgson et al., 1964) have shown that blindness and/or reproductive impairment can result from vitamin A deficiency. Sutton and associates (1940) also noted a marked decrease in the incidence of pneumonia when calves on a diet deficient in vitamin A or carotene were fed supplemental vitamin A. In addition, supplemental vitamin A has also been shown to increase weight gains when rations are marginal or deficient in vitamin A (Beeson et al., 1961; Smith et al., 1961; Perry et al., 1962; and Chapman et al., 1964). Although vitamin A addition to the ration does not always increase performance (Weichenthal et al., 1963) it is a relatively inexpensive nutrient and is frequently included in the ration when there is doubt about the vitamin A status of the animals in question.

Several workers have indicated that vitamin A deficiency could be diagnosed by blood analysis (Moore, 1939; Davis and Madsen, 1941; Kuhlman and Gallup, 1942; Braun, 1945; and Pope et al., 1958), or that there was a direct or indirect relationship between plasma and hepatic vitamin A levels (Frey et al., 1947; Hoefer and Gallup, 1947; Almquist, 1952; and Rousseau et al., 1958). However, Ralston and Dyer (1959), after studying bovine plasma and hepatic vitamin A levels in several areas of the state of Washington, concluded that hepatic stores of vitamin A could not be determined by plasma analysis alone. In addition, Bodansky and

Markart (1951) found measurable amounts of vitamin A in rat plasma although the liver was entirely depleted.

Wheeler et al. (1957) reported that pregnant cows accumulate large stores of vitamin A when grazing spring range which will supply their vitamin A needs during winter even though very low levels of carotene and vitamin A are available in their winter rations. However, they speculated that vitamin A deficiency might occur in young calves that are nursing their dams when they are not permitted to consume at least small quantities of hay or other carotene bearing feeds.

Studies by Guilbert and Hart (1935) and Baker et al. (1953) showed that cows with low liver stores maintained on a low carotene diet were unable to secrete sufficient vitamin A in the milk to protect their nursing calves against avitaminosis A. In a follow-up experiment, Baker et al. (1954) found that the vitamin A content of the milk seemed more closely related to dietary carotene intake during lactation than to differential liver stores resulting from various levels of carotene intake preparturition.

It appears that ruminant animals are poor converters of carotene to vitamin A (Tillman, 1962). Similarly, Myers et al. (1959) reported that there was a greater storage response to vitamin A than to carotene. Therefore, it is logical to provide supplemental compounds in the form of vitamin A rather than in the form of carotenoids.

Summary

Poor quality, weathered forages have been found to be deficient in energy, protein, phosphorus and vitamin A. The performance of cattle can be improved by proper supplementation of these nutrients. Although performance may be maximized by using cereal grains and natural protein, supplement cost may be greatly reduced by utilizing urea and molasses.

Liquid high urea supplements have been found to have equal feeding value to dry high urea supplements as long as both rations contain the same nutrient balance. Performance of cattle on high urea rations may be improved by the addition of dehydrated alfalfa, distillers solubles or fish solubles as a source of unidentified-urea protein factors (UPF).

Self-feeding supplements with an ingredient such as salt or phosphoric acid added as an intake control has been reported to give equal performance without any harmful side effects. In addition, phosphoric acid has been shown to be a readily available source of phosphorus.

The performance of cattle can be improved by providing adequate intakes of vitamin A unless they already have sufficient hepatic stores. The performance of nursing calves may be improved by providing them or their dams with an adequate intake of vitamin A or carotene.

III. MATERIALS AND METHODS

Three grazing trials and two nitrogen balance trials were conducted concurrently to test the value of two commercially available liquid supplements for supplementing cows and steers while grazing winter pastures in Argentina. The supplements used were supplied by ProRico Industries of Mobile, Alabama, and are sold under the trade names of "ProLix" and "Rico 30". The ingredients and analysis of these supplements are shown in Tables 1 and 2. Funds for travel and other expenses associated with this study were provided by ProRico Industries.

The trials were initiated just after the first frost in the fall of 1969 and were terminated when the grass turned green in the spring of 1969. The grazing experiments involved 150 Angus cows, 90 of them with calves, and 250 Angus steers on two types of pasture. The two nitrogen balance studies were 3 x 3 latin squares using three steers each, three supplements each and two different forages. All of the cows included in the grazing trials were maintained on native pastures 30 to 60 days prior to the experiment. The experimental steers were maintained on corn aftermath pastures for 60 days prior to the experiment. Materials and methods are presented under experimental headings.

Table 1.--Analysis of Supplements Used

Nutrient	Pro-Lix		Rico-30	
Crude Protein, minimum	35.0	%	30.0	%
Protein Equivalent from NPN, max.	27.0	%	28.0	%
Fat, minimum	0.70	%	---	
Fiber	---		---	
Sugar (invert), minimum	35.0	%	35.0	%
Vitamin A (U.S.P. units/mg), min.	44.0		38.5	
Vitamin D (U.S.P. units/mg), min.	11.0		11.0	
Vitamin E (I.U./kg), minimum	30.3		30.3	
Calcium, minimum	0.52	%	0.52	%
Phosphorus, minimum	0.51	%	0.51	%
Phosphorus, maximum	1.50	%	1.50	%
Cobalt, minimum	0.0003	%	0.0003	%
Copper, minimum	0.006	%	0.006	%
Iron, minimum	0.02	%	0.02	%
Magnesium, minimum	0.22	%	---	
Manganese, minimum	0.0008	%	---	
Zinc, minimum	0.00085	%	---	
Iodine, minimum	0.00025	%	---	
Ash, maximum	10.0	%	10.0	%

Table 2.--Ingredients of the Supplements Used

Ingredients in Both Pro-Lix and Rico-30	Ingredients in Pro-Lix Only
Molasses	Fish Solubles
Urea	Fermentation Solubles
Phosphoric Acid	Brewers Yeast
Vitamin A Palmitate	Manganese Sulfate
D-Activated Plant Sterol (D ²)	Zinc Sulfate
Copper Sulfate	Ethylene Diamine Dihydroiodide
Cobalt Sulfate	

Experiment 1 -- Supplementation of Steers Grazing Sorghum
(leotl red) Pastures

Design: A total of 250 steers were randomly assigned to five groups 60 days prior to initiating the experiment. At the beginning of the experiment all steers were individually weighed and identified. The first 50 steers were assigned to one group, the next 50 were assigned to a second group and the process continued until 50 steers had been assigned to each of five groups. The steers were identified by both the neck tag number and numerical brands.

Three of the five groups were assigned to sorghum pastures and the other two groups were assigned to agropero (Agropirum elongatum) pastures. The three sorghum groups were randomly assigned to one of three supplements: "Pro-Lix", "Rico-30", and a no supplement control. Each treatment group was then randomly assigned to one of three adjacent sorghum pastures of 50 hectares each.

Method of Supplementation: All experimental animals were offered a "Pro-Lix" mineral supplement for 60 days prior to the initiation of the experiment. The guaranteed analysis of this mineral mix is shown in Table 3. After the experiment was started, all the groups receiving liquid supplements were continued ad libitum on "Pro-Lix" mineral mix. On August 15, the "Pro-Lix" mineral mix was depleted and the cattle were changed to a mineral supplement of one-half salt and one-half bone meal.

The liquid supplement was fed ad libitum for the first

Table 3.--Analysis of Pro-Lix Mineral

Ingredient	Quantity
Phosphorus, minimum	15.00 %
Calcium, minimum	15.00 %
Calcium, maximum	18.00 %
Sodium Chloride, minimum	9.00 %
Sodium Chloride, maximum	10.00 %
Magnesium	0.50 %
Sulfur	0.20 %
Zinc	0.15 %
Manganese	0.20 %
Copper	0.02 %
Iodine	0.01 %
Iron	0.25 %
Cobalt	0.02 %
Fluorine	0.19 %
Mineral ingredients	91.75 %
Vitamin A (U.S.P. units/mg)	220.3
Vitamin D ₂ (U.S.P. units/mg)	56.1
Vitamin E ² (I.U./kg)	110.1

three weeks in a feeder identical to that shown in Figure 1. After the first three weeks, the amount of supplement was regulated by gravity-flow from the storage tank to the feed pan below. Enough supplement was dispensed every other day to amount to approximately 900 grams per steer per day.



Figure 1.--Supplement Feeder Used for Sorghum Steers and Cows

Pasture: The sorghum pasture had been previously grazed to the extent that there was very little grain remaining. The forage was badly weathered and very little of it was still standing. Forage samples were taken for laboratory analysis on July 1, August 15 and October 1.

Representative samples were taken from various areas of the field and pooled at each sample date. Samples were thoroughly mixed, subsampled and ground in an electric blender. The sample was then analyzed for crude protein by the micro-Kjeldahl procedure. Drymatters were determined by oven drying the forage at 110°C for 24 hours.

Original plans called for a carotene analysis of all forage samples. However, this was not possible because of insufficient equipment and the extensive treatment required to bring forage samples back to the United States would have destroyed most of the carotene present.

Management: The steers were weighed on June 26, August 14 and September 30. All weights were taken after the steers had been corralled overnight without feed or water.

All animals were vaccinated for Aftosa and Anthrax during the experiment. They were also sprayed twice at a 14-day interval for external parasites.

Carotene and Vitamin A Determination: Jugular blood samples were taken from the first 15 steers from each treatment group as they came through the chute at the time of the first weighing. Additional blood samples were taken from the same steers at the second and third weighing. To prevent

clotting, 2 ml of heparin were added to each blood sample and mixed thoroughly. The samples were then chilled and taken to a laboratory in Rosario (approximately 250 kilometers) before being centrifuged and the serum separated with a Pasteur type pipet. The serum was immediately frozen and held for less than 30 days before it was analyzed for carotene and vitamin A.

After thawing, 3 ml serum were treated with absolute ethanol and the carotenoids and vitamin A were extracted with petroleum ether. The sample was then centrifuged, an aliquot taken, and the percent absorbance determined at 440 nm on the spectronic 20. The concentration of carotene was determined from a standard curve of β -carotene. Each sample was duplicated.

The ether was evaporated by use of a vacuum oven at 60°C and the vitamin A concentration determined by utilizing the color reaction of Carr and Price (1926). The vitamin A and carotene was dissolved in chloroform, antimony trichloride was added and the percent absorbance read immediately at 620 nm. The concentration of vitamin A was determined from a standard curve of vitamin A acetate.

Experiment 2 -- Supplementation of Steers Grazing Agropero (Agropirum elongatum) Pastures

Design: The two groups of steers assigned to agropero pasture were randomly assigned to one of two supplements: "Pro-Lix" and a no supplement control. They were then

randomly allotted to one of two adjacent 50 hectare pastures. After the mid-experimental weight was taken, the pastures were alternated to minimize pasture effects.

Method of Supplementation: Mineral supplementation was the same as for the sorghum steers. The liquid supplement was first offered in the wheel type self-feeder shown in Figure 2. However, it was difficult to get steers started on the wheel type feeder and their daily consumption was very low. The agropero steers were changed to the feeder shown in Figure 1 after two weeks and the supplement was fed ad libitum from this feeder for the remainder of the trial.

Pasture: The agropero pasture had not been grazed during the previous six months and there was an excessive amount of forage available. Pasture samples were taken and analyzed in the same manner as described in Experiment 1.

Figure 2.--Wheel Type Feeder Initially Used for Agropero Steers



Management: The management and determinations of plasma vitamin A and carotene concentrations were identical to that described for Experiment 1.

Experiment 3 -- Cows and Calves Grazing Sorghum Pastures

Design: A 3 x 2 factorial design was utilized to study the effect of providing supplement to cows on winter pasture. The same three treatments were used for cows as for the sorghum steers in Experiment 1. Thirty lactating Angus cows with calves and 20 pregnant Angus cows were randomly assigned to each treatment group in the same manner as described for the steer groups. The three groups were then assigned to one of three adjacent 50 hectare pastures. Since there appeared to be a difference in the quantity of forage in the three pastures, the cows were rotated from one pasture to another every two weeks to minimize pasture effects.

Method of Supplementation: The liquid supplements were fed ad libitum for the first two weeks and consumption was in excess of 1 kg per cow per day. After the first two weeks supplement consumption was regulated to approximately 900 grams per cow per day and 225 grams per calf per day. The same type of feeder was used for the cows as described for the sorghum steers (Figure 1) and the cow groups were provided minerals in the same manner as the sorghum steers.

Pasture: The pasture had been managed the same and was very similar to the sorghum that the steers grazed in Experiment 1. Pasture samples were taken and analyzed in

the same manner as described for the sorghum steers.

Management: The cows were weighed on July 1, August 15 and October 1. All weights were taken after the cows had been separated from water and feed overnight. Jugular blood samples were taken from the first eight lactating and the first seven pregnant cows to come through the chute at the time of the first weighing. Blood samples were taken from the same cows on the second and third weigh dates. All blood samples were treated as described in Experiment 1.

There were no records as to which calf belonged to a particular cow and the calves had to be separated by observation. During this process, six calves were either lost or failed to be identified. The cows whose calves were never found were carried through the experiment and their performance was analyzed along with the pregnant non-lactating cows.

On July 5, the cows and calves were brought back to the corral in groups. The calves were weighed and identified with a neck tag of the same color as their dams. A cow and her offspring were paired as the calves nursed after they had been separated from their dams overnight. The second and final weights of the calves were taken on the same day that the cows were weighed.

The spraying and vaccination of the cows and calves were done on the same days and in the same way as for the sorghum steers.

Experiments 4 and 5 -- Nitrogen Balance Studies

Design: A 3 x 3 latin square design was utilized for a nitrogen balance study on both agropero and sorghum forages. The trial was initiated on August 3 and terminated on October 6. Six yearling Angus steers averaging 231 kg at the start of the trials were utilized in these experiments.



Figure 3.--One of the 6 collection stalls used in the metabolic studies.

Facilities: Six individual stalls (Figure 3) were constructed for the nitrogen balance studies. They were approximately 60 cm wide and 200 cm long. The feed container was made by placing a partition across the concrete floor of the stall, 45 cm from the front. A recessed area was placed in the center of the stall floor. The recessed area sloped sharply and served to catch urine and deliver it to a screen

covered plastic bucket outside the stall.

The steers were kept in the stalls for 3 weeks at first to adjust them to the conditions and to the presence of men. They were then returned to pasture for two weeks while final modifications were made on the stalls. When the steers were returned on August 3, they started their first two week adaptation period to the diet. The first week was spent in a ten meter by ten meter pen, after which they were moved to the collection stalls for another week of adaptation and a week of collection. Each animal occupied the same stall throughout the experiment so that the stall effects were confounded with animal differences.

Feeding regime and sample collections: The steers were fed roughage (agropero or sorghum) ad libitum. The feed containers were filled at 8 a.m., 11 a.m., 2 p.m. and 5 p.m. daily. The unconsumed forage was removed, sampled and weighed on both the third and final day of collections.

The forage fed was collected weekly throughout the experiment from experimental pastures used in the grazing trials. The forage was harvested or collected by hand and stored in burlap sacks. Samples were taken from each sack of forage as it was weighed. All sorghum samples were pooled for one period and subsampled for lab analysis. The agropero samples were handled in an identical fashion.

Total fecal collections were made by collecting the feces after it had dropped to the concrete floor of the stalls. The feces was collected the first thing every

morning and throughout the day. Feces were stored in a bucket until they were weighed and a sample taken for lab analysis each morning.

Total urine excretion was collected in a screen covered bucket which contained 30 ml of 6 normal sulfuric acid. The total volume was measured daily and diluted to five liters with water. A one liter sample of the diluted urine from each of the seven days was saved until the end of the collection period when a subsample was taken from the pooled samples.

Laboratory Analysis: Drymatter of the forage offered, the forage refused and the feces were determined by drying the samples at 110°C for 24 hours.

Total nitrogen of all dry forage samples and dry feces was determined by the micro-Kjeldahl procedure after they had been pulverized by an electric blender. The same method was used to determine the total nitrogen of the urine samples.

Statistical Analysis

All data reported in this dissertaion were analyzed on an IBM 3600 computer at the Michigan State University Computer Laboratory. Analysis of variance procedures were used in all experiments, and Duncan's New Multiple Range Test was used to test for significant differences between means.

IV. RESULTS AND DISCUSSION

Experiment 1 - Steers Grazing Sorghum Pastures

Complete results of this experiment are shown in Tables 4 through 9. Only 146 of the 150 steers that were allotted to sorghum pastures finished the experiment (Table 4). One of the "Pro-Lix" steers broke his leg while being sprayed and had to be removed from the experiment on August 2. Three of the steers (2 control and 1 "Pro-Lix") died within a period of 8 days during the experiment (August 6, 7 and 13). The cause of death was not positively established, but anthrax was suspected. Subsequently, all experimental animals were vaccinated for anthrax and no other death or illness was observed in the steer groups.

Supplement and Feed Intake: As shown in Table 5, the crude protein analysis of the sorghum was relatively constant from period to period. However, the forage appeared to be composed of primarily stalks and roots at the end of the trial. Since most of the digestible protein contained in sorghum is found in the leaf blades and grains (Quinby and Marion, 1966) it is probable that the digestible protein decreased as the trial progressed. As expected, the actual crude protein levels found in this severely weathered forage (4 - 4.6%) is substantially below the 8.3% requirement given by the National Research Council (1970). The deficiency of protein in weathered, winter forage is in agreement with

Table 4.--Number of Animals Starting and Finishing Experiment and Reasons for Removal from Experiment.

Type of Animal	Treatment	Assigned to Treatment	Calves Lost Prior to First Wt. Experiment	Dying During Experiment	Transferred to or from Group	Removed for Other Reasons	Finishing Experiment
Lac. Cow	Control	30	-	- ²	3	-	27
	Rico-30	30	-	2	4	-	24
	Pro-Lix	30	-	-	3	-	27
Non-Lac. Cow	Control	20	-	-	3	- ³	23
	Rico-30	20	-	-	4	1 ³	23
	Pro-Lix	20	-	-	3	1 ¹¹	22
Calves	Control	30	2	1 ⁴	-	1 ⁷	26
	Rico-30	30	3	1 ⁵	-	-	26
	Pro-Lix	30	1	1 ⁶	-	-	27
Sorghum Steers	Control	50	-	2 ⁸	-	-	48
	Rico-30	50	-	- ⁹	-	-	50
	Pro-Lix	50	-	1	-	1 ¹⁰	48
Agropero Steers	Control	50	-	-	-	-	50
	Rico-30	50	-	-	-	-	50

¹ If a calf was lost the cow was treated as a non-lactating cow. ² Both of these cows exhibited tetany-like symptoms. ³ Calved prior to termination of experiment. ⁴ Very small calf -- died of pneumonia. ⁵ Cause of death unknown. ⁶ Both calves died early during experiment, of unknown cause. ⁷ Leg broken while being worked. ⁸ Suspected anthrax. ⁹ Cause unknown. ¹⁰ Broken leg. ¹¹ Injured during mid-experiment weight and removed from experiment.

other work previously cited.

Wallace and Denham (1970) and Harris et al. (1957) have reported that the nutritive value of representative samples of forage may be misleading because the diet of cattle on range may differ significantly from total herbage available. Cook et al. (1948) reported that a much higher quality forage is consumed than chemical analysis of bulk samples would

Table 5.--Crude Protein Levels Found in Representative Samples of Experimental Pastures.*

Experiment	Initial Analysis	Mid-Experiment Analysis	Final Analysis
Date of Samples	June 30	August 14	October 2
1 (sorghum steers)	4.0	4.2	4.6
2 (Agropero steers)	5.1	4.0	4.5
3 (sorghum cows)	3.4	4.5	4.4

*All values are expressed on a 100% drymatter basis.

indicate. In spite of these recognized limitations of representative forage samples, the extremely low protein content of the forages (Table 5) does indicate a need for protein supplementation especially if the forages are to be used for young cattle.

After three weeks of ad libitum supplement feeding, the amount of "Pro-Lix" and "Rico-30" offered was limited so that the average daily intake per steer (Table 6) was 833.8 and 818.7 g for the "Rico-30" and "Pro-Lix" treatments,

Table 6.--Supplement Consumption of Animals in Experiments 1 through 3.

Experiment	Supplement	Days on Expt.	Animal Days	Total Con- sumption ²	Daily Animal Consumption	Total Animal Consumption
1 (sorghum steers)	Rico-30	96	4800	4002	833.8	80.0
1	Pro-Lix	96	4745	3880	817.7	78.5
2 (Agropero steers)	Pro-Lix	96	4800	2700	562.5	54.0
3 (sorghum cows)	Rico-30	93	4590 (2449) ⁴	3728	705.4 ⁵	--
3	Pro-Lix	93	4602 (2558) ⁴	4136	787.4 ⁵	--

31

¹Includes animals removed from experiment.

²Kilograms

³Grams

⁴Number of calf days are shown in parenthesis.

⁵Assuming each calf consumed 200 g per day.

respectively. The daily supplement intake was below that originally planned and was a result of the approximate nature of the release of supplement from the storage tank to the feed pan of the supplement feeder. The "Pro-Lix" supplement is 5% higher in crude protein equivalent than "Rico-30" (35% versus 30%). Therefore, the actual crude protein equivalent provided per day was 286 g for "Pro-Lix" and 250 g for "Rico-30".

Weight Changes: The weight changes of the sorghum steers are shown in Table 7. The average initial weight was 240.6, 240.8 and 243.0 kg for the control, "Rico-30", and "Pro-Lix" steers, respectively. There was no significant difference in initial weight.

The control steers lost an average of 3.3 kg during the first 49 days of the experiment while the "Rico-30" steers gained 4.2 kg and the "Pro-Lix" steers gained 2.7 kg. The difference between the "Pro-Lix" and "Rico-30" treatments were not significant, but both groups of supplemented steers performed significantly better than the control steers ($P < 0.05$). During the first period, 30 of the control steers lost weight while only 17 "Rico-30" steers and 18 "Pro-Lix" steers lost weight.

During the second half of the experiment, the forage was much sparser, the weather was colder and all but 10 of the 146 steers grazing sorghum lost weight. Eight of the steers that did not lose weight were in the "Pro-Lix" treatment group and two were in the "Rico-30" treatment group.

Table 7.--Weight Changes of Steers on Sorghum Pasture^{1,2}

	Treatments		
	Control	Rico-30	Pro-Lix
No. of Steers	48	50	48
Initial Wt. (6/26)	240.6	240.8	243.0
Mid-Expt. Wt. (8/14)	237.3 ^{a,b}	245.0 ^a	245.6 ^b
Days on Test	49	49	49
Av. Gain Since Initial Wt.	-3.3 ^{a,b}	4.2 ^a	2.7 ^b
No. of Steers Losing Wt.	30	17	18
Final Wt. (9/30)	218.1 ^a	231.9 ^a	238.1 ^a
Days Since Last Wt.	47	47	47
Av. Gain Since Last Wt.	-19.2 ^a	-13.1 ^a	-7.5 ^a
No. of Steers Losing Wt.	48	48	40
Total Days on Test	96	96	96
Total Gain on Test	-22.5 ^a	-8.9 ^a	-4.9 ^a
No. of Steers Losing Wt.	48	41	37

¹All weights and gains are kilograms.

²Values with the same superscripts and in the same row are significantly different ($P < 0.05$).

The average weight losses during the last period were 19.2, 13.1 and 7.5 kg for the control, "Rico-30" and "Pro-Lix" groups respectively. All of the differences in final weights, weight losses during the second period and total weight losses were significant ($P < 0.05$). The control steers lost an average of 22.5 kg during the experiment while the "Rico-30" and "Pro-Lix" treatment lost an average of only 8.9 and 4.9 kg respectively.

Table 8 shows the necessary cost of the supplements relative to the price of cattle to justify providing supplements. The cost of 5.9 kg of "Rico-30" would have to be less than the price of a kilogram of cattle to justify supplementing steers with "Rico-30" when they are wintered on sorghum pastures under conditions similar to this experiment. Similarly, the total cost of 4.5 kg of "Pro-Lix" would have to be less than the price of one kilogram of live beef to make "Pro-Lix" supplementation profitable. In other words, if cattle are selling for \$0.25 per kg (a typical Argentine price) then "Rico-30" would have to sell for less than \$0.042 per kg and "Pro-Lix" would have to sell for less than \$0.056 per kg to be profitable.

It should be emphasized that these figures pertain only when similar cattle are fed the same level of supplement and under similar conditions. This was a very atypical year in Argentina. There was an abundant rainfall during the early winter and this apparently helped the agropero pastures and lessened the value of the sorghum pastures.

In a typical year, steers grazed on sorghum perform much better than the sorghum steers in this experiment and steers grazed on agropero perform much worse than the agropero steers in this experiment (Haumüller, 1969). In addition, it is probable that feeding supplements at different levels would give entirely different results.

Table 8.--Cost of Supplement Necessary to Make Supplementa-
tion Profitable for Steers Wintered on Sorghum.

	Treatments		
	Control	Rico-30	Pro-Lix
Av. Total Wt. Gain (Table 7)	-22.5 ¹	-8.9	-4.9
Av. Wt. Advantage	--	13.6	17.6
Av. Supplement Consumption (Table 6)	--	80.0	78.5
Relative Value of Supplement ²	--	5.9	4.5

¹All weights are kilograms.

²Kilograms of supplement required to produce 1 kilogram wt. advantage over the controls.

Plasma Carotene and Vitamin A Concentrations: The plasma carotene and vitamin A values of the steers on sorghum pasture are in general agreement with the ranges reported by Lexlesz (1939), Wheeler et al. (1957), Beeson et al. (1961), Wellenreiter et al. (1969) and Ullrey et al. (1970). The average initial and mid-experiment vitamin A levels for the sorghum steers (Table 9) were above the concentrations

Table 9.--Plasma Carotene and Vitamin A Concentrations of Sorghum Steers^{1,2}

	Treatments		
	Control	Rico-30	Pro-Lix
No. of Steers Sampled	15	15	14
Date: June 26			
Initial Plasma Carotene	316	309	363
Standard Error	28.4	28.4	28.4
Initial Plasma Vitamin A	29.2	27.0	32.4
Standard Error	3.8	3.8	3.8
Date: August 14			
Mid-Expt. Plasma Carotene	215	161	185
Standard Error	16.5	16.5	16.5
Mid-Expt. Plasma Vitamin A	30.3 ^a	32.8	39.0 ^a
Standard Error	2.3	2.3	2.3
Date: September 30			
Final-Plasma Carotene	469	440	384
Standard Error	24.8	24.8	24.8
Final Plasma Vitamin A	14.4	12.4	15.4
Standard Error	1.8	1.8	1.8

¹All carotene and vitamin A values are mcg/100 ml plasma.

²Values with the same superscript are significantly different (P < 0.05).

reported as adequate for normal health and growth by Moore (1939), Davis and Madsen (1941) and Kohlmer and Burroughs (1970). These workers reported the minimal adequate plasma vitamin A values as 20 to 25 mcg per 100 ml of blood plasma. The "Pro-Lix" treatment had a significantly higher ($P < 0.05$) plasma vitamin A concentration at the mid-experiment determination, but there were no other significant differences among the treatments for measures of plasma vitamin A and carotene.

The final plasma vitamin A levels were below the 20 to 25 mcg per 100 ml plasma that was reported as normal, but no clinical symptoms of vitamin A deficiency were observed. Providing vitamin A in the supplement to the "Pro-Lix" and "Rico-30" treatments did not help to avoid a decrease in plasma vitamin A levels. These results are in agreement with work reported by Smith et al. (1964) who found that plasma vitamin A levels were not significantly affected by diet. Ullrey and co-workers (1970) found virtually no difference in plasma concentrations of vitamin A injected cows when compared with cows that received no vitamin A injections (24.2 and 24.4 mcg per 100 ml, respectively). In contrast, several experiments have demonstrated the dependence of plasma vitamin A and carotene concentrations on both previous stores and current intake (Davis and Madsen, 1941; Kuhlman and Gallup, 1942; Braun, 1945 and Pope et al., 1958).

Similar to the final plasma carotene concentrations

in this study, Ullrey et al. (1970) found high plasma carotene values (428 and 445 mcg per 100 ml) associated with low plasma vitamin A levels (19.6 and 20.9 mcg per 100 ml) at the time initial samples were taken. In all other work reviewed the ratio of carotene concentration to vitamin A concentration was much lower. The analysis used for carotene did not discriminate between the various carotenoids and the amount of vitamin A that they can be converted to. This is probably one of the factors responsible for the variability of carotene-vitamin A ratios found in blood plasma.

There is disagreement in the literature concerning the effect of protein or nitrogen level in the ration on vitamin A and carotene metabolism. Rechcigl et al. (1962), Erwin et al. (1963) and Smith et al. (1964) reported that plasma vitamin A concentrations were depressed by high levels of protein or urea in the diet. In contrast, Gallup and associates (1950 and 1951) reported that the level of urea in the diet had no effect on carotene and vitamin A utilization. The failure of the supplemented groups to respond with higher plasma vitamin A concentrations may be due to an interaction with the nitrogen or nitrogen compounds in the diet.

Experiment 2 - Steers Grazing Agropero (Agropirum elongatum)

Pastures

Complete results of the parameters measured of the two groups grazing agropero pastures are shown in Tables 4

through 6 and Tables 10 through 12. All 50 steers in both the control and "Pro-Lix" treatments completed the experiment (Table 4).

Supplement and Feed Intake: As shown in Table 5 the crude protein levels of the agropero samples declined from 5.1% to 4.0% during the experiment. The agropero pastures were highly variable in the type of forage available. It is doubtful that the forage analyzed was truly representative of the forage consumed. The herbage consisted primarily of dry, dead older growth and a green undergrowth. The steers exhibited a preference for the younger grass, but it was not possible to accurately sample the relative amount of the two types of forage consumed. This observation is supported by the results of Cook et al. (1948) who reported that sheep consumed a much higher quality forage than shown in the bulk samples that were analyzed.

The final forage sample was collected just after grass started to turn green in the spring and this probably accounts for the increase in crude protein from 4.0% during the middle of the experiment to 4.5% crude protein in the drymatter of the forage at the end of the trial. The protein level of all agropero samples analyzed was below the 7.8% requirement listed by the National Research Council (1970).

The "Pro-Lix" supplement was provided ad libitum to the agropero steers throughout the experiment. The daily consumption of "Pro-Lix" per steer (562.5 g) was considerably

lower than the expected daily consumption of approximately 900 g (Table 6). This was especially true during the first two-thirds of the trial when the daily consumption of "Pro-Lix" per steer was only 500 g. The steers were consuming approximately 800 g per day when the experiment was terminated.

Weight Changes: The weight gains of the agropero steers are shown in Table 10. The average initial weight was 242.4 kg for the control and 236.7 kg for the "Pro-Lix" steers. The difference in initial weight was not significant.

The weight gains were inconsistent as the control steers gained significantly ($P < 0.05$) more weight than the "Pro-Lix" steers during the first 49 days and the "Pro-Lix" steers gained significantly ($P < 0.05$) more than the control steers in the second half of the experiment. The total gain of the "Pro-Lix" steers (23.4 kg) was significantly ($P < 0.05$) higher than the total gain of the control steers (17.5 kg). The average mid-experiment weight of the control steers was significantly ($P < 0.05$) higher than the "Pro-Lix" steers. However, there was virtually no difference between the treatment groups for final weight. In contrast with the weight losses found with steers grazing sorghum only two of the steers grazing agropero lost weight during the experiment (Table 10).

The pastures used for the agropero steers were changed at the time of the mid-experiment weight so that each group grazed each of the two pastures for one-half of the experiment.

Table 10.--Weight Changes of Steers on Agroporo Pasture^{1,2}

	Treatments	
	Control	Pro-Lix
No. of Steers	50	50
Initial Wt. (6/26)	242.4	236.7
Mid-Expt. Wt. (8/14)	254.6 ^a	241.5 ^a
Days on Test	49	49
Av. Gain Since Initial Wt.	12.3 ^a	4.8 ^a
No. of Steers Losing Wt.	4	14
Final Wt. (9/30)	259.9	260.2
Days Since Last Wt.	47	47
Av. Gain Since Last Wt.	5.2 ^a	18.7 ^a
No. of Steers Losing Wt.	11	0
Total Days of Test	96	96
Total Gain on Test	17.5 ^a	23.5 ^a
No. of Steers Losing Wt.	2	0

¹All weights and gains are kilograms.

²Values with the same superscripts and in the same row are significantly different ($P < 0.05$).

Therefore, part of the difference in performance of the treatment groups may have been a result of the pasture being grazed. The two agropero pastures used were adjacent and there were only minor observable differences between them.

The agropero steers were infected with mange during the first 30 days of the experiment. All experimental animals were sprayed twice at a 14 day interval for external parasites after detection of the mange infestation. The mange infestation appeared much more severe in the agropero steers than in any of the other experimental groups. The agropero steers receiving "Pro-Lix" supplement appeared to have a more severe infestation than the control steers.

Brannon and associates (1954) reported that the feeding of molasses depressed the intake of herbage. It is doubtful that this finding explains the decreased gain of the "Pro-Lix" steers in the first half of the experiment since the supplemented steers outgained the controls during the last half of the trial. Further, several workers have reported that increasing the protein content of a low protein diet increases the feed intake and weight gains (Ross et al., 1954; Bush et al., 1955; and Woods et al., 1956).

Table 11 shows the necessary cost of "Pro-Lix" relative to the price of live beef to justify feeding "Pro-Lix" to steers grazing agropero pastures under the conditions of this experiment. The cost of 9 kg of "Pro-Lix" would have to be less than the price of 1 kg of live cattle to have been profitable in this experiment. Steers wintered on

agropero in Argentina usually lose weight (Haumüller, 1969) so it is doubtful that the 9:1 ratio of supplement to beef is truly representative of the value of supplement over a number of years.

Table 11.--Cost of Supplement Necessary to Make Supplementation Profitable for Steers Wintered on Agropero¹

	Treatments	
	Control	Pro-Lix
Av. Total Wt. Gain (Table 10)	17.5	23.5
Av. Weight Advantage over Control	--	6.0
Av. Supplement Consumption (Table 6)	--	54.0
Relative Value of Supplement ²	--	9.0

¹All weights are kilograms.

²Kilograms of supplement required to produce 1 kilogram wt. advantage over the controls.

Carotene and Vitamin A: The carotene and vitamin A concentrations of the blood plasma for the agropero steers are shown in Table 12. The final plasma vitamin A values were below the 20-25 mcg per 100 ml reported as minimal for normal health and growth by Moore (1939) and Davis and Madsen (1941). There were no clinical symptoms of vitamin A deficiency observed during the experiment. The final plasma vitamin A concentrations were similar for the sorghum and agropero steers in spite of the fact that the sorghum steers lost weight and the agropero steers gained weight. This observation indicates that vitamin A deficiency was not

Table 12.--Plasma Carotene and Vitamin A Concentration
of Agropero Steers^{1,2}

	Treatments	
	Control	Pro-Lix
No. of Steers Sampled	15	15
Date: June 26		
Initial Plasma Carotene	294	279
Standard Error	23.9	23.9
Initial Plasma Vitamin A	26.1	27.9
Standard Error	3.4	3.4
Date: August 14		
Mid-Expt. Plasma Carotene	449 ^a	329 ^a
Standard Error	26.9	26.9
Mid-Expt. Plasma Vitamin A	47.7	41.2
Standard Error	3.8	3.8
Date: September 30		
Final Plasma Carotene	459 ^a	320 ^a
Standard Error	22.5	22.5
Final Plasma Vitamin A	19.4	17.7
Standard Error	2.1	2.1

¹All carotene and vitamin A values are mcg/100 ml plasma.

²Values with the same superscript are significantly different (P < 0.05).

the reason for the weight loss of the sorghum steers.

The plasma vitamin A concentrations were much higher during the middle of the experiment than at either the initial or final determinations. All steers were maintained on corn aftermath pastures for 60 days prior to the initiation of the experiment and the relatively low plasma vitamin A and carotene concentrations at the initiation of the experiment are probably a result of low carotene in the diet.

The increased plasma vitamin A and carotene concentrations during the first half of the experiment for the agropero steers was probably due to an increased level of carotene in the forage. In contrast, the plasma carotene concentrations in the sorghum steers decreased during the first half of the experiment (Table 9). The experimental design included plans for carotene determination of all forage samples. However, these plans had to be abandoned due to a lack of equipment and the fact that the stringent treatment required to bring any biological material back to the United States would have destroyed most of the carotene present.

There was no significant difference between the two treatments in any of the vitamin A determinations. However, the control steers had a significantly higher ($P < 0.05$) plasma carotene concentration at both the mid-experiment and final analysis. This tendency was also observed in the sorghum steers. The control steers received all of their

vitamin A in the form of carotene from the forage consumed while the supplemented groups received vitamin A in the form of vitamin A in the supplement. The increased dietary vitamin A levels of the supplemented steers may have resulted in a decreased absorption of carotene and therefore explain the differences among treatment combinations in the plasma carotene concentrations.

Experiment 3 - Cows and Calves Grazing Sorghum Pastures

Results of this experiment are shown in Tables 4 - 6, 13, 14, and 16. This experiment was analyzed in 3 units: lactating cows, non-lactating cows and calves. All cows and calves receiving the same supplement were run together. Since the cows whose calves were never found were continued on the experiment as non-lactating cows, the number of cows completing the experiment was different than originally planned and varied among treatments (Table 4). There were 27, 24 and 27 lactating cows that completed the experiment for the control, "Rico-30" and "Pro-Lix" treatments, respectively. Similarly, 23 control and "Rico-30" and 22 "Pro-Lix" non-lactating cows completed the experiment. One of the non-lactating cows calved on September 3 and was not included in the analysis of weight gains. One of the "Pro-Lix" non-lactating cows was injured on August 15 while being weighed and was removed from the experiment. In addition, two lactating cows receiving the "Rico-30" supplement died during the experiment. These cows exhibited tetany-like

staggers and weakness prior to death, but death occurred in both cases after the cows were down for over a week and they failed to respond to an intraveinuous administration of calcium glutamate which contained magnesium. The cause of death was not definitely established. Both lactating cows died at the first of September and their calves were not removed from the experiment.

The number of calves finishing the experiment is also shown in Table 4. Four calves died during the experiment and 1 calf had to be removed because of an injury. There were 26 control and "Rico-30" calves and 27 "Pro-Lix" calves that completed the experiment.

Supplement and Feed Intake: It was impossible to ascertain the consumption of supplement by the different types of cattle since the lactating cows, their calves and the non-lactating cows on each treatment were maintained together. The total consumption of supplement (Table 6) was 3728 kg for the "Rico-30" group and 4136 kg for the "Pro-Lix" cattle. If each calf consumed approximately 200 g of supplement daily then the daily consumption of each cow would have been approximately 705 g for the "Rico-30" cows and 787 g for the "Pro-Lix" cows.

The quantity of sorghum pastures remaining during the latter part of the experiment was extremely sparse and obviously insufficient to maintain the number of cattle carried on it. Table 5 shows the results of the crude protein analysis of the pasture samples. The initial

sample contained 3.4% crude protein in the drymatter and was slightly below the protein level found in the initial sorghum sample from the steer pastures.

The mid-experiment and final crude protein analysis of the sorghum pastures was virtually the same for the cows and steers. The nutrient requirements for beef cattle (N.R.C., 1970) gives the crude protein requirement for lactating and dry cows as 9.2 and 5.9%, respectively. The crude protein level of the sorghum pastures were approximately one-half the requirement for lactating cows and substantially below the requirement for dry pregnant cows.

Weight Changes of Non-Lactating Cows: The experimental weights and weight changes of the non-lactating cows are shown in Table 13. None of the differences among treatments for either weights or weight gains were significant. During the first half of the trial all but 5 cows gained weight. The average weight gain was 17.0, 23.3 and 22.5 kg for the control, "Rico-30" and "Pro-Lix" groups respectively.

During the last 48 days of the experiment, 52 of 68 non-lactating cows lost weight. The average weight losses were 3.0, 9.0 and 6.2 kg for the control, "Rico-30" and "Pro-Lix" cows. The weight losses during the second half of the experiment did not obliterate weight gains in the previous period. The control, "Rico-30" and "Pro-Lix" cows had respective average total gains of 14.0, 14.3 and 16.2 kg. The large weight gains of the control cows during the first half of the experiment make it clear that

Table 13.--Weight Changes of Non-Lactating Cows^{1,2}

	Treatments		
	Control	Rico-30	Pro-Lix
No. of Cows	23	23	22
Initial Wt. (7/1)	349.1	333.5	351.1
Mid-Expt. Wt. (8/15)	366.1	356.9	373.6
Days on Test	45	45	45
Av. Gain Since Initial Wt.	17.0	23.3	22.5
No. of Cows Losing Wt.	3	0	2
Final Wt. (10/1)	363.1	347.9	367.4
Days Since Last Wt.	48	48	48
Av. Gain Since Last Wt.	-3.0	-9.0	-6.2
No. of Cows Losing Wt.	14	21	17
Total Days on Test	93	93	93
Total Gain on Test	14.0	14.3	16.2
No. of Cows Losing Wt.	4	4	3

¹All weights and gains are kilograms.

²All values with the same superscripts and in the same row are significantly different ($P < 0.05$).

supplementation is not necessary for non-lactating cows grazing sorghum pastures when adequate forage is available.

Weight Changes of Lactating Cows: Table 14 shows the weight changes of the lactating cows in this experiment. The control lactating cows had a significantly ($P < 0.05$) heavier initial, mid-experiment and final weight than the "Rico-30" cows. This difference was not a result of the treatment, but due to the method of assigning the cattle to groups. The weight loss of the "Pro-Lix" cows (21.2 kg) during the second half of the experiment was significantly ($P < 0.05$) greater than the loss of either the control (15.3 kg) or "Rico-30" cows (13.8 kg). The "Pro-Lix" cows lost less weight during the first half of the experiment than the other two groups. The primary reason for the difference in the performance of the "Pro-Lix" cows was an error made during the time the cows were removed from feed and water the night before weighing for the mid-experiment weight. The "Pro-Lix" cows were inadvertently left in a lot that had access to water. When this was discovered the following morning, the cows were immediately removed from water and weighed in the afternoon, but they were not held away from water as long as the other two groups.

There were no significant differences among the treatment groups for total loss of weight during the experiment. The respective total weight losses of the control, "Rico-30" and "Pro-Lix" lactating cows were 24.1, 21.9 and 24.4 kg. The fact that protein supplements did not alter the weight

Table 14.--Weight Changes of Lactating Cows^{1,2}

	Treatments		
	Control	Rico-30	Pro-Lix
No. of Cows	27	24	27
Initial Wt. (7/1)	355.1 ^a	320.0 ^a	336.7
Mid-Expt. Wt. (8/15)	346.3 ^a	311.8 ^a	333.5
Days on Test	45	45	45
Av. Gain Since Initial Wt.	-8.9	-8.2	-3.3
No. of Cows Losing Wt.	21	17	16
Final Wt. (10/1)	331.0 ^a	298.1 ^a	312.3
Days Since Last Wt.	48	48	48
Av. Gain Since Last Wt.	-15.3 ^b	-13.8 ^a	-21.2 ^{a,b}
No. of Cows Losing Wt.	26	22	26
Total Days on Test	93	93	93
Total Gain on Test	-24.1	-21.9	-24.4
No. of Cows Losing Wt.	26	23	27

¹All weights and gains are kilograms.

²All values with the same superscript in the same row are significantly different ($P < 0.05$).

losses of the lactating cows indicates that the primary limiting factor is either energy or a combination of energy and protein. Obviously, the sorghum pastures were inept at meeting the nutritional requirements for lactating cows.

Weight Changes of Calves: The weight changes of the calves nursing the lactating cows are shown in Table 15. All calves gained weight throughout the experiment. Since there was an unequal ratio of male to female calves within the different treatments, the weight gains were analyzed both for all calves and for the bull and heifer calves separately. The average total gain during the experiment was 20.4 kg for the bull calves and 18.8 kg for the heifer calves.

The difference in total gain among the treatments for the bull calves approached significance. When the gains of the bull and heifer calves were analyzed together the "Pro-Lix" calves gained significantly ($P < 0.05$) more weight than either the "Rico-30" or the control calves. The average total gain of the control, "Rico-30" and "Pro-Lix" calves was 17.7, 18.9 and 23.0 kg, respectively. Thus, the "Pro-Lix" calves had a 5.3 kg advantage over the controls while the "Rico-30" calves only had a 1.2 kg advantage. A weight differential of this magnitude is not great enough to pay for the supplement required for both cow and calf under these conditions if the calf weight gains are the only advantage accrued.

It is possible that much of the advantage gained by

Table 15.--Weight Changes of Calves^{1,2}

Treatment	No. of Animals	Initial Weight	Mid-Expt. Weight	Final Weight	First Gain	Second Gain	Total Gain
Control (all)	26	82.4	88.1	100.2	7.9 ^A	9.8	17.7 ^a
Bull calves	20	83.1	91.2	101.0	8.1 ^b	9.8	17.9
Heifer calves	6	80.2	87.8	97.5	7.7	9.7	17.3
Rico-30 (all)	26	74.2	84.3	93.1	10.1 ^A	8.8	18.9 ^b
Bull calves	8	78.4	88.0	98.8	9.6 ^b	10.8	20.4
Heifer calves	18	70.0	80.2	87.7	10.2	7.6	17.7
Pro-Lix (all)	27	76.9	98.3	100.0	12.4 ^A	10.6	23.0 ^{a,b}
Bull calves	21	82.4	95.2	106.5	12.8 ^b	11.3	24.1
Heifer calves	6	68.3	79.8	90.2	11.5	10.3	21.8
All Calves	79	77.1	87.2	96.8	10.1	9.6	19.7
All bull calves	49	81.3	91.6	102.0	10.3	10.4	20.7
All heifer calves	30	72.9	82.8	91.7	10.0	8.8	18.8
Date of Weight		7/5	8/15	9/30			
Std. Error of Means		4.2	4.1	4.4	0.9	0.8	1.4

¹All values are kilograms. The means for all calves and the error term are the result of least square analysis without an interaction term in the model. The mean for the heifer and bull calves under each treatment are actual means.

²Values in the same column with the same superscripts are significantly different (upper case = $P < 0.01$; lower case = $P < 0.05$).

supplementing lactating cows would be in a decreased calving interval. Further, the results could be entirely different if lactating cows were given access to pastures with ample forage, forage of a different type or if just the calves were given access to the supplement.

Carotene and Vitamin A of Cows: The results of the plasma carotene and vitamin A analysis of both the lactating and non-lactating cows are shown in Table 16. The plasma carotene and vitamin A values for the cows were analyzed by least squares. There did not appear to be any interaction between the type of cow and the supplements used. None of the differences among treatments for either plasma carotene or plasma vitamin A concentrations were significant. Similar to both the steer experiments, the final plasma vitamin A concentrations were below the level listed as adequate for normal growth and health by Davis and Madsen (1941) and Kuhlman and Gallup (1942). In addition, these workers as well as Payne and Kingman (1947) reported that levels of vitamin A for optimum reproduction are substantially higher and range from 78 to 150 mcg per 100 ml of plasma.

The initial carotene concentration of the non-lactating cows was significantly higher than for the lactating cows. However, all other carotene and vitamin A concentrations are virtually the same for lactating and non-lactating cows.

Table 16.--Carotene and Vitamin A of Cows^{1,2}

Treatment	No. of Animals	Initial Carotene	Initial Vitamin A	Mid-Expt. Carotene	Mid-Expt. Vitamin A	Final Carotene	Final Vitamin A
Control	15	369	23.2	140	27.5	526	21.7
Rico-30	14	398	24.7	138	27.8	495	22.2
Pro-Lix	14	346	29.3	127	29.8	463	19.4
All Cows	43	371 ^a	25.7	135	28.4	494	21.1
All Non-Lactating	24	410 ^a	27.5	126	29.2	467	21.3
All Lactating	19	331 ^a	23.8	144	27.5	524	21.0
Std. Error of Means		27.7	2.6	14.9	2.5	37.4	1.5

55

¹All values are mcg /100 ml. The means and the error term are the result of least square analysis without an interaction term in the model.

²Values with the same superscripts in the same column are significantly different (P < 0.05).

Experiments 4 and 5 - Nitrogen Balance Studies

Feed and Supplement Analysis: Results of the analysis are shown in Table 17. The forages were harvested weekly by hand from the same pastures that were used for the experimental steers. The drymatter content was relatively constant for both forages until the final collection period when the percent drymatter dropped on both agropero and sorghum due to rain. The percent crude protein of the sorghum was relatively constant for all sorghum samples including the feed that was refused.

The crude protein levels found in the agropero samples were much more variable than that is the sorghum samples, but in all cases were below the requirements listed by the Nutrient Requirements of Beef Cattle (N.A.S., 1970). The agropero pasture had not been grazed for six months prior to the experiment and consisted of two types of growth: a greener, more palatable undergrowth and a dry, unpalatable older growth. The unconsumed portion of the agropero feed consisted almost entirely of the poorer quality feed and ranged in protein from 2.36 to 2.51%. The agropero fed in the first trial was considerably higher in protein than in the following two trials and was primarily a result of a higher proportion of the green undergrowth in the feed. The percent crude protein in the two supplements were 36.5 and 29.2% for "Pro-Lix" and "Rico-30" respectively.

Table 17.--Drymatter and Crude Protein Levels of Forage and Supplements Offered and Forage Not Consumed by Cattle on Nitrogen Balance Studies.

Trial	Type of Feed	% D.M.	% Crude Protein ¹
1	Sorghum	88.0	3.18
1	Sorghum Refused	63.7	3.94
2	Sorghum	89.3	4.44
2	Sorghum Refused	81.3	4.04
3	Sorghum	69.3	4.40
3	Sorghum Refused	81.1	4.83
1	Agropero	87.3	5.05
1	Agropero Refused	69.3	2.51
2	Agropero	87.7	2.24
2	Agropero Refused	83.9	2.36
3	Agropero	78.9	3.35
3	Agropero Refused	87.7	2.40
All	Pro-Lix Supplement	53.7	36.5
All	Rico-30 Supplement	53.9	29.2

¹Percent crude protein in the drymatter.

Drymatter Intake and Digestibility: As shown in Table 18, the drymatter consumption of the supplemented treatments for both agropero and sorghum forage was higher than the controls. The differences were significant ($P < 0.05$) for the agropero forage but not for the sorghum. There was no significant difference in drymatter intake between the "Rico-30" and "Pro-Lix" supplemented treatments for either forage. These results disagree with Brannon et al. (1954) who reported that increasing the energy content of the ration resulted in a decrease in drymatter consumption. However, Ross et al. (1954), Bush et al. (1955), Woods et al. (1956) and Raleigh and Wallace (1963) all reported similar increases in drymatter consumption of a low protein diet when the protein level was increased.

There were no significant differences among any of the treatment groups for drymatter digestibility. The drymatter digestibility ranged from 45.1 to 48.6% with an average of 46.3% for the sorghum steers. Similarly, the drymatter digestibility of the agropero fed steers ranged from 44.4 to 48.2% and averaged 45.8%

Nitrogen Balance: The actual means of all nitrogen parameters measured are listed in Table 18. The differences in nitrogen intake among the different treatments (Table 18) were highly significant ($P < 0.01$) for both the agropero and sorghum steers. The average daily nitrogen intake for the sorghum fed steers was 24.9, 64.4 and 75.7 g for the control, "Rico-30" and "Pro-Lix" steers respectively.

Table 18.--Actual Treatment Means for Metabolic Study^{1,2}

Treat- ment	DM Con- sumed	DM Ex- creted	DM Ab- sorbed	% DM Di- gested	Con- sumed N	Fecal N	Ab- sorbed N	Ur- inary N	Re- tained N	% N Re- tained	% Retained Of N Absorbed
SORGHUM FORAGE											
Control	3903	2141	1762	45.1	24.9 ^A	27.6	-2.7 ^{A,a}	9.4 ^{A,B}	-12.1	nitrogen loss	
Rico-30	4472	2454	2018	45.1	64.4 ^A	30.9	33.5 ^a	26.7 ^A	6.8	10.6	20.3
Pro-Lix	4729	2430	2299	48.6	75.7 ^A	33.3	42.4 ^A	30.6 ^B	11.8	15.6	27.8
$\bar{X}$				46.3					2.2		
AGROPERO FORAGE											
Control	3121 ^{A,B}	1724	1397	44.8	22.9 ^A	14.1	8.8 ^{A,a}	11.6	-2.8	nitrogen loss	
Rico-30	3452 ^A	1789	1663	48.2	61.2 ^A	15.2	46.0 ^a	36.7	9.3	15.2	20.2
Pro-Lix	3410 ^B	1895	1515	44.4	68.4 ^A	13.2	55.2 ^A	42.3	12.9	18.9	23.4
$\bar{X}$				45.8					6.5		

¹All values are grams per day unless otherwise indicated.

²Values with the same superscripts in the same column and for the same forage are significantly different (upper case = $P < 0.01$; lower case = $P < 0.05$).

Likewise, the agropero control, "Rico-30" and "Pro-Lix" treatments averaged 22.9, 61.2 and 68.4 g nitrogen consumed daily.

"Pro-Lix" and "Rico-30" treatments on both forages had a significantly higher ($P < 0.01$) quantity of nitrogen absorbed daily than the control treatments. In addition, the "Pro-Lix" supplemented steers had a significantly ($P < 0.05$) greater amount of nitrogen absorbed per day than the "Rico-30" supplemented steers. The differences in absorbed nitrogen were reflections of the differences in nitrogen consumed.

As expected, the treatment combinations that had higher nitrogen intakes resulted in higher losses of nitrogen in the urine. The increased urinary nitrogen excretion was a result of a 2 to 3-fold increase in both urine volume and the concentration of nitrogen in the urine. Although the fecal nitrogen excretion differed tremendously between forages, there were no significant differences among supplements for daily fecal nitrogen excretion.

The average nitrogen retention for the non-supplemented control treatments was negative for both forages. All three of the sorghum steers and two of the agropero steers were in a negative nitrogen balance while not receiving supplement. The differences in nitrogen retention among the supplements on sorghum forage approach significance while the differences among the agropero treatments were non-significant.

V. SUMMARY

The value of providing liquid supplements to steers and cows grazing frosted winter pastures in Argentina was studied in three feeding trials and two nitrogen balance studies. Two types of pasture, Agropirum elongatum (agropero) and leoti red (sorghum), and two supplements, "Pro-Lix" and "Rico-30", were used. The vitamin A status of the animals involved in the feeding trials was monitored by determining plasma carotene and vitamin A levels of a randomly selected group from each treatment combination.

Almost all of the yearling steers grazing sorghum lost weight during the experiment. The average total loss of the control, "Rico-30" and "Pro-Lix" supplemented steers during the experiment was 22.5, 8.9 and 4.9 kg, respectively. All of the differences among treatments in total weight loss were significant ($P < 0.05$). In order for supplementation to be profitable for steers grazing sorghum pastures under the conditions of this experiment, the price of 5.9 kg of "Rico-30" or the price of 4.5 kg of "Pro-Lix" would have to be less than the price of 1 kg of live beef cattle.

In contrast to the weight loss of the sorghum steers, the agropero steers gained weight during the experiment. The average total weight gain of the control and "Pro-Lix" steers was 17.5 and 23.5 kg respectively. The control steers actually outgained the supplemented steers during the first

half of the experiment but this advantage was more than offset by the significantly higher ($P < 0.05$) weight gains of the "Pro-Lix" steers during the last half of the experiment. Nine kilograms of the "Pro-Lix" supplement would have to sell for less than 1 kg of live beef to make supplementation of steers on agropero pastures profitable under the conditions of this experiment.

There was virtually no difference in the performance of the non-lactating and lactating cows regardless of whether they were supplemented or not. However, the calves nursing cows receiving "Pro-Lix" supplement gained significantly more weight ($P < 0.05$) than the calves in either the "Rico-30" or control treatment groups. The average total gain of the control, "Rico-30" and "Pro-Lix" calves was 17.7, 18.9 and 23.0 kg, respectively. The 5.3 kg advantage of the "Pro-Lix" calves would not be sufficient to offset the cost of supplement consumed by both the dam and calf throughout the experiment. However, calf weight gains may not be the only advantage of supplementing lactating cows.

The conditions of this experiment were rather atypical for Argentina. Normally steers grazed on sorghum out-perform steers grazed on agropero. The agropero pastures were extremely good because they had not been grazed for six months and there was unusual rain during the early winter. The quantity of forage available in the sorghum pastures was insufficient for the number of cattle grazed in them. This was especially true for cows grazing sorghum pastures.

There is considerable disagreement as to the value of plasma carotene and vitamin A levels for predicting the vitamin A status of cattle. The plasma values represent molecules which have been absorbed and are being transported to storage as well as molecules that have been mobilized from storage and are being transported to sites of conversion or use.

There were few differences among the different supplements for any of the analysis of plasma vitamin A levels. The final plasma vitamin A concentration of all treatment groups was below the level reported as adequate for normal health and growth by Davis and Madsen (1941) and Kuhlman and Gallup (1942). The plasma carotene concentration of the control agropetro steers was significantly ($P < 0.05$) greater than that for the "Pro-Lix" steers on the same pasture. Although not significant, there was a trend for the plasma carotene concentration of the controls to exceed the carotene level of the supplemented animals in all experiments. The control animals received all of their vitamin A in the form of carotene from the forage consumed while the supplemented groups received vitamin A in the form of vitamin A in the supplement. The increased dietary vitamin A levels of the supplemented animals may have resulted in a decreased carotene absorption and therefore, explain the lower plasma carotene concentrations of the supplemented steers.

The nitrogen balance of the control treatment was

negative for both the agropero and sorghum forages. The drymatter intake was greater for the supplemented steers on both forages, but only the differences on agropero were statistically significant ($P < 0.05$). There were no significant differences among any of the supplements for drymatter digestibility.

The results of this experiment illustrate a great potential for increasing beef production in Argentina. The year (1969) in which this experiment was conducted was unusually favorable for agropero pastures and the experiment should be replicated to eliminate the season variables. There apparently is no return for supplementing pregnant, non-lactating cows, but much incentive exists for further study on supplementation of lactating cows with calves and steers. It is quite possible that further study will illustrate how supplementation can be regulated to increase the response found in this study.

BIBLIOGRAPHY

BIBLIOGRAPHY

- Almquist, H. J. 1952. Relation of vitamin A intake to plasma and liver vitamin A content. Arch. Biochem. 39:243.
- Arias, C., W. Burroughs, P. Gerlaugh, and R. M. Bethka. 1951. The influence of different amounts and sources of energy upon in vitro urea utilization by rumen microorganisms. J. Animal Sci. 10:683.
- Baker, F. H., R. MacVicar and L. S. Pope. 1953. Placental and mammary transfer of vitamin A and carotene by beef cows. Proc. Soc. Exp. Biol. and Med. 83:571.
- Baker, F. H., L. S. Pope and R. MacVicar. 1954. The effect of vitamin A stores and carotene intake of beef cows on the vitamin A content of the liver and plasma of their calves. J. Animal Sci. 13:802.
- Bartlett, S., and A. G. Cotton. 1938. Urea as a protein substitute in the diet of young cattle. J. Dairy Res. 9:263.
- Beeson, W. M., M. T. Mohler, and T. W. Perry. 1964a. Supplement A vs. Purdue 64 supplement and the effect of Co-Ral, Selenium and tylosin on the performance of steers. Purdue Agr. Exp. Sta. Cattle Feeders Day Rept.
- Beeson, W. M. and T. W. Perry. 1964b. 1964 Purdue Protein supplements for beef cattle. Purdue agr. Exp. Sta. Cattle Feeders Day Rept.
- Beeson, W. M. and T. W. Perry. 1969. Effective utilization of urea by beef cattle. Purdue Agr. Exp. Sta. Cattle Feeders Day Rept., AS-386, p. 6.
- Beeson, W. M. and T. W. Perry. 1970. Liquid feeding: History - Problems - Research. Purdue Agr. Exp. Sta. Cattle Feeders Day Rept., AS-391, p. 5.
- Beeson, W. M., T. W. Perry, C. F. Hatch, and M. T. Mohler. 1961. Nutritional factors affecting the utilization of dry and liquid high-urea supplements. Purdue Agr. Exp. Sta. Cattle Feeders Day Rept., p. 35.
- Beeson, W. M., T. W. Perry, W. H. Smith and M. T. Mohler. 1961. Levels of supplemental vitamin A for fattening beef cattle. J. Animal Sci. 20:925 (Abst.)

- Beeson, W. M., T. W. Perry, C. G. VanSlyke and M. T. Mohler. 1968. The value of dehydrated alfalfa products and distillers dried grains with solubles on the utilization of high-urea supplements for finishing beef cattle. Purdue Agr. Exp. Sta. Cattle Feeders Day Rept.
- Belasco, I. J. 1954. New nitrogen feed compounds for ruminants -- a laboratory evaluation. J. Animal Sci. 13: 601.
- Belasco, I. J. 1956. The role of carbohydrates in urea utilization, cellulose digestion and fatty acid formation. J. Animal Sci. 15:496.
- Bell, M. C., W. D. Gallup and C. K. Whitehair. 1953. Value of urea nitrogen in rations containing different carbohydrate feeds. J. Animal Sci. 12:787.
- Bhattacharga, A. N. and R. G. Warner. 1967. Rumen pH as a factor for controlling feed intake of ruminants. J. Dairy Sci. 50:1116.
- Bodansky, O. and B. Markardt. 1951. Effect of Reichstein's compound L acetate on plasma, liver and kidney vitamin A. J. Biol. Chem. 190:83.
- Bowstead, J. E. and H. T. Freedon. 1948. Feeding urea to dairy cows with special reference to the palatability of feed mixtures containing urea. Sci. Agr. 28:66.
- Brannon, W. F., J. T. Reid and J. I. Miller. 1954. The influence of certain factors upon the digestibility and intake of pasture herbage by beef steers. J. Animal Sci. 13:535.
- Braun, W. 1945. Studies on the carotenoid and vitamin A levels in cattle. J. Nutr. 29:73.
- Briggs, H. M., W. D. Gallup, A. E. Darlow, D. F. Stephens, and C. Ninney. 1947. Urea as an extender of protein when fed to cattle. J. Animal Sci. 6:445.
- Brown, L. D., C. A. Lassiter, J. P. Everett and J. W. Rust. 1956. The utilization of urea nitrogen by young dairy calves. J. Animal Sci. 15:1125.
- Burroughs, W., P. Gerlaugh, B. H. Edgington and R. M. Bethke. 1949. Further observations of the effect of protein upon roughage digestion in cattle. J. Animal Sci. 8:9.

- Burroughs, W., J. Long, P. Gerlaugh and R. M. Bethke. 1950. Cellulose digestion by rumen micro-organisms as influenced by cereal grains and protein rich feeds commonly fed to cattle using an artificial rumen. J. Animal Sci. 9:523.
- Burroughs, W., F. H. McGuire and C. Cooper. 1969. Attempts to improve liquid and dry all-urea type cattle supplements with fish soluble additions. Iowa State Univ. A.S. Leaflet R118.
- Bush, L. F., J. P. Williams and F. B. Morrison. 1955. A study of the protein requirements of fattening feeder lambs. J. Animal Sci. 14:465.
- Campbell, C. M., L. B. Sherrod and S. M. Ishizaki. 1969. Effect of supplemental protein and energy levels on the utilization of kikuyu grass (*Pennisetum clandestinum*). J. Animal Sci. 29:634.
- Carr, F. H. and E. A. Price. 1926. Colour reactions attributed to vitamin A. Biochem. J. 20:497.
- Chapman, H. L., Jr., R. L. Shirley, A. Z. Palmer, C. E. Haines, J. W. Carpenter and T. J. Cunha. 1964. Vitamins A and E in steer fattening rations on pasture. J. Animal Sci. 23:659.
- Cook, C. W., L. E. Harris and L. A. Stoddart. 1948. Measuring the nutritive content of a foraging sheep's diet under range conditions. J. Animal Sci. 7:170.
- Davis, R. E. and L. L. Madsen. 1941. Carotene and vitamin A in cattle blood plasma with observations on reproductive performance at restricted levels of carotene intake. J. Nutr. 21:135.
- Dinning, J. S., H. M. Briggs and W. D. Gallup. 1949. The value of urea in protein supplements for cattle and sheep. J. Animal Sci. 8:24.
- Erwin, E. S., R. S. Gordon and J. W. Algero. 1963. Effect of antioxidant, protein and energy on vitamin A and feed utilization in steers. J. Animal Sci. 22:341.
- Ewing, S. A. and W. Burroughs. 1963. Urea supplements in beef cow wintering rations. Iowa State Univ. A.S. Leaflet R56.
- Flora, C. C., R. E. Ward, S. I. Bechdel, N. B. Guerrant and R. A. Dutcher. 1939. Carotene in the nutrition of dairy calves. J. Dairy Sci. 22:321.

- Frey, P., R. Jensen and W. E. Connell. 1947. Vitamin A intake in cattle in relation to hepatic stores and blood levels. J. Nutr. 34:421.
- Gallup, W. D. and H. M. Briggs. 1948. The apparent digestibility of prairie hay of variable protein content, with some observations of fecal nitrogen excretion by steers in relationship to their dry matter intake. J. Animal Sci. 7:110.
- Gallup, W. D., H. M. Briggs, L. S. Pope and J. Tucker. 1950. Possible effect of urea and source of protein supplement on vitamin A utilization by sheep. J. Animal Sci. 9:656 (Abst.)
- Gallup, W. D., H. M. Briggs, L. S. Pope and J. Tucker. 1951. Comparative effect on vitamin A metabolism in sheep of urea, soybean oil meal, and cottonseed meal as sources of protein. J. Animal Sci. 10:252.
- Gallup, W. D., C. K. Whitehair and M. C. Bell. 1954. Utilization of urea and protein nitrogen by ruminants fed high-molasses and sugar rations. J. Animal Sci. 13:594.
- Gay, N. and R. L. Vetter. 1967. A comparison of liquid and meal type supplements for feedlot cattle. Iowa State Univ. A.S. Leaflet R96.
- Guilbert, H. R. and G. H. Hart. 1935. Minimum vitamin A requirements with particular reference to cattle. J. Nutr. 10:409.
- Hamilton, T. S., W. B. Robinson and B. C. Johnson. 1948. Further comparisons of the utilization of nitrogen with that of some feed proteins by sheep. J. Animal Sci. 7:26.
- Harris, L. E., J. C. James and C. W. Cook. 1957. A method of feeding supplements to individual cattle on winter range. J. Animal Sci. 16:872.
- Harris, L. E. and H. H. Mitchell. 1941. The value of urea in the synthesis of protein in the paunch of the ruminant. II. In growth. J. Nutr. 22:183.
- Harris, L. E., S. H. Work and L. A. Henke. 1943. The utilization of urea and soybean oil meal nitrogen by steers. J. Animal Sci. 2:328.

- Hart, E. B., G. Bohstedt, H. J. Deobald and M. I. Wegner. 1939. The utilization of simple nitrogenous compounds such as urea and ammonium carbonate by growing calves. *J. Dairy Sci.* 22:785.
- Haumüller, R. 1969. Personal communication. Campo Vet. Rosario, Argentina.
- Henderson, H. E. and M. R. Geasler. 1970. Urea treated corn silage full fed with varying levels of protein, sources of protein and concentrate levels. Rept. of Beef Cattle Research, Michigan State University, p. 25.
- Henderson, H. E., H. W. Newland and W. K. Brown. 1960. Simple and complex protein supplements for fattening steer calves. 37th Annual Cattle Feeders Day Rept., Michigan State University, p. 8.
- Henderson, H. E. and B. Purser. 1968a. Urea additions to corn silage. Michigan State University Beef Cattle Day Rept., p. 29.
- Henderson, H. E., and B. Purser. 1968b. Effect of type of silo and urea addition on feeding value of late harvested corn silage. Michigan State University Beef Cattle Day Rept., p. 39.
- Hobbs, C. S., W. D. Gallup and R. B. Taylor. 1945. The composition and apparent digestibility of bluestem grass in the growing stage and in the dry and hay stages when supplemented with cottonseed cake. *J. Animal Sci.* 4:395.
- Hodgson, R. E., S. R. Hall, W. J. Sweetman and H. T. Converse. 1964. The effect of vitamin A deficiency on reproduction in dairy bulls. *J. Dairy Sci.* 29:669.
- Hoefer, J. A. and W. D. Gallup. 1947. The comparative value of carotene concentrate, alfalfa meal and fish liver oil in maintaining the vitamin A content of the blood and liver of fattening lambs. *J. Animal Sci.* 6:325.
- Johnson, B. C., T. S. Hamilton, H. H. Mitchell and W. B. Robinson. 1942. The relative efficiency of urea as a protein substitute in the ration of ruminants. *J. Animal Sci.* 1:236.
- Kercher, C. J. and L. Paules. 1967. Liquid vs. dry protein supplements for fattening yearling steers. *J. Animal Sci.* 26:921 (Abst.)

- Kohlmer, R. H. and W. Burroughs. 1970. Estimation of critical plasma and liver vitamin A levels in feedlot cattle with observations upon influences of body stores and daily dietary requirements. *J. Animal Sci.* 30:1012.
- Kuhlman, A. H. and W. D. Gallup. 1942. The relation of carotene intake to blood carotene values of dairy cattle. *J. Animal Sci.* 1:68.
- Lelesz, E. 1939. Investigations of the vitamin content of blood. Estimation of vitamin A in the blood of livestock. *Acta. Vitaminologiae.* 5:42.
- Lofgreen, G. P. 1965. Net energy of fat and molasses for beef heifers with observations on the method for net energy determination. *J. Animal Sci.* 24:480.
- Lofgreen, G. P. and K. K. Otagaki. 1960. The net energy of blackstrap molasses for fattening steers as determined by comparative slaughter techniques. *J. Animal Sci.* 19:392.
- Ludwig, C., S. A. Ewing, L. S. Pope and D. F. Stephens. 1967. The cumulative influence of level of wintering on the lifetime performance of beef females through seven calf crops. *Okla. Agr. Exp. Sta. Feeders Day Rept.*, p. 58.
- Martin, T. G., W. M. Beeson, M. T. Mohler and T. W. Perry. 1968. High-urea vs. natural protein supplements for finishing bulls. *Purdue Agr. Exp. Sta. Cattle Feeders Day Rept.*
- McNaught, M. L. and J. A. B. Smith. 1947. The role of the microflora of the alimentary tract of herbivora with special reference to ruminants. 4. nitrogen metabolism in the rumen. *Nutr. Abstr. and Rev.* 17:18.
- Menzies, C. W., D. Richardson, F. H. Baker and R. F. Cox. 1955. Phosphoric acid as a source of phosphorus for ruminants. *J. Animal Sci.* 14:1217 (Abst.)
- Meyer, J. H., J. L. Hull, W. H. Weifkamp and S. Bonilla. 1965. Compensatory growth responses of fattening steers following various low energy intake regimes on hay or irrigated pasture. *J. Animal Sci.* 24:29.
- Miller, J. A., A. B. Nelson and G. R. Waller. 1958. Protein supplements for wintering fall calving cows. *Okla. Agr. Exp. Sta. Feeders Day Rept.*, p. 102.

- Mills, R. C., A. N. Booth, G. Bohstedt and E. B. Hart.
1942. The utilization of urea by ruminants as influenced by the presence of starch in the ration. J. Dairy Sci. 27:571.
- Mills, R. C., C. C. Lardinois, I. W. Rupel and E. B. Hart.
1944. Utilization of urea and growth of heifer calves with corn molasses or cane molasses as the only readily available carbohydrate in the ration. J. Dairy Sci. 27:571.
- Moore, L. A. 1939. Carotene intake, level of blood plasma carotene, and the development of papillary edema and nyctalopia in calves. J. Dairy Sci. 22:803.
- Myers, G. S., Jr., H. O. Eaton and J. E. Rousseau, Jr.
1959. Relative value of carotene from alfalfa and vitamin A from a dry carrier fed to lambs and pigs. J. Animal Sci. 18:288.
- National Research Council. 1970. Nutrient Requirements of Beef Cattle. Fourth revised edition, National Academy of Sciences, Washington, D. C.
- Nelson, A. B., R. D. Furr and G. R. Waller. 1962. Level of wintering fall calving beef cows. Okla. Agr. Exp. Sta. Feeders Day Rept., p. 71.
- Nelson, A. B., L. R. Kuhlman, G. R. Waller and W. D. Campbell. 1961. Urea in protein supplements for wintering steer calves grazing native grass. Okla. Agr. Exp. Sta. Feeders Day Rept., p. 76.
- Newland, H. W., H. E. Henderson, W. T. Magee, R. J. Deans, L. J. Bratzler, A. L. Pearson, R. W. Luecke and R. H. Nelson. 1961. Urea and energy levels, lysine supplementation and hormones for fattening steer calves. Michigan Cattle Feeders Day Rept., A.H. 67.
- Owen, E. C. 1951. Reviews of the progress of dairy science. II. Physiology and biochemistry of rumination. J. Dairy Res. 18:113.
- Payne, M. G. and H. E. Kingman. 1947. Carotene blood levels and reproductive performance in range Hereford cattle. J. Animal Sci. 6:50.
- Perry, T. W. and W. M. Beeson. 1968. Liquid non-protein nitrogen supplements for beef cattle. Purdue Agr. Exp. Sta. Cattle Feeders Day Rept., RPR-379.

- Perry, T. W., W. M. Beeson, M. T. Mohler, and W. H. Smith. 1962. Levels of supplemental vitamin A with and without sun cured alfalfa meal for fattening steer calves. J. Animal Sci. 21:333.
- Perry, T. W., W. M. Beeson, D. M. Robinson and M. T. Mohler. 1967. Liquid vs. dry supplements for fattening steers. Purdue Agr. Exp. Sta. Cattle Feeders Day Rept., RPR-303.
- Perry, T. W., R. C. Peterson and W. M. Beeson. 1969. The value of supplemental distillers solubles, fish solubles, or alfalfa solubles in liquid supplements for fattening beef cattle. Purdue Agr. Exp. Sta. Cattle Feeders Day Rept., p. 29.
- Pinney, D. O., L. S. Pope, C. V. Cotthem and K. Urban. 1962a. Effect of winter plane of nutrition on the performance of three- and four-year-old beef cows. Okla. Agr. Exp. Sta. Feeders Day Rept., p. 50.
- Pinney, D. O., L. S. Pope, L. E. Malkus and D. Stephens. 1962b. Feedlot performance and carcass composition of slaughter cattle as affected by winter feed level of their dams. Okla. Agr. Exp. Sta. Feeders Day Rept., p. 25.
- Pinney, D. O., L. S. Pope, D. Stephens and L. M. Henderson. 1962c. Lifetime performance of beef cows wintered each year on three different levels. Okla. Agr. Exp. Sta. Feeders Day Rept., p. 63.
- Pope, L. S., J. L. Pitts and G. Waller. 1958. Effect of three levels of carotene intake during lactation on the performance of beef cows and their calves. Okla. Agr. Exp. Sta. Feeders Day Rept., p. 42.
- Quinby, J. R. and P. T. Marion. 1966. Sorghum for Forage. Forages. Edited by H. D. Hughes, M. E. Heath and D. S. Metcalfe. The Iowa State University Press. p. 346.
- Raleigh, R. J. and J. D. Wallace. 1963. Effect of urea at different nitrogen levels on digestibility and on performance of growing steers fed low quality flood meadow roughage. J. Animal Sci. 22:330.
- Ralston, A. T. and I. A. Dyer. 1959. Relationship of liver and plasma carotenoid and vitamin A content in cattle as affected by location and season. J. Animal Sci. 18:874.
- Rechcigl, M., Jr., S. Berger, J. K. Loosli and H. H. Williams. 1962. Dietary protein and utilization of vitamin A. J. Nutrition 76:435.

- Reid, J. T. 1953. Urea as a protein replacement for ruminants: A review. J. Dairy Sci. 36:955.
- Riggs, J. K. 1940. The length of time required for depletion of vitamin A reserves in range cattle. J. Nutrition 20:491.
- Riggs, J. K., R. W. Colby and L. V. Sells. 1953. The effect of self-feeding salt-cottonseed meal mixtures to beef cows. J. Animal Sci. 12:379.
- Ross, C. V., U. S. Garrigus, T. S. Hamilton and E. B. Earley. 1954. Comparing high-, medium-high-, and low-protein corn for fattening lambs. J. Animal Sci. 13:433.
- Rousseau, J. E., Jr., R. Teichman, H. D. Eaton, M. Dicks, K. L. Dolge, C. F. Helmboldt and E. L. Jungherr. 1958. Effect of initial vitamin A status on subsequent response of Holstein calves to carotene intake from artificial dehydrated alfalfa. J. Dairy Sci. 41:514.
- Rupel, I. W., G. Gohstedt, and E. B. Hart. 1943. The comparative value of urea and linseed meal for milk production. J. Dairy Sci. 26:647.
- Smith, G. S., S. B. Love, W. M. Durdle, E. E. Hatfield, U. S. Garrigus and A. L. Neumann. 1964. Influence of urea upon vitamin A nutrition of ruminants. J. Animal Sci. 23:47.
- Smith, G. S., A. L. Neumann, W. G. Huber, A. H. Jordan and O. B. Ross. 1961. Avitaminosis in cattle fed silage rations supplemented with vitamin A. J. Animal Sci. 20:952. (Abst.)
- Speth, C. F., V. R. Bohman, H. Melendy and M. A. Wade. 1962. Effect of dietary supplements on cows on a semi-desert range. J. Animal Sci. 21:444.
- Sutton, T. S., W. E. Krauss and S. L. Hansard. 1940. The effect of vitamin A deficiency on the young male bovine. J. Dairy Sci. 23:574.
- Swift, R. W., E. J. Thacker, A. Black, J. W. Bratzler and W. H. James. 1947. Digestibility of rations for ruminants as affected by proportions of nutrients. J. Animal Sci. 6:432.
- Tillman, A. D. 1962. Mineral-vitamin interrelationship in ruminant nutrition. Okla. Agr. Exp. Sta. Livestock Feeders Day Rept.

- Tillman, A. D., D. B. Singletary, J. F. Kidwell and C. I. Bray. 1951. Methods of feeding cane molasses and urea to beef cattle. *J. Animal Sci.* 10:939.
- Ullrey, D. E., R. L. Covert, R. H. Wellenreiter, T. R. Greathouse and W. T. Magee. 1970. Vitamin A injections for wintering beef cows. Report of Beef Cattle Forage Research 1970. Michigan State Univ., p. 38.
- Wallace, J. D. and A. H. Denham. 1970. Digestion of range forage by sheep collected by esophageal fistulated cattle. *J. Animal Sci.* 30:605.
- Wallace, J. D., K. L. Knox and D. N. Hyder. 1970. Energy and nitrogen value of sandhill range forage selected by cattle. *J. Animal Sci.* 31:398.
- Watkins, W. E., J. H. Knox and J. W. Benner. 1950. Carotene and vitamin A in the blood plasma of range cows. *New Mex. Agr. Exp. Sta. Bul.* 335.
- Weichenthal, B. A., L. B. Embry, R. J. Emerick and F. W. Whetzal. 1963. Influence of sodium nitrate, vitamin A and protein level on feedlot performance and vitamin A status of fattening cattle. *J. Animal Sci.* 22:979.
- Weir, W. C. and R. F. Miller, Jr. 1953. The use of salt as a regulator of protein supplement intake by breeding ewes. *J. Animal Sci.* 12:219.
- Weir, W. C. and D. T. Torrell. 1953. Salt-cottonseed meal mixture as a supplement for breeding ewes on the range. *J. Animal Sci.* 12:353.
- Wellenreiter, R. H., D. E. Ullrey, T. R. Greathouse, W. T. Magee and B. L. Schoepke. 1969. Vitamin A status of wintering beef cows. Report of Beef Cattle Forage Research 1969. Michigan State Univ., p. 30.
- Wheeler, R. R., P. H. Weswig, W. F. Brannon, F. E. Hubbert, Jr., and W. A. Sawyer. 1957. The carotene content of plasma and liver of range Hereford cows and their calves in the Northern Great Basin. *J. Animal Sci.* 16:525.
- Willett, E. L., L. A. Henke and C. Marugame. 1946. The use of urea in rations for dairy cows under Hawaiian conditions. *J. Dairy Sci.* 29:629.
- Williams, D. L., J. V. Whiteman, R. S. Pittman and A. D. Tillman. 1968. A comparison of cottonseed meal and urea in low protein winter range supplements for cattle. *Okla. Agr. Exp. Sta. Misc. publ. No. 80*, p. 10.

Woods, W. R., C. M. Thompson and R. B. Grainger. 1956.
The effect of varying levels of protein and cerelose
on the utilization of mature timothy hay by sheep.
J. Animal Sci. 15:1141.

MICHIGAN STATE UNIVERSITY LIBRARIES



3 1293 03037 9535