Effect of barley preparation and roughage level upon the performance of fattening steers
by Lyle Leslie Myers

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in ANIMAL SCIENCE
Montana State University

Abstract:
Yearling Hereford steers were fed steam-rolled and dry-rolled barley with varying levels of hay and two pounds of a protein supplement per head daily in two similar fattening experiments (trials I and II).

Hereford calves were fed steam-rolled barley, steam-rolled barley with molasses, and dry-rolled barley during a wintering experiment and a fattening experiment. All steers received hay and a protein supplement.

The weight gain of steers sired by performance tested bulls was compared with steers sired by untested bulls.

Steers fed steam-rolled barley or dry-rolled barley plus two pounds of hay had the same average daily gain during trial I; however, steers fed day-rolled barley gained slightly faster during trial II= Feed consumption and feed efficiency were about the same for steers fed steam-rolled and day-rolled barley= Het return favored the steers that received day-rolled barley= The performance of steers fed steam-rolled barley plus molasses was similar to the performance of steers that received steam-rolled or day-rolled barley= Steers fed an all-concentrate ration consumed less feed and were more efficient than steers that received barley and hay= Average daily gain, carcass grades, and net returns were about the same for steers fed an allconcentrate ration and steers fed barley plus two pounds of hay per head daily= Steers fed five or six pounds of hay per head daily did not perform as well as steers that received two pounds of hay or no hay= There was a significant difference ($P<0.05$) in average daily gain between steers fed six pounds of hay and steers fed two pounds of hay per animal daily= The steers fed five or six pounds of hey daily consumed more feed, were less efficient, and had a lower net return than steers fed lower levels of hay= The average daily gain of steers sired by performance tested bulls was significantly greater ($P<0.0l$) than the gain of steers sired by untested bulls = These experiments indicated that: (l) method of barley preparation did not significantly affect the performance of fattening steers, (2) there was little difference in performance of steers fed an all-concentrate ration versus steers fed a full feed of barley plus two pounds of hay, (3) steers fed five or six pounds of hay did not perform as well as steers that received lower levels of hay, and (4) steers sired by performance tested bulls gained significantly faster than steers sired by untested bulls =

EFFECT OF BARLEY PREPARATION AND ROUGHAGE LEVEL UPON THE PERFORMANCE OF FATTENING STEERS

by

LYLE LESLIE MYERS

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE

in

ANIMAL SCIENCE

Approved:

Fred S. Willson
Head, Major Department

Oscar O. Thomas
Chairman, Examining Committee

Leon H. Johnson
Dean, Graduate Division

MONTANA STATE COLLEGE
Bozeman, Montana

August, 1962

ACKNOWLEDGMENTS

I express thanks to Dr. O. O. Thomas for his guidance in conducting the research work and in the writing of this thesis. His help during my graduate study is also appreciated. Thanks is give to Dr. D. W. Blackmore and Dr. Kenneth Goering for their suggestions in the preparation of this manuscript and to Dr. Ervin P. Smith for his help with the statistical analysis. Appreciation is also expressed to Gary L. Cowman, a fellow graduate student, who helped in the collection of the experimental data.

I am especially grateful to my wife, Patricia, who made this work possible through her sacrifices, work, and encouragement.

I am thankful for my parents, Mr. and Mrs. James E. Myers, who were instrumental in the advancement of my education.

Thanks is given to Don Tavenner, Deer Lodge, Montana, who supplied the certified steers used in two of the experiments and to the Peter Hand Foundation for furnishing Cellu-ade.

TABLE OF CONTENTS

Page

INDEX TO THE TABLES

INDEX TO THE FIGURES

INDEX TO THE APPENDIX

Appendix Table | Page

ABSTRACT

Yearling Hereford steers were fed steam-rolled and dry-rolled barley with varying levels of hay and two pounds of a protein supplement per head daily in two similar fattening experiments (trials I and II).

Hereford calves were fed steam-rolled barley, steam-rolled barley with molasses, and dry-rolled barley during a wintering experiment and a fattening experiment. All steers received hay and a protein supplement. The weight gain of steers sired by performance tested bulls was compared with steers sired by untested bulls.

Steers fed steam-rolled barley or dry-rolled barley plus two pounds of hay had the same average daily gain during trial I; however, steers fed dry-rolled barley gained slightly faster during trial II. Feed consumption and feed efficiency were about the same for steers fed steam-rolled and dry-rolled barley. Net return favored the steers that received dry-rolled barley. The performance of steers fed steam-rolled barley plus molasses was similar to the performance of steers that received steam-rolled or dry-rolled barley.

Steers fed an all-concentrate ration consumed less feed and were more efficient than steers that received barley and hay. Average daily gain, carcass grades, and net returns were about the same for steers fed an all-concentrate ration and steers fed barley plus two pounds of hay per head daily.

Steers fed five or six pounds of hay per head daily did not perform as well as steers that received two pounds of hay or no hay. There was a significant difference ($P<0.05$) in average daily gain between steers fed six pounds of hay and steers fed two pounds of hay per animal daily. The steers fed five or six pounds of hay daily consumed more feed, were less efficient, and had a lower net return than steers fed lower levels of hay.

The average daily gain of steers sired by performance tested bulls was significantly greater ($P<0.01$) than the gain of steers sired by untested bulls.

These experiments indicated that: (1) method of barley preparation did not significantly affect the performance of fattening steers, (2) there was little difference in performance of steers fed an all-concentrate ration versus steers fed a full feed of barley plus two pounds of hay, (3) steers fed five or six pounds of hay did not perform as well as steers that received lower levels of hay, and (4) steers sired by performance tested bulls gained significantly faster than steers sired by untested bulls.

INTRODUCTION

The fattening of beef cattle is increasing in importance in Montana. These cattle supply distant markets located in high population areas as well as local markets. The feedlot operator must buy high quality cattle at a reasonable price and follow good nutrition practices if he is to compete effectively on the market. Steers sired by Individual Performance Record (IPR) bulls are preferred by many cattle feeders. These steers often gain faster than steers from untested sires.

There is an abundance of barley and hay produced in Montana and much of it is used locally for the fattening of beef cattle. Because barley is commonly prepared in several physical forms, it is important to evaluate these forms as to their relative fattening value.

The level of hay to use in the ration is an important consideration when fattening cattle, because it directly affects the energy value of the ration. Early workers concluded that hay was necessary in the ration of the ruminant. More recent investigation has tended to disprove this belief. It would seem that present day investigations should be designed to study the fattening value of rations with varying levels of hay and to learn more about feed preparation.

REVIEW OF LITERATURE

Ruminant Digestion

The ruminant, or cud-chewing animal, is a herbivore with a digestive system especially adapted for efficient utilization of roughage. The rumen and reticulum provide a favorable environment for bacteria and protozoa which are important in the digestion of cellulose (Rogers, 1958). The microorganisms can also assimilate non-protein nitrogen (NPN) with the subsequent formation of protein (Phillipson, 1960). Rumen microorganisms decompose the plant materials in the rumen into short-chained fatty acids, principally acetic acid (Rogers, 1958). Ruminants can synthesize vitamin K and most of the B vitamins, including thiamine, riboflavin, niacin, pyridoxine, pantothenic acid, biotin, folic acid, and B_{12} (Agarwala, 1958).

Carbohydrates. Cellulose digestion is carried out mostly by iodophilic bacteria with the production of volatile fatty acids (VFA's) and gases (Agarwala, 1958). Annison and Lewis (1959) suggested that a series of enzymes are involved in the hydrolysis of cellulose. Cellulases of the bacterial cell cause the formation of eroded areas of cellulolytic material. These eroded areas make it possible for the bacteria to further degrade cellulose material.

There are many factors that can affect the rate and degree of cellulose digestion. According to MacLeod and Murray (1956), a combination of valine, leucine, and isoleucine is responsible for a strong stimulation of cellulose digestion. Annison and Lewis (1959) stated that, if a more readily fermentable carbohydrate such as starch is added to the ration, the degree of digestibility of dietary cellulose is reduced. Increasing the total nitrogen in the ration above one percent did not affect the digestion of cellulose. The extent of cellulose digestion is also affected by the age of the plant and the degree of lignification of the plant fiber (Phillipson, 1960).

Starch is fermented in the rumen with the production of volatile and non-volatile fatty acids. Starch digestion differs from cellulose digestion as the rumen is not essential for starch utilization. Starch is readily depolymerized to glucose by the action of the digestive secretions of the small intestine and is readily absorbed in the small intestine. The fermentation of starch in the rumen is a slow and complex process accompanied by multiplication of the microorganisms concerned. The utilization of starch in the rumen is important in the maintenance of a flourishing rumen flora (Annison and Lewis, 1959).

Proteins. During the first six hours after feeding, the predominant phenomenon occurring in the ruminant is the rapid digestion of proteins (Hale et al., 1947). Blaizot and Raynaird, in 1957, identified 17 amino acids in the rumen of cattle 24 hours after a feed of lucerne hay. This amount was less than was in the feed. However, it was concluded that amino acids were produced by microorganisms.

A ration may contain nitrogen in two forms: protein nitrogen or non-protein nitrogen (NPN). Experiments have shown that urea and other NPN sources in rations containing a small percentage of protein can be used by ruminants to supply a part of the dietary protein requirement. Microbial proteins may be metabolized from either dietary proteins or NPN. Microbial protein and dietary protein are attacked enzymatically in the abomasum and small intestine and are absorbed as polypeptides and amino acids in the small intestine (Lewis, 1961). The conversion of NPN to protein is retarded after a level of 12 percent protein is reached in the diet (Agarwala, 1958).

One important factor influencing the fate of protein in the rumen is its solubility. With highly soluble material, there is considerable microbial degradation of protein with the production of ammonia. The ammonia diffuses into the blood stream and may be converted to urea in the liver and excreted. Some of the blood ammonia returns to the rumen via the saliva and may be resynthesized into microbial protein (Head, 1960). The microorganisms pass out of the rumen and are digested in the abomasum. Four-hundred four milligrams of dry microbial substance per 100 milliliters of liquor provide the animal with at least 180 grams of protein, 80 grams of carbohydrate, and 8 grams of ether extract daily (Thaysen, 1951).

Davis et al. (1957) have shown that the amounts of propionic, valeric, and butyric acids rose significantly with high (15 percent) protein intake. The percent of acetic acid decreased but the total amount of VFA production increased significantly when protein was increased.

Oyaert and Bouckaert (1961) conducted investigations of quantitative aspects of food digestion in the rumen. They found that losses of nitrogen were significantly reduced by the presence of starch in the rumen.

At low protein intakes, rumen ammonia production was low, but there was an increase in protein nitrogen in the rumen showing that the bacteria can use NPN for protein synthesis.

Vitamins. The adult ruminant does not require B vitamins in the diet, as these vitamins are synthesized by rumen microorganisms. Vitamin K is also synthesized in the rumen (Annison and Lewis, 1959). The reticulum is the major site of synthesis of thiamine, riboflavin, niacin, and pantothenic acid. Vitamin B_{12} is synthesized in the rumen and the caecum. All the other B vitamins are synthesized in the rumen. Absorption of B vitamins occurs through the wall of the abomasum and small intestine (Nutrition Reviews, 1956).

Thaysen (1951) stated that the chief organisms concerned in vitamin B synthesis are iodophilic cocci. A definite relationship exists between the population of these organisms and the amounts of proteins and polysaccharides synthesized.

According to Hollis et al. (1954), the type of roughage fed had a direct effect on the amount of B vitamins synthesized in the rumen. When a low quality roughage was fed, there was less synthesis of B vitamins. The addition of alfalfa ash to a ration containing a low quality roughage improved B vitamin synthesis.

The B vitamins, especially pyridoxine, are important in stimulating cellulose digestion (MacLeod and Murray, 1956).

Minerals. There are numerous functions of minerals in the body. These functions can be classified under four headings: (1) they contribute to the structure of the body, (2) they maintain the tissues against the constant erosion of life processes, (3) they participate in the functional activities of the body, such as muscular activity, and (4) they are a part of the enzyme systems in the tissues (Mitchel, 1947).

Ruminant foodstuffs are usually comparatively rich in inorganic substances, especially the chlorides and phosphates of potassium and calcium (Annison and Lewis, 1959).

Soluble ingested minerals are absorbed from the rumen and from the other parts of the alimentary tract. Absorbed minerals in excess of body requirements are excreted in the urine. The large amount of saliva normally secreted by the ruminant is the major factor in the maintenance of the inorganic composition of the rumen contents (Annison and Lewis, 1959).

Volatile fatty acids. The amounts and proportions of volatile fatty acids produced by the ruminant depends on the type of diet, the time after feeding, and the age of the animal (Stewart et al., 1958). The main VFA's present in the rumen are butyric, propionic, and acetic acids. The proportions of VFA's in the rumen are butyric 15 percent, propionic 20 percent, and acetic acid 65 percent. Almost all dietary carbohydrate is absorbed from the rumen as volatile fatty acids.

According to Lewis (1961), the short-chained VFA's are produced by bacterial carbohydrate fermentation and bacterial metabolism of amino acids. The peak of VFA production is reached four to six hours after feeding. The digestion of cellulose yields more propionic acid and less acetic acid and butyric acid than the digestion of starch. In general, feedstuffs which are rapidly fermented in the rumen give rise to less acetic acid. A probable explanation is the lowered rumen pH observed under these conditions which encourages the growth of organisms which produce propionic acid.

Investigations by Hibbs et al. (1956) showed that there was no effect of hay-grain ratio on the total VFA's in the rumen juice. Rumen pH increased with advancing age but was maintained at a lower level in the calves receiving the higher levels of concentrates.

Two cows and a bullock with rumen fistulae were studied for volatile fatty acid production at intervals after feeding (Emery et al., 1956). The specific acids studied were acetic, propionic, and butyric acids. On a roughage and a roughage-concentrate ration, the formation of acids increased for four hours and then slowly decreased to the end of a 24-hour period. On hay alone, more acetic acid and propionic acid and less butyric acid were produced than on a ration of grain and hay.

In a study by Krotkova et al. (1961), the effect of concentrates on the total VFA's in the rumen and on the pH of the urine was studied in the milk cow. With high levels of concentrates in the diet, there was a large volatile fatty acid accummulation in the rumen, but much of the VFA's were not used in the body. There was a shift to the acid side of the acid-base balance in the rumen beginning the first few days after a high concentrate diet was fed. There was also an increase in the acidity of the urine and blood. When the concentrate was decreased, these physiological balances became normal. Disorders of animal digestion coincided with the most extreme shifts of the acid-base equilibrium toward the acid side.

Acetic, propionic, and butyric acids are absorbed in substantial amounts from the rumen of sheep. The rate at which VFA's leave the rumen is not proportional to the concentration of individual acids present in the blood. When equimolar solutions of VFA's are present in the rumen, the concentration in the blood leaving the rumen is in the following order: acetate > propionate > butyrate (Masson and Phillipson, 1951).

According to Pennington (1952), the absorption of VFA's from the rumen is probably a simple diffusion process. During the absorption of VFA's, there was appreciable utilization of acetic, propionic, and butyric acids by the rumen epithelium. Butyric acid was more readily utilized than acetic or propionic acids. The uptake of acetic and butyric acids was accompanied by some ketone body production, but propionic acid absorption was found to diminish the amount of ketone bodies produced by the tissues. It is not clear whether the nutritional requirements of the epithelium are supplied wholly or in part by the VFA's or by the blood (Annison and Lewis, 1959).

The caloric value of the VFA's depends on the amount of individual acids produced and their heat of combustion. As the digested calories increase in the ration, the VFA caloric value also increases, but at a diminishing rate. These acids account for approximately 60 percent of the energy requirement of the steer for maintenance (Stewart et al., 1958).

Stewart et al. (1958) conducted investigations with several common dairy feeds to study the production of VFA's. They found that fresh hand-clipped legume mixed grass caused a greater VFA production than did legume hay. The grass, however, markedly depressed acetic acid production. Beet pulp significantly increased acetic acid production and corn meal increased propionic acid production. Urea increased VFA production.

Nutrient Requirements of Fattening Cattle

A steer fattening ration is most likely to be deficient in proteins, minerals, and vitamins. This is especially true when high concentrate rations are fed. The high daily gain reached in the feedlot places a stress on the fattening animal. Therefore, the ration must be adequate to meet the higher requirements of the animal.

Proteins. Protein is the principal constituent of the organs and soft structures of the animal body, and a liberal and continuous supply is needed in the diet of the animal throughout life (Maynard and Loosli, 1956). The amount of proteins, vitamins, and minerals needed for fattening cattle will depend chiefly upon the age of the animal. The nutrient requirements are much greater for young animals per 100 pounds of body weight than for those that are well grown when fattening begins. When immature animals are being fattened, there is considerable muscle growth or protein storage in the gain produced. More protein is needed for a young animal than for a mature animal that is storing more fat (Morrison, 1959). If fattening animals are fed a ration high in carbohydrate and fat and low in protein, they are likely to go "off feed." Morrison recommends that a ration for fattening should contain at least nine percent crude protein.

Hubbert et al. (1960) fed fattening beef cattle varying levels of protein on a 126-day fattening experiment. They found that steers fed a 14 percent crude protein ration gained 11 percent faster than steers fed a ration that contained 10 percent crude protein. The steers fed the 14 percent crude protein ration required 5 percent less feed per unit of gain than the steers fed the 10 percent crude protein.

Klosterman et al. (1956) conducted experiments with fattening cattle to study the relationship between levels of protein, molasses, trace minerals, and quality of hay. There were highly significant differences in rate of gain of steers fed various amounts of protein. The amount of protein in the ration was of much greater importance when fed with poor quality timothy hay than with good quality mixed hay. It was concluded that there was little advantage in providing extra protein without added trace minerals. Molasses supplied the necessary trace minerals and also had a sparing effect on the protein requirement.

Vitamins. Vitamin A is of primary concern to cattle feeders who use high concentrate rations. Most cereal grains are low or lacking in vitamin A, whereas good quality roughages are often high in the vitamin.

Work at Purdue University by Beeson et al. (1961) was conducted to study levels of supplemental vitamin A required with and without alfalfa hay for fattening steer calves. Calves that received a ration without alfalfa hay showed a highly significant increase of 22 percent in average daily gain from an intake of 20,000 I. U. of vitamin A. Levels of vitamin A between 20,000 and 50,000 I. U. per head daily did not improve the performance of the steers. When cattle received a ration containing 10 percent sun-cured alfalfa pellets, there was little increase in daily gain when a vitamin A supplement was fed.

Hubbert *et al.* (1961) conducted an experiment with four lots of eight steers each to study the vitamin A requirement for feedlot cattle. The cattle were fed a control ration of 46 percent steam-rolled barley, 19 percent ground alfalfa, 19 percent Bermuda straw, 5 percent molasses, 10 percent cottonseed meal, and 1 percent urea. The ration contained 14 percent protein. The two treatments assigned the four groups of steers were a control ration and a control plus 20,000 I. U. of vitamin A daily. The cattle that received the vitamin A supplement gained 0.2 pounds more per steer daily, apparently because of an increased feed consumption. Feed efficiency was improved slightly in the steers fed the vitamin A supplement.

In a vitamin A study by Hale *et al.* (1961), feedlot steers were fed high levels of vitamin A. There was no vitamin A toxicity in steers fed 2,560,000 I. U. of vitamin A per head daily for 168 days. They found that most of the stored vitamin A was deposited in the liver, with some of the vitamin stored in the fat tissue only when the dietary level was very high. Ten thousand I. U. of vitamin A did not maintain liver stores in the cattle.

Minerals. It is important to provide an adequate mineral level in the rations of farm animals to insure a good appetite, a favorable feed efficiency, and a healthy animal (Mitchel, 1947). All the cereal grains are extremely low in calcium. High concentrate rations are very likely to be deficient in calcium. Usually the hays, either mixed or legume, will supply adequate calcium, but are low in phosphorus, ranging from 0.15 to 0.30 percent phosphorus (Morrison, 1959).

Hubbert et al. (1955) studied the importance of minerals for the cellulolytic rumen microorganisms. These investigators found that removal of each of the following minerals individually from the rumen media resulted in reduced cellulose digestion: sodium, potassium, phosphorus, magnesium, manganese, iron, and sulfur. High levels of copper, zinc, and cobalt were inhibitory to cellulose digestion. These investigators concluded that rumen microorganisms can tolerate a wide range of concentrations of certain mineral elements.

Trace minerals in the diet of steers were studied by Bentley et al. (1954). A trace mineral supplement significantly increased the average daily gain of steers individually fed a ration of mature timothy hay, ground ear corn, urea, cerelose, calcium, phosphorus, iodized salt, and vitamin A. Studies indicated that cobalt increased gains and the vitamin B_{12} content of the liver. The addition of trace minerals also increased feed intake and feed efficiency.

Barley

Barley is one of the world's most widely used grains and can be grown in a greater variety of climates than corn, wheat, or oats (Nutrition Reviews, 1958). It is best adapted to cool summers and regions of well-drained soils (Morrison, 1959).

Barley is believed to have originated in Western Asia where it served as food for man and beast. The earliest settlers brought barley to the North American continent (Encyclopedia Americana, 1961).

Barley ranks fourth in importance as a grain crop in the United States (Morrison, 1959). About two-thirds of the 340 million bushels of barley used in the United States in 1958 was fed to livestock (Senti and Maclay, 1961). Barley averages 12.7 percent protein, except in the Pacific Coast states where the protein content is lower (Morrison, 1959). Proteins found in barley are albumins, globulins, prolamine, and glutelin (Barton-Wright, 1958). The protein of barley is not of good quality, though it is of better quality than the protein of corn. The hulls form 15 percent of the barley. Barley has about 5.4 percent fiber. It lacks carotene and vitamin D and is low in riboflavin. It is rich in niacin, with three times as much as is present in corn (Morrison, 1959).

The amino acid nitrogen of barley in percent of total nitrogen follows (Ljungdahl and Sandegren, 1956):

amino acid	% of total nitrogen
Alanine	3.4
Arginine	9.9
Aspartic acid	3.4
Cystine	0.6
Glutamic acid	13.6
Glycine	7.1
Histidine	3.5
Isoleucine	2.1
Leucine	4.7
Lysine	4.9
Phenylalanine	2.0
Proline	6.3
Serine	3.0
Threonine	3.3
Tyrosine	1.3
Valine	3.1

When barley is steam-rolled, the moisture content is increased 3 to 5 percent (Taylor *et al.*, 1960). Steam-rolling as compared to dry-rolling resulted in a 6.5 percent increase in rate of gain of steers and a 5 percent saving in feed required per unit of gain. Steers that averaged 596