Utilization of wheat straw in fattening rations for beef steers
by Jerry R Border

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Animal Industry
Montana State University

Abstract:
Forty yearling steers were fed wheat straw as a roughage during a 152-day fattening experiment to determine the feasibility and economy of straw utilization. The animals were randomly divided into four lots of ten head each. Each lot received a basal concentrate ration (barley and wheat mixed feed) fed according to appetite. In addition, two pounds per steer, per day, of a 32 per cent protein supplemental pellet was fed three lots. Similarly a 14 per cent pellet was fed the fourth lot. Pellets differed in constituents. Straw served as roughage for three lots and alfalfa hay fed the fourth lot served as the control roughage. Each roughage was fed ad libitium.

One of the three supplemental pellets fed with straw roughage was designated a control, the other two contained additional ingredients. One contained additional molasses and the other contained yeast and bovirum.

Steers showed a dislike for Straw, which influenced efficiency of feed utilization. Steers fed straw averaged. 12 per cent higher efficiency from this roughage than alfalfa fed steers did from their roughage. The converse was true for concentrate utilization (19 per cent). There were no significant differences between the average daily gains of each lot; however, steers fed alfalfa show 0.3 pound greater average daily gain than those steers fed straw.

The monetary return for steers fed alfalfa hay averaged $5.79 per steer, while each lot fed straw showed an average deficit ranging from $9.26 to $16.87 per steer. The data does indicate, however, that it is entirely possible for wheat straw to be utilized nutritionally and economically in a beef fattening program.

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JERRY R. BORDER

30

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Approved:

Fred S. Willson
Head, Major Department

Oscar O. Thomas
Chairman, Examining Committee

Leon H. Johnson
Dean, Graduate Division

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ABSTRACT

Forty yearling steers were fed wheat straw as a roughage during a 152-day fattening experiment to determine the feasibility and economy of straw utilization. The animals were randomly divided into four lots of ten head each. Each lot received a basal concentrate ration (barley and wheat mixed feed) fed according to appetite. In addition, two pounds per steer, per day, of a 32 per cent protein supplemental pellet was fed three lots. Similarly a 14 per cent pellet was fed the fourth lot. Pellets differed in constituents. Straw served as roughage for three lots and alfalfa hay fed the fourth lot served as the control roughage. Each roughage was fed *ad libitium*.

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The monetary return for steers fed alfalfa hay averaged $5.79 per steer, while each lot fed straw showed an average deficit ranging from $9.26 to $16.87 per steer. The data does indicate, however, that it is entirely possible for wheat straw to be utilized nutritionally and economically in a beef fattening program.

UTILIZATION OF WHEAT STRAW IN FATTENING RATIONS FOR BEEF STEERS

INTRODUCTION

The rumen, or first compartment of the ruminant stomach, is one of man's greatest economic assets because of the symbiotic relationship existing between the rumen microorganisms and the host animal. These microorganisms provide enzyme systems enabling conversion of feeds of little value to man into nutrients used by the host animal to produce some of our best food.

Limited amounts of good quality roughages, influenced by climate, and soil, and economic availability, have induced utilization of poorer quality roughages in ruminant rations. With proper supplementation, low quality roughages can be efficiently and economically integrated into the diet of these unique converters.

Many countries have used less desirable roughage foodstuffs for some time because of insufficient supply of hay and/or pasture, thus pointing the way toward new horizons in utilizing readily accessible low quality roughages. More recently, there has been increased interest in utilization of low quality roughages in the United States, not entirely for the same reasons, however. Economic production of livestock and efficient use of products otherwise considered waste materials have been the influence here.

Late-cut hays, straws, corn cobs, corn stover, cottonseed hulls and other materials of high fiber content are often plentiful and available for use in areas where there is considerable production of cattle.

In Montana, there is an abundance of cereal straw--oat, barley, and wheat--which could be used for ruminant consumption. However, most of the cattle fattening has been confined to irrigated areas and communities near the beet pulp industry. Recently, more fattening of cattle has taken place under conditions where dryland farmers and ranchers have access to grains and straws and limited access to alfalfa and grass hays, beet pulp and pasture.

In utilizing low quality roughages, particularly wheat straw, as part of cattle fattening rations, many influencing factors should be borne in mind. Much is yet to be learned and many questions to be answered, such as the following: what specific nutrients, and how much, are needed to meet rumen nutrient requirements? Can low quality roughages, properly supplemented, produce economical gains in cattle? Man's continuing challenge in ruminant nutrition is to learn the nutritive requirements of microorganisms so that more low quality roughages and other feeds can be used efficiently. It is with factors like these our interest lie.

The experiment reported herein was undertaken for the purpose of developing rations which will effectively and economically supplement the deficiencies of wheat straw when used in a cattle fattening program. If these supplements, fed with straw and a barley base concentrate feed, can produce weight gains in fattening cattle as economically as when a high quality roughage is used, then many ranchers in dryland areas may be able to utilize their straw and surplus barley to an advantage in ruminant feeding.

LITERATURE REVIEW

Ruminants are polygastric animals and are vastly different from monogastric animals in their physiology of digestion because of the integral part the bacterial enzymes play in the digestion of the roughages they consume. A thorough knowledge of the biochemical and physiological factors involved in ruminant digestion is essential for efficient use of low quality roughage in the rations of these animals. The understanding of these factors is limited, however, information has shown that use can be made of the rumen bacteria and their enzymes to improve the economy of ruminant feeding. The important contributions of rumen bacteria seem to be: synthesis of vitamins, synthesis of amino acids, and proteins, as well as the digestion of cellulose and production of fatty acids (Davis 1954, Burroughs and Hall 1954).

I. THE RUMEN AND ITS MICROORGANISMS

The rumen is the first of four compartments in a ruminant's compound stomach. After one year of age it contributes approximately 80 per cent of the total stomach volume. Depending upon the size of the animal, an estimate of 20 to 40 gallons is normal rumen capacity for adult cattle (Burroughs and Hall 1954). Emery _et al._ (1957) estimated the rumen contents of three animals, averaging 1200 pounds each, to be 70 kilograms of liquid. In the rumen, feed is stored, mixed and softened with water and saliva. It is here that most of the digestive activity resulting from bacteria takes place.

The rumen, reticulum, and omasum secrete no digestive enzymes, whereas the abomasum or so called true stomach does. This stomach is similar to the stomach of monogastric animals because it produces digestive enzymes and hydrochloric acid (Burroughs and Hall 1954).

Burroughs et al. (1950) divided into two groups some general factors which involve rumen microbiological digestion. The first, regulated by the physiology and anatomy of the host, is more or less fixed. The second represents variable conditions related to environment of the rumen and indirectly related environment of the host.

Group I-	Temperature Moisture Saliva and its buffering action Salts in saliva Anaerobiosis	Absorption of organic acids through the rumen wall Rumen motion Possibly exclusion of light
Group II-	Types of microorganisms Nutrients available to bacteria present Hydrogen ion concentration	Total salt concentration Oxidation-reduction potential Possible synergistic relations of organisms

Another important factor is the length of time ingested feed remains in the rumen. Feeds entering the rumen of cattle must be acted upon in a very short time. According to Burroughs et al. (1946), feeds must be acted upon within periods averaging 24 hours or less. Again in 1954, Burroughs and Hall stated that feed may remain in the rumen 60 to 72 hours; the majority of it remaining much less. Compared with other forms of microbiological decomposition, i.e. organic matter break down in the soil, sewage disposal and industrial fermentations of fibrous materials, this is an extremely short period for fiber digestion. The rate of fermentation is hastened by rumen temperature (Burroughs et al. 1950c) although fermentation is nearly constant throughout a 24-hour day. Little differences in temperature exist between breeds of cattle.

Monroe and Perkins (1939) stated that one of the requirements for optimal bacterial activity is maintenance of a proper hydrogen ion concentration. No doubt nature regulates the rumen pH reaction by some means, however it is probable that extremes in feeding have an influence. Fattening or high production rations where heavy grain feeding or excessive use of corn or silage may affect the pH balance (Monroe and Perkins).

Dukes (1937) states, "the reaction of the rumen content of the ox is always alkaline; the average is pH 8.89 (Gabriel)." It is because of the highly alkaline saliva secreted by ruminants there is such a constant reaction, Dukes explains. When hay or straw was fed with oats or bran, or hay alone, Stalfors (1926) noted an alkaline rumen reaction. In 1926, Swarz and Stremnitzer found upon slaughtering eleven animals, an average pH of 8.28 (reported by Monroe and Perkins 1939). These animals were fed a ration consisting of hay and straw. Higher alkaline rumen values were found when alfalfa hay was fed, also variations in pH were noted during the day. Kick _et al_. (1938) found that pH values were not the same in all parts of the rumen and that the greatest variations were found soon after the steers consumed their rations.

It has been assumed that the bacteria present in sheep and cattle would be different because of Hasting's statement that the pH in the rumen of the sheep is the higher of the two species. In their studies, when both species were fed the same type of ration, Gall _et al_. (1949) found the pH was similar, as was the bacterial population.

Rumen microorganisms appear to be able to tolerate a higher pH better than a low pH (Cheng et al. 1955). These workers also state it is very likely that different animals fed different rations also differ to some extent in their rumen microfloral activity.

Although the classification of the rumen microorganisms is imcomplete, bacteria, protozoa and yeast are the three general groups of microorganisms present in the rumen (Burroughs and Hall 1954). These workers also related that incomplete classification of rumen microorganisms exists partially because of the many species and types of microflora and microfauna in the rumen. Environmental rumen conditions have some influence upon the predominant types of microorganisms at a specific time. An example of this is, microorganisms from the water and feed consumed add to the complexity and confusion of identifying the native rumen population.

Protozoa are the most primitive members of the animal Kingdom, being microscopic in size, yet much larger than bacteria. Some of the larger protozoa may be 100,000 times larger in volume than some genera of bacteria (Heald and Oxford 1953). Protozoa possess a definite nucleus, celia, vacuoles and can ingest solid food but must absorb their nutrients in solution.

Mowry and Becker (1930) maintain that much importance is attached to the amount and kind of feed consumed in regulation of the number of organisms present in the rumen. They remarked that, under normal feeding conditions, approximately 1,000,000 microorganisms per cubic centimeter were present in the rumen. By direct count methods, Van Der Wath (1948) found an average of one to two billion microorganisms per milliliter of rumen contents.

Hungate (1947) stated that species and breed within species played no specific role in influencing rumen flora. High grain rations encouraged an increase in a type of organism already present in moderate numbers in the rumen, instead of an entirely different type of bacteria. Hungate also noted, that animals on pasture had greater numbers of bacteria in their rumen.

Gall et al. (1949) made direct counts of the rumen bacteria of cattle and sheep on pasture and reported numbers as high as 96×10^9 cells per gram of rumen contents. The numbers were somewhat lower in animals on wintering type rations.

Burroughs and Hall (1954) in describing yeast said, "yeasts resemble bacteria in being unicellular, non-motile, devoid of chlorophyll and require food material in a soluble form which can pass through the cell wall by diffusion. Yeasts differ from bacteria in their modes of reproduction and are generally much larger. Yeast cells also possess distinct muclei and vacuoles of various kinds. It appears that yeasts are a relatively insignificant group of microorganisms in the rumen."

Resulting from their unique and dependent relationship, the ruminant supplies the material and the rumen microorganisms break down these substances so the nutrients can be utilized by the animal. These rumen microorganisms grow and multiply, and a great many of them are digested as they pass through the lower digestive tract (Burroughs and Hall 1954).

Early workers found that cellulose was decomposed by ruminants. They offered as evidence of rumen microbial cellulolytic activity, the lack of cellulase in the fore-stomach of ruminants (Burroughs and Hall 1954).

Hungate (1947) while working with high dilutions of rumen contents succeeded in isolating cellulose-digesting bacteria. It is now common knowledge that bacteria breakdown and digest cellulose (Bryant and Doetch 1955, Burroughs and Hall 1954); however, little is known of protozoan function within the rumen. Cellulolytic properties have been atributed to these microorganisms by some workers, (Burroughs and Hall 1954); nevertheless, it is not known whether protozoa or the bacteria ingested by the protozoa, digest the cellulose. Soluble carbohydrates are stored within protozoan cytoplasm (Burroughs and Hall 1954) as complex polysacharide vacuoles. Protozoa also become available to the animal in the lower digestive tract and serve as food for the host animal. Becker et al. (1929) removed the protozoa from the rumen of goats and the feed utilization was compared between these and normal animals. While possessing normal bacterial flora and having an absence of protozoa Becker et al. found no difference in the digestion coefficients of the feed nutrients in the treated and untreated animals.

II. FACTORS AFFECTING ROUGHAGE UTILIZATION BY MICROORGANISMS

It is a general concept that rumen microorganisms have nutritional requirements, and if efficient roughage (cellulose) digestion is to take place, these requirements must be fulfilled. Good quality roughages have ample quantities of these nutrients, while inadequate amounts are present in some poor quality roughages. Burroughs et al. (1949a, 1949b, 1949c, and 1950a, 1950b, 1950c) furnished additional support to this concenpt. Their results indicate the presence or absence of certain nutrients, needed by rumen organisms, affect the efficiency of digestion of roughage dry matter.

The nutrient requirement for the mixed rumen microflora appears to be relatively simple because they have such a large and varied synthesizing ability. There is evidence that the types of nutrients required by rumen microorganisms may fall into four general classifications (Davis 1954):

Type A. Energy - Nutrients related to energy, which are primarily soluble carbohydrates (presumably the motivation force of the digestion of compounds such as cellulose by rumen bacteria).

Type B. Protein- A nitrogen source related to protein (urea, ammonium salts etc.) or protein elements which can be synthesized into protein material.

Type C. Minerals-(major and minor minerals) Inorganic nutrients believed to be part of enzyme systems.

Type D. Factors- Unidentified stimulatory factors.

A. ENERGY

1. CELLULOSE AND FATTY ACIDS. Belasco (1956) stated that, "cellulose digestion in the ruminant is dependent on the nutritive status and requirements of the rumen microorganisms." He emphasized how carbohydrates yield fatty acids. Fatty acids are essential as energy, intermediates for tissue biosynthesis and milk production. The composition of feed ingredients have a direct bearing on the amount and distribution of volatile fatty acids in the rumen (Gray et al. 1951, El-Shazly 1952). Belasco (1956) stated that the amount and type of carbohydrate used, affects the amount and distribution of fatty acids.

Burroughs and Hall (1954) said, "the end products of cellulose decomposition consist primarily of acetic, proprionic and butyric acids." One pathway of cellulose breakdown is by way of cellobiase to glucose and then to volatile fatty acids perhaps by way of pyruvic or lactic acid (Phillipson

1947). Other carbohydrates, such as starch and sugars are broken down to these same fatty acids. Acetic acid is usually produced in greatest quantity, followed by propionic and butyric acid, depending upon the type of carbohydrate fermented (Phillipson 1947).

As indicated by the large amount of volatile fatty acids in the rumen the reticulum and relatively smaller amounts in the abomasum, these acids are absorbed from the rumen (Burroughs and Hall 1954). Phillipson and McAanally (as reported by Burroughs and Hall 1954) showed that blood draining the rumen, reticulum, omasum and caecum contained a higher concentration of volatile fatty acids than peripheral blood. This was good evidence that absorption was occuring from the rumen.

These volatile acids may enter various metabolic pathways. Propionic acid is converted to glycogen (Deuel et al. 1935, Doetch et al. 1952). Acetic acid after combining with coenzyme A to form acetyl coenzyme A, may be used in forming fat. It may be converted to sugar or glycogen, going through the intermediates of the krebs cycle to malate, from which it is converted to phosphoenolpyruvate, then to sugar. Because of the dynamic effect of feeds in ruminants, a great deal of the acetic acid is thought to be oxidized to CO_2 ≁ H_2O directly (Burroughs and Hall 1954).

Cellulose digesting bacterium, Bacteriodes succinogenes, have been shown to require branched and straight chain fatty acids (Bryant and Doetch 1955). Bently (1954) reported that valeric and caproic acids increased cellulose digestion in the artificial rumen and that some of the fatty acids stimulate fermentation by mixed rumen bacteria in vitro. Hungate and Dyer (1956) suggest that small amounts of appropriate acids might improve utilization of poor quality roughages. However, their results show no significant difference in weight gains, and rumen microbial activity between these steers fed with or without small amounts of valeric and isovaleric acids. These steers were fed a high wheat straw ration. Hungate and Dyer felt that the reason for this negative result might be due to lack of sufficient digestible carbohydrate in the ration. Those steers receiving the acid did display a stimulated appetite.

2. STARCH. Starch disturbs roughage digestion in ruminants in a manner probably related to the alimentary tract in habitation of biological microorganisms. An exact explanation of this necessitates direct bacteriological study.

As reported by Burroughs et al. (1949c) investigators, (Kellner and Hamilton) suggest when steers are fed a carbohydrate ration, the alimentary microorganisms might break down the simpler carbohydrates. Burroughs et al. (1949a, b) indicated starch and roughage are acted upon together by rumen microorganisms and that the addition of starch in their studies was found to decrease the apparent digestibility of crude fiber, throughout a wide range in protein intake.

Arias et al. (1951) observed that high levels of readily available carbohydrates decrease cellulose digestion. They suggested that in the interval between the time when the cellulose is broken down to a form which is utilizable by the cell, (glucose) some readily available energy is needed. If too much of the soluble carbohydrate is supplied, then the energy requirement of the bacteria will be satisfied and they no longer need to break down cellulose for energy.

From pH measurements taken right after feeding, Burroughs and Gerlaugh (1949a) found the attack on starch either precedes or takes place at a faster rate than it does when roughage replaces starch. Monroe and Perkins (1939) showed that the pH value decreases immediately two to four hours following feeding. Lower pH values are obtained in a shorter period of time when the starch to roughage ratio is increased in a ration (Burroughs et al. (1949c). These same workers noted that four pounds of starch decreased corn cob digestion appreciably. When the same amount of starch was added to alfalfa hay, no effect was noted. They stated that alfalfa hay contained more essential nutrients for promoting growth of microorganisms than did corn cobs. The alfalfa hay had adequate nutrients to withstand starch fermentation and enough left to promote growth of rouchage digesting microorganisms.

3. FAT. The level of fat was indicated to have a critical effect upon cellulose breakdown by sheep microbial organisms, as interpreted by Brooks et al. (1953) in seven trials with 130 artificial rumina. In these trials, 10 milligrams of corn oil added to the basal ration increased cellulose breakdown an average of 8 per cent. Cellulose digestion was decreased 4.8 per cent by adding 20 milligrams of oil and decreased 35 per cent by adding 40 milligrams of oil.

Erwin et al. (1955) found that fat significantly increased the digestibility of dry matter and crude fiber of steer rations. Tillman et al. (1956) conducted study using 141 sheep, involving the effect of fat and/or alfalfa ash upon the utilization of different types of rations containing low quality roughages. The levels of fat were 2.5 and 15 per cent, combined with varying amounts of low quality roughages. These data support the idea that under certain conditions even small amounts of supplemental fat may decrease the value of certain rations for sheep.

Willey et al. (1954) observed a faster rate of gain with increased feed efficiency when yearling steers were fed 5 per cent tallow in their ration.

Steers fed pellets containing alfalfa were noted to have increased rates of gain when 7 per cent fat (bleachable fancy tallow) was added to their ration (Erwin et al. 1956a). Steers consuming wheat straw showed a reduced rate of gain with the same level of fat. These differences may be explained (Erwin et al. 1956a) in that fat tends to reduce crude fiber breakdown, and wheat straw has a higher crude fiber content than alfalfa hay (Morrison 1956).

Brooks and fellow workers (1954) observed a reduction in cellulose digestion in vitro from the addition of fat. Ruminant feedstuffs could be affected considerably by fat because a large part is composed of cellulose. In the work done by Swift et al. (1948), digestibility of fat was increased as the level of fat increased in the ration. However, a trend was noticed toward decreasing dry matter digestibility as fat increased in the ration. Erwin, et al. (1956b) reported 7 per cent fat added in steer rations fed alfalfa and straw reduced the digestibility of the dry matter and crude fiber.

Erwin et al. (1956b) stated, "The mode of action of fat in reducing the digestibility of certain nutrients in the ration has not been definitely established. A possibility exists that the depressing effect is physical - that is, by coating the fiber so that the cellulolytic microorganisms cannot fully degradate the fiber."

4. MOLASSES. High levels of molasses produce a varied effect with different rations. Low levels of molasses appear to stimulate cellulose digestion with some rations and have no effect with others (Davis 1954). Molasses will usually increase the palatability of any roughage on which it is fed. It may be used to increase intakes and allow ruminants to obtain more nutrients from roughages. However, it must be remembered that this treatment will not turn poor-quality roughages into a higher class rations.

Molasses has been used as feed for at least sixty years and perhaps longer in the United States. Early work, as reported by Bohman et al. (1954) indicated that molasses was not an adequate carbohydrate for urea utilization, when fed with little or no starchy carbohydrate. As determined by nitrogen balance data, adequate synthesis of protein from urea did not occur in these rations. Further, the digestibility of dry matter, organic matter, either extract and crude fiber was found to be depressed by molasses.

Molasses competes directly with grains and mill feeds as a source of nutrients for livestock. However, Allan (1954) stated that molasses is an extremely poor source of protein.

Steer calves fed poor quality hay and two levels of protein showed an increased liveweight upon supplementing with molasses or trace minerals (Klosterman et al. 1956). These workers found that one pound of cane molasses per head, daily, improved the carcass grade of the finished cattle as well as their rate of gain.

The value of molasses has been associated with poor quality feeds. An investigation at Cornell indicates maximum value of molasses may be realized only when used with the best quality feeds, according to Fry (1956).

B. PROTEIN AND AMMONIATED PRODUCTS.

1. PROTEIN. Early work concerning ruminant synthesis of protein dates as far back as 1891. Improved digestibility by the addition of protein supplements to ruminants' rations have been observed by many. Watson et al. (1947), Swift et al., (1947), Gallup and Briggs (1948) and Morrison (1956) are a few of the many who have noted the influence of protein upon digestibility in ruminants. Davis (1954) recognized that for optimum function of rumen bacteria, there is need for some natural protein and a specific source of energy.

Because the bacterial cell is approximately fifty per cent protein, a nitrogen source is extremely important if they are to multiply. The following steps are involved in protein utilization by ruminants: (1) bacterial breakdown of a large part of the protein and non-protein nitrogen in the ration to ammonia, (2) incorporation of ammonia nitrogen into bacterial protein, (3) digestion of the bacterial protein as it passes through the lower digestive tract. Protozoa are known to ingest large numbers of bacteria and they in turn are digested by the animal (Burroughs and Hall 1954). Bacterial and protozoan protein has been found to have a biological value of 81 and 80 respectively and a true digestibility of 74 and 91 per cent (McNaught et al. 1954).

Burroughs et al. (1949b) stated that the decrease in protein digestibility of low protein rations is more apparent than real because fecal metabolic nitrogen is not taken into account. However, a decrease in non-protein digestibility may impair the digestive actions of the microorganisms in the rumen and digestive activity of these microorganisms. Proteins presumably serve two physiological functions when fed to ruminants (Burroughs et al. 1949b).

Function I - Pertains to growth and development of roughage digesting microorganisms, and amino acid and B-vitamin synthesis.

Function II - Relates to growth in the ruminant body proper.

Because the same feed-protein serves both functions, the total minimum protein required for maximum production depends upon which functional need is greatest. This production is difficult because under different conditions the protein requirement is variable in both instances. For example, the requirement for growth of body tissue protein for growing and fattening cattle decreases as the animal becomes older. More starchy feeds are consumed compared to roughage while fattening these animals, which in turn increases the protein requirement for roughage digestion. When corn cobs are fed in the absence of starch, the protein requirement for efficient utilization is as little as four per cent (Burroughs et al. 1949b).

Feeding grain in addition to roughage may furnish enough protein for body needs, yet may furnish insufficient protein to maintain efficient roughage utilization. This type of protein deficiency would affect mostly cattle being fattened, particularly older animals.

Because of the incomplete understanding of the role starch plays an increasing protein requirements in roughage digestion, an accurate minimal protein level has not been established. It is suggested, however, that this level falls between eight and twelve per cent protein. (Burroughs et al. 1949b). Burroughs et al. (1950b) again reported an apparent need for a minimal amount of protein in cattle rations to facilitate maximum roughage digestion. At times, they said, it appeared this level exceeded eleven per cent protein.

In the absence of starchy feeds or when a roughage is fed alone, the importance of protein per se to roughage digestion is quite small. Burroughs et al. (1950a) maintain that as starchy grains are reduced in a ration, apparently so is the protein requirement for efficient roughage digestion. As stated by Burroughs et al. (1950a), "this should not be inferred to mean that this small amount of protein in a roughage is ample in meeting the needs of cattle because requirements for roughage digestion and body needs are distinct and not additive even though ration protein jointly serves the two requirements."

The theory that protein aids roughage digestion by furnishing an essential nutrient for rumen bacteria was offered by Burroughs et al. (1949c). Following this thinking, Burroughs suggested that protein requirements for roughage digestion is actually the protein (nitrogen) requirements for rumen bacterial growth. As observed in these same studies, sufficient numbers of rumen bacteria were present when adequate protein was fed and roughage digestion was good. The predominating types of bacteria differed morphologically and culturally from those found when roughage digestion was poor.

Urea provides a satisfactory source of nitrogen for mature ruminants when thirty per cent or less of the total crude protein is furnished by urea (Davis 1954). In their in vitro studies of urea utilization by ruminants, Pearson and Smith (1943) found the first step in the use of urea to be its conversion to ammonia. Greater conversion was noted occurring at temperatures around 40° to 50° C. and hydrogen ion concentrations between 7 and 9. The second step was the incorporation of ammonia-nitrogen into protein. Pearson and Smith suggested this conversion was done by bacteria.

Burroughs et al. (1951) and McDonald (1951), as reported by Burroughs and Hall 1954, have both suggested that ammonia is the important intermediate in the digestion or utilization of protein or non-protein nitrogen by rumen bacteria. Bentley et al. (1953) found that urea (which is partially converted to ammonia) in combination with minerals and glucose gave great increases in in vitro cellulolytic activity.

Davis (1954) remarked there is a need for a more satisfactory source of non-protein nitrogen for ruminant feeding. Urea is rapidly broken down to carbon dioxide and ammonia which quickly escapes from the rumen. This action apparently occurs before the bacteria have an opportunity to use it completely for the synthesis of amino acids and protein.

Non-protein nitrogen was released enzymatically proportionate to the growth of the rumen bacteria which were synthesizing protein. This would appear to be a more useful source of nitrogen than urea. According to Davis (1954), a way to provide for the slow release of urea nitrogen in the form of ammonia is now under consideration. Several non-protein nitrogen compounds containing soluble ammonia or ammonia made available through enzymatic breakdown, provide good sources of nitrogen (Belasco 1954). His work was done in vitro. Magruder and Knodt (1954) indicated a compound called dicyanodiamide may provide a useful source of non-protein nitrogen for ruminants. Its nitrogen content is 66 per cent.

Results in their study (Burroughs <u>et</u> <u>al</u>. 1950b) with cattle indicate protein influenced favorable roughage digestion when roughages were fed in rations containing starch. Substantially the same results were observed by Burroughs <u>et</u> <u>al</u>. (1949a and 1949b) in which soybean oil meal and skim milk both increased the digestion of roughage. They also studied the effect of soybean oil meal upon corn cob and timothy hay dry matter digestion in a fattening ration. An average increase of about fifteen per cent in dry matter digestion occurred with the soybean oil meal addition.

Practical significance can be attached to the improvement in roughage digestion resulting from adding soybean oil meal to a low protein fattening ration. It is entirely possible that soybean oil meal might contribute some beneficial nutritional property to the ration other than protein. (Burroughs and Gerlaugh 1949a, b and c).

Extensive studies with artificial rumina showed that many protein rich feeds increased cellulose digestion by rumen bacteria (Burroughs <u>et</u> <u>al</u>. 1950d).

2. AMMONIATED PRODUCTS. The production of ammonia in the rumen at a greater rate than can be utilized by rumen microorganisms is an important problem in feeding non-protein nitrogen compounds to ruminants. Hale and King (1955) proclaim accumulation of ammonia in the rumen is undesirable and may be detrimental; and that among other things available carbohydrates are required for ammonia utilization.

Methods have been developed that may release ammoniated nitrogen in the rumen near the rate which complex carbohydrates are hydrolyzed and become available for protein synthesis. This is done by impregnating several agricultural products with ammonia-inducing chemical combinations, thus reducing its release to about the correct rate. Many feeds and industrial byproducts have been ammoniated under varying temperatures and pressure. Understanding of the chemical combinations occurring from these reactions are not well understood (Tillman et al. 1957). In several ammoniated products, much of the nitrogen might be unavailable to rumen bacteria because of its form (Davis 1954).

Ten to fifteen per cent ammoniated molasses has been fed as a substitute in grain rations for cottonseed oil meal and with no adverse effects (Fry 1956). When the level of ammoniated molasses was increased to 25 per cent, undesirable symptoms were observed, such as excited condition, muscular tremors, twisted jaw, head turned sideways, closed or staring eyes, running in circles or jumping at top speed when startled by the slightest noise or movement. High levels of ammoniated molasses may react or combine with certain compounds in the rumen or intestine to produce a specific compound which might cause this abnormal stimulation.

Tillman et al. (1957) reported that cattle fed a high-test ammoniated molasses (32 per cent protein equivalent) at two pounds per day, had a peculiar reaction within five to six days. For short periods, these cattle reacted with violence and injured themselves by running into fences and attempting to climb them. It was also noted by these investigators, that utilization of nitrogen was not efficient from ammoniated cow manure or ammoniated furfural residue. Similar results are recorded from digestion and nitrogen balance trials with fattening-type rations. Wintering trials with cattle on winter range or wheat straw supplemented with ammoniated cow manure extract revealed both inefficient and efficient utilization of nitrogen.

C. MINERALS AND ASH.

1. MINERALS. The mineral requirement of the ruminant is generally assumed to be more complex than for monogastric animals because of additional mineral needs for bacterial activity in the rumen. McNaught _et al._ (1950) reported that iron, cobalt, copper, zinc, and manganese stimulated the utilization of non-protein nitrogen by rumen bacteria. Gall _et al._ (1949) found a marked difference in types and number of bacteria in the rumen of cobalt-deficient sheep.

Studies with a purified type of steer ration reveals that mature timothy hay did not supply enough cobalt. Results indicated the lack of cobalt was critical. Thus, the possibility of border-line deficiencies of trace minerals for cattle and sheep are most likely to occur when they are fed poor quality roughages, such as corn cobs, corn stover, and mature and rained-on hays, particularly those high in grasses. Corn is low in trace minerals (Bentley and Klosterman 1953).

There are several known physiological functions of trace minerals, especially in blood formation. However, the role of trace minerals in ruminant metabolism may have added significance because of their influence on the activity of the rumen microorganisms. A good example is the tie-up between the trace mineral cobalt and vitamin B_{12} synthesis. It is thought that cobalt has an effect on the activity of the rumen organisms (Bentley and Klosterman 1953).

Using in vitro studies, Farris et al. (1955) showed reduced cellulose digestion when each of the following minerals were removed from the media: sodium, potassium, phosphorus, magnesium, manganese, iron, and sulphur. These workers found high levels of copper, zinc, and cobalt inhibited cellulose digestion, also that a wide range of certain mineral concentrations could be tolerated by rumen microorganisms.

The beneficial effect of adding minerals (Chappel et al. 1955) in the form of alfalfa ash or synthetic ash, may be due to:

I - The addition of some other essential micro-nutrient contained in the natural ash and present as a constituent in the salts;

II - An increase in the total ash content of a low ash ration with a subsequent favorable effect of undetermined nature on the rumen bacteria;

III - Some combination of known nutrients which are present in inadequate or unbalanced amount.

Alfalfa ash may promote better appetite by virtue of its higher alkalinity. Similarly, natural alfalfa ash which also has a high pH, might also have its favorable influence on appetite for the same reason (Chappel et al. 1955). In addition, these workers found the presence of alfalfa ash or a synthetic alfalfa ash in lamb rations increased the crude fiber and organic matter digestion significantly. Appetite of the lambs was also improved by either of these mineral additions. It was concluded that there was little advantage in providing extra protein without added trace minerals. The trace minerals also had a sparing effect on protein requirements.

Bentley and Klosterman (1953) suggested that in any program in which poor quality roughage is used, it would be advisable to feed mineralized salt. If plenty of good quality, high-legume roughage is being fed, it is doubtful if trace mineral supplements are necessary. In addition, it should be emphasized that trace minerals, plus poor quality roughages, will not replace good quality hay in a feeding program where roughage supplies the major portion of the nutrients. They added that there is a possibility of feeding too high a concentration of trace minerals.

2. ASH. Swift and co-workers (1951) suggested that alfalfa ash increased fermentation in the rumen, making available more feed energy to the animal, even after paying for the overhead (methane), as they put it. This observed increased production of methane supports Burroughs et al. in their theory of how alfalfa ash aids roughage digestion.

Tillman et al. (1956) said a large part of the increased utilization of low quality roughage, because of adding alfalfa ash, was due to the major minerals of the ash (salts of calcium, phosphorus, sodium, potassium, chlorine and magnesium). Iron and/or copper content of the forage appeared to be responsible for a small part of the increase. Bentley and Klosterman (1953) showed that molasses ash could be replaced with a mixture of copper, cobalt, zinc, manganese, and iron.

Some of the beneficial results of alfalfa ash was due to its action on the added fat in the ration (Tillman et al. 1954). However, no beneficial results occurred from the action of alfalfa ash upon added fat in their experimental work.

Burroughs et al. (1950b) showed the addition of alfalfa ash promoted greater digestibility of corn cobs. Alfalfa ash was postulated to enhance greater utilization of crude fiber and other constituents in the ration.

Steers fed poor quality hay were noted to have gained significantly more when the ash of dehydrated alfalfa meal was added to their ration (Klosterman 1953).

Tillman et al. (1954) found the addition of alfalfa ash to a semi-purified sheep ration improved the digestibility of all the ration components. Cottonseed hulls supplied all the minerals in the ration except calcium, phosphorus, sodium, chlorine and sulphur. They suggested the total ash and trace mineral content may be major considerations in the explanation why alfalfa ash increases the digestibility of some roughages and is of no value in others. Tillman and workers also found neither alfalfa ash nor a complete mineral mixture improved the apparent digestibility of the ration or any of its proximate components.

Bentley and Moxon (1952) reported that poor quality timothy hay was low in cobalt and that either alfalfa ash or a cobalt-containing salt mixture corrected this deficiency.

Bentley et al. (1953) observed that alfalfa or molasses ash doubled the rate of cellulose digestion.

D. FACTORS.

1. UNIDENTIFIED FACTORS. Many natural substances are known to enhance rumen microbial activity *in vitro*. Attempts to explain the stimulatory properties of such substances on the basis of known chemical composition have failed thus far (Burroughs et al. 1950e). Certain feedstuffs and other material contribute additional factors, thought to be unidentified bacterial nutrients, that help improve rumen fermentation (Ruf et al. 1953). Burroughs et al. (1949 and 1950), Hungate (1950) and Doetch et al. (1952)

demonstrated a need for materials of unknown nature for optimal growth of rumen bacteria.

Some of these natural substances which increase microbial activity *in vitro* are rumen liquor, yeast extract, manure extract, oil meals, alfalfa meal, and molasses. Burroughs *et al.* (1950c) found that manure extract, plus a complex mineral mixture and available nitrogen, greatly increases the breakdown of poor quality roughages in the artificial rumen. Addition of distillers dried solubles, soybean oil meal, cane molasses, corn, wheat bran, and cottonseed meal were found to be stimulatory.

Part of the stimulatory action of some of these feed substances may be explained by known chemical constituents. For example, it is known that the mineral content of alfalfa meal will stimulate cellulose digestion (Burroughs *et al.* 1950d). The soluble carbohydrate content of rumen liquor will also contribute to cellulose digestion. Bentley *et al.* (1954) indicated that five and six carbon fatty acids are a major component of the stimulatory factors in rumen liquor. However, when all of these known constituents are included in a medium, additions of the natural substances still result in a further increase in micorbial activity. Klosterman *et al.* (1956) also surmised an unidentified factor to be in hay of good quality, other than trace minerals or protein. Studies of these unidentified factors have shown that they often occur in largest quantities in feeds either rich in protein or in natural feeds rich in non-protein nitrogen.

Unknown nutrients present in rumen juice, dried distillers residues, grass juice, yeast, cow manure extract and other sources required by rumen bacteria were detected by Burroughs *et al.* (1950), Ruf *et al.* (1953), Bentley et al. (1953). Davis (1954) reported it has been indicated that the presence of alfalfa in the ration improves non-protein nitrogen utilization. Whether this is a direct effect or a general stimulation to the rumen flora is not known. Bentley et al. (1953) found in addition to rumen juice, factor(s) present in dried yeast and hot water extract of alfalfa leaf meal or hay.

Burroughs and associates (1949) imply factors other than protein intake were responsible for increased digestion of dry matter by addition of soybean oil meal. Missouri workers (Brooks et al. 1954) have indicated that certain steroid compounds such as cholesterol stimulate cellulose digestion. Other substances such as feather meal, hair, and drackett protein have stimulatory properties when subjected to mild hydrolysis. The stimulatory properties of these protein hydrolyzates appear to be fully as active in autoclaved rumen liquor in stimulating cellulose digestion by rumen microorganisms (Burroughs et al. 1950d).

The identification of the factor which favorably influences cellulose digestion is not known. Its significance to the nutrition of cattle and sheep also cannot be fully appraised (Ruf et al. 1953). Ruf suggests the factor is beneficial in maintaining appetite and rate of gain in lambs. Yeast supplies an unidentified factor helpful to cellulose digestion by rumen microorganisms. Ruf relates this material is quite generally distributed in the major feeds consumed by cattle and sheep. However, this widespread distribution does not preclude the possibility of inadequacy in present day ruminant rations, both concentrates and roughages. Yeast and manure extract were particularly rich sources of the material.

The factor is heat-stable and soluble in water and low concentrations of ethanol. Ashing destroyed the factor, indicating that the active material was not a mineral but rather an organic substance. The factors did not appear to be a B-complex vitamin or protein because the removal of proteins by precipitation failed to remove the active principle, and various B-vitamins and amino acid supplements failed to stimulate cellulose digestion (Ruf _et al_. 1953).

Yeast supplements added to a ration high in corn cobs and soybean oil meal improved liveweight gains in cattle (Beeson and Perry 1951). Thompson and Tosic (1949) showed a stimulation from yeast upon the rate of gain in sheep consuming a semi-purified and a natural ration respectively.

Hall _et al_. (1953, 1955) found no combination of B-vitamins which stimulated cellulose digestion as much as that obtained from yeast extract and autoclaved rumen liquid. These substances, no doubt, contain unidentified factors stimulatory to cellulose digestion in addition to the B-vitamins. The complete answer to unidentified cellulolytic factors is not B-vitamins; however, they may be partially responsible for the cellulolytic properties of yeast extract rumen liquid and possible other sources of factors.

2. VITAMINS. There is much experimental work showing microbial synthesis of thiamine, biotin, folic acid, nicotinic acid, pantothenic acid, pyridoxine and riboflavin (McNaught and Smith 1947). Vitamin B_{12} is also known to be synthesized by rumen bacteria (Bentley and Klosterman 1953). Vitamin K is the only fat soluble vitamin produced in the rumen (Davis 1954 and Burroughs and Hall 1954).

Until 1954, all the work on vitamin synthesis was qualitative. No work has been done on total vitamin production as related to metabolic requirements (Burroughs and Hall 1954). Normally no visible signs of deficiency of the B-vitamins and Vitamin K occur in the ruminant; therefore, it is assumed that vitamins are produced in sufficient quantities to meet body demands (Davis 1954, Burroughs and Hall 1953 and Hall et al. 1955). While on certain types of rations it is possible some of these vitamins may not be produced in large enough numbers for the animal's best performance. Following this thinking, several B-vitamins have been shown to enhance cellulose digestion in vitro (Burroughs and Hall 1954). For example, Hall et al. (1953) used washed suspensions of rumen microorganisms, found Vitamin B_{12}, biotin, pyridoxine, folic acid, para amino benzoic acid and riboflavin stimulated cellulose digestion. These workers also found that of the combinations of vitamins studied, B_{12} and biotin were the only vitamins which had synergistic action. A greater stimulation of cellulose digestion was observed from a combination of these two vitamins than any other single vitamin or combination.

Hall et al. (1955) later stated that no significant increase in cellulose digestion resulted from adding chlorine chloride, inositol, niacin, pantothenic acid or thiamine at levels ranging from 1 to 100 micrograms in a basal medium containing no vitamins and 0.5 per cent cellulose.

Bentley (1953) found that the stimulatory effect of rumen juice could be partially replaced by adding nine B-vitamins and adenine, uracil, and xanthine. A combination of B-vitamins and alfalfa ash was thought to be responsible for most of the increased cellulolytic activity. However, neither B-vitamins nor ash showed much activity. In 1955, Hall, et al. remarked that it is not known whether or not B-vitamins stimulating cellulose digestion in vitro, perform similarly in vivo. It may possibly be these B-vitamins required by cellulolytic microorganisms may be synthetically supplied by other microbes. These symbiotic relationships undoubtedly exist in the normal rumen.

Hunt et al. (1954) found that starch increased the synthesis of riboflavin, niacin, pantothenic acid and vitamin B_{12} in vitro. They also found that rumen inoculum from steers eating good quality alfalfa hay synthesized more B_{12} than inoculum from steers fed poor hay. Hallis et al. (1954) reported that the addition of soybean oil meal or urea (as a source of nitrogen) to corn caused a sharp increase in the synthesis of vitamins by those animals fed prairie hay as a basal ration. In addition, they found alfalfa ash and corn cobs as the main roughage, also resulted in an increased synthesis of all vitamins.

Dietary vitamin C is not required by ruminants. It is felt that this vitamin is produced by the tissue rather than by the microbes. Also, there is no evidence for synthesis of vitamin C by rumen bacteria (Burroughs and Hall 1954).

3. ANTIBIOTICS. Neumann et al. (1951) reported chloretetracycline had no beneficial effect on performance of beef heifers fed a fattening ration composed of corn silage, ground yellow corn, linseed meal and salt. Bridges et al. (1953) fed 1.1 to 15 milligrams of chlortetracycline per pound of feed to lambs weighing from 56 to 64 pounds without observing any significant increase in the rate of gain.

Dairy heifers fed rations containing 51 per cent ground corn cobs showed increase gains when aureomycin was added to their feed (Harshborger 1955). Rates of gain were significantly increased by adding aureomycin to alfalfa or wheat straw, making up 50 to 83 per cent of the roughage in beef cattle rations (Erwin et al. 1956a). Aureomycin fed at five milligrams per pound did not affect the amount of feed consumed or the efficiency of utilization. It did decrease, insignificantly, the dry matter and crude fiber digestibility. Earlier work by Erwin et al. (1955) with beef cattle showed that chlortetracycline significantly increased the digestibility of ether extract. Erwin and workers (1956) could not explain the increase in gain. They remarked the rapid weight gains may be supported by antibiotic alteration of rumen microflora.

Hungate et al. (1955) found rumen biota were modified by as little as five milligrams of chlortetracycline per pound of feed. He also found certain microorganisms, while in the presence of aureomycin, apparently select themselves on the basis of their resistance to it, and they are at least equally as active in its presence.

Tillman and Mac Vicar (1956) stated no effect upon ration digestibility was observed when 11.8 milligrams of chlortetracycline per 100 pounds of body weight was fed sheep. When the level of chlortetracycline was increased to 15.4 milligrams per 100 pounds of body weight, there was significant reduction in digestibility of dry matter, crude protein, crude fiber, nitrogen-free-extract and energy. The addition of either level of antibiotic had no effect upon nitrogen retention.

It is apparent from the literature that aureomycin exerts different effects upon different nutritional regimes. The stage of rumen development in relation to rumen biota and the type of ration fed appears to influence the effects of chlortetracycline on ruminants (Neumann et al. 1951).

4. HORMONES. Brooks et al. (1953) found the addition of diethylstilbestrol to in vitro fermentation resulted in a substantial increase in cellulose digestion. Stilbestrol did not significantly affect the digestibility of either dry matter, crude fiber, crude protein or ether extract in steer rations. Erwin et al. (1956).

When lambs were fed either high or low protein rations it was shown that nitrogen retention was increased significantly by stilbestrol feeding only in rations containing high protein (14 and 20 per cent). Stilbestrol had little effect upon the nitrogen retention in the low protein (8 per cent) ration. There was no effect upon the digestibility of protein and dry matter from feeding stilbestrol regardless of its influence upon nitrogen retention (Struempler and Burroughs 1956).

Many workers have noted the increased rate of gain and efficiency of feed utilization when diethylstilbestrol is incorporated into a fattening steer ration or when implanted (Burroughs et al. 1954, Luther et al. 1954 and Perry et al. 1955).

According to Brooks et al. (1954) stilbestrol's contribution to accelerated weight gains may be due to an increased digestion of crude fiber. However, the mode of action of stilbestrol has not been definitely established.

Erwin et al. (1956b) witnessed interaction between fat and stilbestrol and fat and chlortetracycline in reducing the digestibility of crude fiber. In addition, they report there was no interaction between chlortetracycline and diethylstilbestrol.

III. LOW QUALITY ROUGHAGE

Low quality roughages utilized all over the world have characteristics in common. A comparison of the chemical composition of some good quality roughages with some poor quality roughages is made in Table I.

As pointed out, in Table I, the low quality roughages are inferior to high quality roughages in many factors. Franklin et al. (1955) discussed the effects of some of the deficiencies found on low quality pastures in New South Wales, Australia. Those mentioned in this report were vitamin D deficiency and protein deficiency. Also, severe occurrences of hypocalcaemia and hypophosphotemia were noted with the occurrence of clinical rickets. In Morrison's description of feed straw, he says, "The straw, which consists of the mature stems and leaves, without the seeds, has relatively little protein, starch, or fat, while the content of fiber and lignin is high." Straw is also low in calcium and phosphorus and in most vitamins, especially in vitamin A content. Straw generally contains considerable vitamin D.

"When low quality feeds are used, extra digestible protein must be used in the ration (Davis 1954). Dyer et al. (1957) reported that protein was apparently the first limiting factor of wheat straw in their observations with pregnant beef heifers and effects of various constituents on roughage utilization. They substantiated this by the observation that feeding minerals without nitrogen resulted in no weight gains in heifers.

The efficiency with which cellulose is utilized in roughage fed to

Table 1. Chemical Composition of Various Roughages. 1/, 2/

Roughage	C.P.	D.P.	E.E.	C.F.	N.F.E.	Ash	Ca.	Phos.	Est. Net Energy
	%	%	%	%	%	%	%	%	Therm/cwt.
			Good quality roughages						
Alfalfa hay, very leafy	17.5	12.8	2.4	22.7	39.5	8.4	1.61	0.24	43.5
Alfalfa hay, all analysis	15.3	10.9	1.9	28.6	36.7	8.0	1.07	0.24	40.6
Clover hay, Ladino before bloom	21.4	16.5	1.4	18.6	36.6	10.4	---	---	48.2
Timothy hay, before bloom	9.7	6.1	2.7	27.9	42.2	6.5	0	0	44.1
			Poor quality roughages						
Timothy hay, late seed	5.3	1.9	2.3	31.2	45.7	4.5	0.14	.15	27.2
Corn cobs, ground	2.3	0	0.4	32.1	54.0	1.6	0.11	.04	40.1*
Wheat straw	3.9	0.3	1.5	37.0	41.9	8.3	0.15	.07	10.0
Cotton seed hulls	3.9	0	0.9	45.0	38.4	2.6	0.13	.06	29.3

1/ Davis, 1954
2/ From Morrison (1956)
* Fed with efficient supplements

cattle and sheep is primarily dependent upon the degree of lignification in plant tissue and whether the conditions (pH, microflora, etc.) are favorable in the rumen for efficient cellulose digestion (Crampton and Maynard 1938). The crude fiber increased as much as sixty per cent in low quality roughages, and with this increase its character changed (Forbes 1948). As plants mature, there is an appreciable increase in lignin. This increase is important because of the indigestibility of lignin and because of the decrease of other nutrient digestibility as the lignin increases.

Davis (1954) suggested that because of the deficient mineral and protein content of poor quality roughage the utilization of the nitrogen-free-extract is generally decreased, although poor quality roughages have a higher nitrogen-free-extract than higher quality roughages. A good indication of a good or poor quality roughage is its estimated net energy. Low quality roughages measured by any of these yardsticks should not be expected to provide results compared with first-class feeds.

IV. FACTORS AFFECTING COMPOSITION OF ROUGHAGES

As reported by Dent (1957), W. M. Ashton examined the chemical composition of straw and grain of three varieties of oats. His conclusion was that little variation exists between varieties at the ripe stage, when grown under similar conditions. He also found that straws harvested at a relatively immature stage at higher altitudes had a superior chemical composition when compared with straw harvested at the normal stage of ripeness at the same altitude, and the digestibility of the crude protein was also higher.

Dent (1957) maintained that environment made a great difference in composition of oat straw. The crude protein content ranged from 1.9 to 7.66 per cent and crops grown under cool and wet conditions always yielded a better quality straw than those grown under a warmer and drier condition in the South of England. He also found the chemical composition of oat straw changed very little between the early binder-ripe stage and the fully ripe combine stage, although physically it tended to become more brittle and less attractive in appearance.

Morrison (1956) says, "If straw from a combined field has lain in the windrow for several days and become weathered and discolored, the feeding value is poor."

In Scotland, it was reported (Dent 1957) that the absorption of nitrogen by the plant was almost complete when the kernel began to develop and that thereafter nutrients were transferred from straw to grain, the nitrogen content and digestibility of the straw decreasing continually with increasing fiber content.

Rao and Narasimhamurty (1954) crossed sorghums with the intention of improving the feeding quality of their straws. Pulped roots and meal are sometime mixed with cut or chaffed straw in Europe and Canada. This moist mass softens and is later fed to cattle and sheep and is readily eaten (Morrison 1956).

In 1951 Gardner and Hutchinson and in 1953 Gardner (as reported by Dent 1957) found that nitrogen dressings (on oats) during May or June, in nearly all cases influenced a substantial rise in crude protein content in both grain and straw. Bently <u>et al</u>. (1956) reported that fertilizers caused changes in the protein and mineral composition of legume hay and affected nutritive values. The sulphur content of hay increased and in some cases the protein did also. Rabbits fed fodder from fertilized plots made faster gains than those fed from unfertilized plots. Baird (1957) fed straw in a fattening ration for beef cattle four consecutive years at Stevensville, Montana. A favorable difference in cattle was observed by those eating straw from barley which had been fertilized. He also noted distinct preference shown fertilized barley straw by cattle having a choice of non-fertilized and fertilized straw. Some preference was even shown this straw over good quality hay.

V. USE OF LOW QUALITY ROUGHAGES IN FOREIGN COUNTRIES

Kellner's findings concerning ruminants, in which digestible cellulose was found to be as valuable as digestible starch in producing fat led to the development of a number of processes that had as their objective, rendering cellulose of cereal straws more available to the animal (Woodsman and Evans 1947).

During World War II, English workers investigated the feeding value of fodder-cellulose, by making wheat straw available to the paper manufacturers. The process of paper making is an efficient means of removing lignin, cellulose and incrusta, making an opportunity for investigation of fodder-cellulose.

The fodder-cellulose used by Kellner in his experiments was prepared by boiling 1000 kilograms of rye straw for 3½ hours, under 7 atmospheres of pressure, with 2070 liters of a solution containing, per liter, 55 grams of caustic soda, 20 grams of sodium carbonate, and 22 grams of a mixture of sodium sulphite and sodium thiosulphate. At the end of this treatment, the residual material was filtered off, well washed, dried and ground to meal. The final product, known as "Strohstoff" in Germany, contained 0.62 per cent crude protein, 19.96 per cent nitrogen-free-extract, 0.20 per cent ether extract, 76.78 per cent crude fiber, and 2.44 per cent ash. Digestion trials with bullocks showed that the total organic matter in Strohstoff was 88 per cent.

Using Kellner's principle, German workers increased the feeding value of cereal straw by digestion with alkaline solutions containing caustic soda, sodium carbonate or quicklime. This is a cold alkali treatment, designed especially for operation on a small farm scale. The pulp is fed in the wet condition. This treatment is milder than the Kellner process and its effect on the feeding value of straw is also less pronounced. This reaction does not eliminate the lignin from the straw, it merely breaks down the association of the cellulose with the incrusta. This allows the cellulose to become more accessible to the digestive action of the rumen bacteria during the time the straw pulp remains in the rumen (Woodman and Evans 1947).

The digestion coefficients for the constituents of fodder-cellulose were obtained from digestion trials with sheep. These values are: crude fiber 90.6 per cent, nitrogen-free-extract 38.6 per cent, ether extract 68.5 per cent, total organic matter 76.5 per cent and total cellulose 81.8 per cent. The crude protein gave a negative digestion coefficient indicating its indigestibility. However, the presence of fodder-cellulose depressed the apparent digestibility of the crude protein in the basal part of the diet. The remaining starch equivalent for fodder-cellulose was found to be 69.7 pounds per 100 pounds of dry matter.

The deficiencies in protein, minerals, vitamins and palatibility must be made good when including fodder-cellulose in the rations of sheep and cattle in order to take full advantage of its starch equivalent (Woodman and Evans 1947a).

Fodder-cellulose cannot be regarded as a suitable feed for simple-stomached animals such as the pig, although they can digest it to a satisfactory degree. Woodman and Evans (1947b) offer reasons for this being so:

I - Fodder-cellulose is too bulky a ration, making consumption slow.

II - Fodder-cellulose is tasteless.

III - The digestion of fodder-cellulose takes place wholly in the large intestine as a consequence of bacterial fermentation. This may cause the pig to be blown.

IV - Fodder-cellulose is a negligible source of protein.

V - It is important to feed the correct amount because of the limited powers of assimilation by bacteria.

In agriculturally advanced countries, only a small portion of the daily ration for livestock is made up of straw. In India, however, the cereal straws occupy a special position, as even under normal conditions these straws provide about fifty per cent of the available roughage for animals (Kehar 1953).

Exploratory experiments showed that when paddy straw was treated with a dilute solution of caustic soda, 70 to 80 per cent of potassium oxalate which interferes with calcium assimilation was removed. The treated straw effected better utilization of calcium and protein from the ration and increased the digestibility of total carbohydrates from 51 to 72 per cent in wheat straw and from 57 to 76 per cent in paddy straw, with the result that the total digestible nutrients in the straws were enhanced by about 45 per cent (Kehar 1953).

At Puri, India, the growth of calves was found to be 77 per cent higher in the treated paddy straw group as compared to the untreated straw group. The number of days required to gain 100 pounds in weight was 452 for the untreated straw group as against 245 in the treated straw group.

The feeding value of paddy straw is improved and the percentage of harmful substances is considerably reduced. Water washing of straw consists of soaking the straw for 24 hours in an earthen pot, after which it is washed with clean water, dried and stored (Kehar 1953).

Kehar (1954) reported a great advantage in feeding alkali treated cereal straws to young cattle when their initial plane of nutrition was poor. No such advantage occurred when fed to adequately nourished animals.

Raju and Varadarajan (1954) reported on bacterial fermentation of paddy straw in India. Finely chopped paddy straw was soaked in water, spread to dry, and supplemented with molasses, superphosphate and ammonium. To this an inoculum of well fermented cattle manure and fresh horse dung was added and mixed. They observed a loss of acid hydrosoluble sugars, crude fiber and cellulose, whereas the ash and crude protein increased. The fermented straw was higher in nutritive value with low fiber content. Feeding trials revealed that cattle do not readily eat this straw.

THE RITTER PROCESS. Mr. E. A. Ritter, near Druban, South Africa, noticed (while conducting paper-making experiments) material made from very old wheat and rice straw, which had been put through a fermentation process and stacked outside; was greedily eaten by a number of mules. Realizing an opportunity to render material, little valued as feed, more available to livestock, Ritter devised a process by which roughages high in fiber can be made more palatable and nutritious. Using as a guide his experience with the processing of paper, this procedure was devised.

Molasses (1/2 to 2 gallons) is added to a 44 gallon drum and then filled within three to four inches of the top with water. The contents of the drum are then heated to a boiling temperature while being stirred. After cooling to 120° F, a quart of thermophilic yeast is added to the drum. If non-thermophilic yeast is used, cool to 100° F. Baker's yeast and brewer's yeast have and can be used. Sometimes auxiliary yeasts (Lactobacillus casei) are used for combatting intrusions. Agriculture department workers also suggest using ruminal contents of cattle to secure additional fermentation.

In the meantime, 900 gallons of water is sterilized by adding 140 grams of fresh chloride of lime while stirring for sixty minutes. Ten to 45 gallons of molasses is then added and the stirring is done again so that any excess chloride of lime spends itself on the molasses. Two hours after the molasses has been introduced, the yeast culture can be added; however, it would be better to wait 24 hours. The straw is then soaked in this mixture for 15 minutes, after which it is drained. After draining, the material is piled into a tightly compacted stack. If the material does not lend itself to stacking compactly, it would be preferable to put it into a pit or trench silo. The ground on which it is stacked should be sterilized by a solution chloride of lime (3 parts to 10,000), otherwise there is a small loss along the bottom due to foreign bacteria.

The process should be complete in two to four weeks, depending upon the fiber content. The grasses and straws will then be soft and if the nodes are pressed between the thumb and finger they can readily be squashed. The finished product has a sweet honey-like smell, is soft and succulent, and is eaten without hesitation by livestock. It is interpreted that this is due to the action of the yeast and not to the molasses, because cattle will not eat the freshly steeped material. However, as soon as the softening takes place, cattle relish what they ordinarily would not touch: rye, wheat straw, thatching grass, thick-stemmed grass, and wire grass. It appears to keep well for some time (2 years) (Bramley 1952).

Many factors, supplements and processes influence the utilization and feeding value of low quality roughages. Some of these processes, for the sake of economy, are used only in times of emergency. However, the principle upon which they are based might be improved to become economically feasible, or may serve as a springboard to new methods of roughage preparation.

It is important for man to visualize the good (often hidden or masked) that is or can be available to him from familiar sources regarded as naught.

PROCEDURE

Forty yearling Hereford steers were purchased from the Wytanna Cattle Company near Manhattan, Montana, on June 15, 1956. The steers were grazing on irrigated pasture at the time of purchase. The steers were placed in dry-lot at Montana State College and fed grass hay until they were placed on experiment, June 26, 1956. On June 18th, the steers were weighed, ear-tagged for identification and assigned to one of four lots according to weight. The average weight of the steers at this time was 595 pounds.

Figure 1 pictures the experimental area, consisting of five separate, but adjoining, dry-lot pens, each with adequate area in a loafing shed. Adjacent to the dry-lots is a holding pen. Joining this and inside the barn, is a sorting chute and scale, facilitating ease of handling experimental animals.

Figure 1. The Experimental Area.

Fresh running water was furnished in tanks, common to each group of ten steers. Each group of steers had one low feed bunk in which concentrates and pellets were fed, while a taller bunk was used for straw or hay.

Salt and mineral boxes were provided inside the shed. The steers were again weighed on June 25th, 26th and 27th, comprising a three-day average weight to be used for the initial weight. These weights were taken each morning before the steers were fed. The middle day, June 26th, was designated as the beginning date of the experiment.

Grass hay was fed all four lots until the morning of June 25th. Three lots of steers, previously assigned at random, were then fed baled wheat straw as the only source of roughage. The fourth lot was fed alfalfa hay.

The second day of the experiment, those steers receiving straw roughage had lost considerable weight. Nearly every steer had lost 30 pounds and some lost as much as 50 pounds. Grass hay was then fed these steers in the afternoon to eliminate, in so far as possible, any further loss in weight while the three day initial weights were being taken. Grass hay was again fed the following morning, for the last time.

The objective of this experiment was to determine whether wheat straw could be used economically as roughage in a fattening program of beef animals. It was also the objective to observe the effects of added supplements to these rations (otherwise balanced nutritionally), such as molasses and bovirum (dried rumen contents from mature animals).

Table II portrays the experimental design of this experiment and Table III shows the composition of the pelleted supplement.

The primary difference between the four rations was the type roughage fed. Secondary differences were between the supplemental ingredients. Ration 1 contained alfalfa as roughage and was the control roughage to which

Table II. The Design and Ration of the Experiment.

Ration No.	1	2	3	4
Roughage	Alfalfa	Straw	Straw	Straw
Pelleted Supplement				
Protein %	14	32	32	32
Molasses %	5	10	20	10
Yeast and Bovirum	0	0	0	X
Basal Ration Concentrate				
75% dry-rolled barley	+	+	+	+
25% wheat mixed feed	+	+	+	+
Animals/treatment	10	10	10	10

the other rations containing wheat straw were compared. Within the three rations containing wheat straw, ration 2 was the control with which ration 3 and 4 were compared. In addition to all the ingredients in ration 2, ration 3 contained twice as much molasses and ration 4 contained yeast and bovirum.

Ration 1 contained the relatively low 14 per cent protein in its supplement because of the greater amount of protein supplied through the alfalfa roughage fed in this ration. Primarily the barley served as a carrier for the stilbestrol in this ration (this will be explained more fully in the discussion of Table III). The barley served well as carrier, for it contained a relatively low amount of protein.

The three rations containing wheat straw as roughage had a 32 per cent protein level in their supplement. The protein level was maintained in these three rations by nearly identical amounts of soybean oil meal, cottonseed oil meal, urea and dehydrated alfalfa.

All four rations received identical amounts of necessary minerals

Table III. The Composition of the Supplemental Pellets.

Pellet No.	1	2	3	4
Ingredients:	Pounds per ton			
Barley	1305	---	---	---
Wheat mixed feed	500	725	450	675
Soybean Oil Meal	---	350	400	350
Cottonseed Oil Meal	---	350	375	350
Urea	---	80	80	80
Dehydrated Alfalfa Meal	---	200	200	200
Dicalcium Phosphate	40	40	40	40
Limestone	20	20	20	20
Salt	20	20	20	20
Trace Mineral Mix (ccc) 1/	5	5	5	5
Stilbosol 2/	10	10	10	10
Vitamin A 3/	+	+	+	+
Vitamin D 4/	+	+	+	+
Molasses	100	200	200	200
Dried Molasses	---	---	200	---
Bovirum 5/	---	---	---	4
Yeast 6/	---	---	---	50
	2000	2000	2000	2004

1/ CCC Trace mineral furnished by Calcium Carbonate Company.
2/ Stilbosol furnished by Eli Lilly and Company.
3/ Vitamin A added to supply 5,000 I.U. per pound.
4/ Vitamin D added to supply 1,000 I.U. per pound.
5/ Bovirum supplied by Cudahy Research Laboratories.
6/ Yeast supplied by Diamond V Mills.

and vitamins within the pelleted supplement. Stilbestrol (presented in Table III under a trade name "Stilbosol") was also incorporated into each pelleted supplement. This synthetic hormone has been accepted in beef fattening programs because it increases weight gains, and it was incorporated into these rations for this purpose. At two pounds per steer, per day of the supplemental pellets, each steer received approximately ten milligrams of stilbestrol each day.

The basal ration consisted of 75 per cent dry-rolled barley and 25 per cent wheat mixed feed. These concentrates along with the roughages were fed according to appetite, beginning at two and seven pounds, respectively, per steer, per day, and were gradually increased or decreased as the experiment progressed. The supplemental pellets were fed at the rate of two pounds per steer, per day, beginning with one-half pound and were increased one-half pound per day until the two pounds were reached.

Initially, the feeding time was 8:00 A.M. each morning. Steers receiving rations 2, 3 and 4 were fed straw first and concentrates with pellets immediately following. Feeding in this order was done to facilitate introduction of the straw and to stimulate its greater consumption. The grain was fed before the roughage for those steers receiving ration 1, as their preference was roughage (alfalfa hay). Twenty-seven days later, as the concentrate consumption neared eight pounds per steer, per day, the feeding was changed from once to twice daily--8:00 A.M. and 5:00 P.M. The total daily concentrate ration was equally divided per feeding. This feeding procedure continued throughout the remainder of the experiment.

Each steer was sprayed with DDT (July 21) as a preventative measure against flies. Animals becoming sick during the trial were attended by a veterinarian, and were usually isolated from the other steers.

The steers were weighed about every 28 days, and, again, three consecutive weights taken daily were averaged for the final weight. The middle weigh day, November 25, 1956, was selected as the date ending the experiment. At 6:00 P.M., November 26, all feed and water was withheld from the steers. The following morning at 6:00 A.M. the steers were weighed again after this 12 hour shrink, loaded on trucks and transported to Great Falls, Montana.

The steers were sold on a carcass grade basis to the Great Falls Meat Packing Company, where the remaining data was taken. Upon arriving in Great Falls, the steers were group-weighed off the trucks in lots of ten. Each ten steers belonged to the same experimental lot they had previously been assigned for this experiment.

Each steer's identification was carried with him through the killing floor until the time he was graded. Individual warm weights were taken immediately after slaughter and again after a 24-hour shrink in the cooler. The chilled carcasses were graded and recorded by a federal grader.

RESULTS AND DISCUSSION

Table IV summarizes the pertinent data of this experiment concerning the average daily weight gains, feed consumption, efficiency of feed utilization and financial return of the experimental animals. One week before these steers were put on experiment, they were weighed and lotted. A difference existed between the average steer weight for each lot of five pounds. The data on weight gains, reveals an average initial weight of 601, 592, 587 and 602 pounds for steers fed rations 1, 2, 3 and 4 respectively. The fifteen pound difference that existed between the average steer weights per lot was due to weight losses experienced by nearly every steer fed straw for the first time as their only roughage. It is possible these initial differences in average group weights had some effect upon the results of the trial.

The final average weight for each lot fed straw in their ration appeared quite similar, whereas the final average weight for the group fed alfalfa was 50 pounds greater than any of the other lots. This difference seemed to indicate a possible significance between weight gains of steers fed the different rations. However, as shown by Table V, the average daily gain per steer, for all rations was subjected to analysis of variance and the differences between treatments were not significant, ($P < .05$). Although the steers fed ration 1 (alfalfa roughage) did show 0.3 of a pound greater average daily gain than either of the three remaining lots fed rations 2, 3 and 4 (straw roughage).

As previously mentioned, the objective of this experiment was to develop a ration which will supplement the deficiencies of wheat straw when

Table IV. Weight Gains, Feed Consumption and Financial Results of the Experiment.

Ration No.	1	2	3	4
Roughage	Alfalfa	Straw	Straw	Straw
Supplement				
Protein %	14	32	32	32
Molasses %	5	10	20	10
Yeast and Bovirum	0	0	0	X
Number of steers	10	10	10	10
Average weight per steer (lbs.)				
Initial	601	592	587	602
Final	1019	966	961	970
Gain	418	374	374	368
Daily gain	2.75	2.46	2.46	2.42
Average daily feed consumption per steer (lbs.)				
Supplement	2	2	2	2
Roughage	6.7	4.4	4.6	4.9
Barley	10.5	10.8	10.8	10.9
Wheat mixed feed	3.5	3.6	3.6	3.6
Total	22.7	20.8	21.0	21.4
Feed per cwt. gain (lbs.)				
Supplement	72.9	81.6	81.6	82.8
Roughage	242.6	177.4	185.5	203.7
Barley	382.2	439.6	443.2	449.2
Wheat mixed feed	127.4	146.5	147.7	149.7
Total	825.1	845.1	858.0	885.4
Feed cost per cwt. gain ($) 1/	13.44	14.24	14.70	14.54
Financial results per steer ($)				
Initial value ($20.00/cwt.)	120.16	118.44	117.40	120.30
Cost of feed	56.20	53.24	54.94	53.51
Investment 2/	176.36	171.68	172.34	173.81
Return per steer 3/	182.15	154.81	163.08	157.99
Net return	5.79	-16.87	-9.26	-15.82

1/ The cost of the feeds used in the trial were as follows:

Alfalfa	$20.00 per ton	Barley	$1.80 per cwt.
Straw	$10.00 per ton	Wheat mixed feed	$2.00 per cwt.

2/ Labor costs not included.

3/ Sold on a carcass grade of $32.65 for choice; $30.65 for good.

Table V. Analysis of Variance on Weight Gains of the Steers.

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square
Total	39		
Treatment	3	14,069	4,670
Within treatment	36	69,759	1,938

used in cattle fattening programs. Some of the ingredients added to the pelleted supplements fed with wheat straw in this experiment (as indicated in Table III) were soybean and cottonseed oil meal, wheat mixed feed, urea, dehydrated alfalfa meal, calcium, phosphorus, trace minerals, stilbestrol, molasses and yeast. Many workers have observed the beneficial effect of these and other additives when used to supplement other low quality roughage rations. Burroughs et al. (1949 and 1950) disclose an increase in cellulose digestion by utilizing cottonseed and soybean oil meal, wheat bran, alfalfa meal and yeast in combination with low quality roughages. Steer calves fed poor quality hay showed an increased gain in weight upon supplementation with molasses compared to controls (Klosterman et al. 1956). Urea gave great increases in in vitro cellulolytic activity (Bentley et al. 1953). Perry et al. (1955) and many others have noted increased rate of gain and efficiency of feed utilization when diethylstilbestrol was incorporated in steer rations compared to the controls receiving no stilbestrol.

The insignificant differences observed between the average daily gains of the steers fed alfalfa as the roughage compared to those fed straw could have been due to the beneficial action of the supplements present in the rations containing straw.

The alfalfa hay fed during this experiment was of the first cutting consisting largely of stems and few leaves. Chemical analysis, as shown in Figure 2 indicates this hay was not of the highest quality. It compares very closely to alfalfa hay classified by Morrison (1956) as stemmy (over 34 per cent fiber). Dehydrated alfalfa meal, present at a ten per cent

Ingredient	Alfalfa Hay	Wheat Straw
Moisture	10.7	8.0
Protein	13.2	2.5
Ether Extract	1.5	1.2
Crude Fiber	32.9	36.9
Phosphorus	.20	.04
Calcium	1.16	.22
Ash	6.6	5.5
Carotene	14.0	---

Figure 2. Chemical Analysis of Alfalfa Hay and Wheat Straw Roughages Fed in this Experiment.

level in the supplemental pellets fed as part of rations 2, 3 and 4, may account for some of the similarity in average daily gains between treatments.

Because of the steers initial low straw consumption their daily ration consisted mostly of grain. It is possible that this was partly the cause of the steers going off feed. On the ninth day of the experiment, profuse scouring and bloody feces were observed among those steers fed ration 1 and 3. At the same time, steers fed ration 1 went off feed, eating no concentrates and little hay for two days. Feces samples were collected from some of the steers showing acute scouring symptoms, and coccidiosis determination was determined. Results from the determination showed normal bacterial count.

As the grain consumption increased, for all steers, the roughage consumption decreased. Again by interpretation it is supposed this wider spread in concentrate-roughage ratio had an effect upon the steers contracting scours. Scouring necessitated a reduction in amount of concentrates fed, which seemed to help encourage recuperation, as measured by more normal fecal consistency and appetite. When the steers regained their appetite, the grain consumption would again gradually exceed that of the roughage, and this cycle would repeat itself. This cycle was familiar among the entire group of forty animals. Individuals and groups were affected differently, some staying on feed longer than others.

Average and cumulative average daily gains are presented in graphic from in Figures 3 and 4. These data show that the same general trend is followed by each group of steers fed rations containing straw. The first 28-day period these same steers gained on the average of 1.1 pounds each day. During this same period, steers fed ration 1 gained 2.1 pounds each day. No doubt one reason for this difference in gain is because the steers fed straw in their rations had not yet become accustom to it and were eating little of it at that time, whereas the other steers ate more readily of their roughage.

During the second 28-day period, all four groups made substantial daily gains. The steers fed straw as roughage made greater gains during this period than did those fed alfalfa; however, because they were behind in gain from the previous period, their terminal figures for average daily gain during the entire period, fell short (0.25 pounds) of that for alfalfa. Steers fed ration 2 were an exception to this rule, in that their average daily gain for the second period rose to 4.05 pounds, fully one-

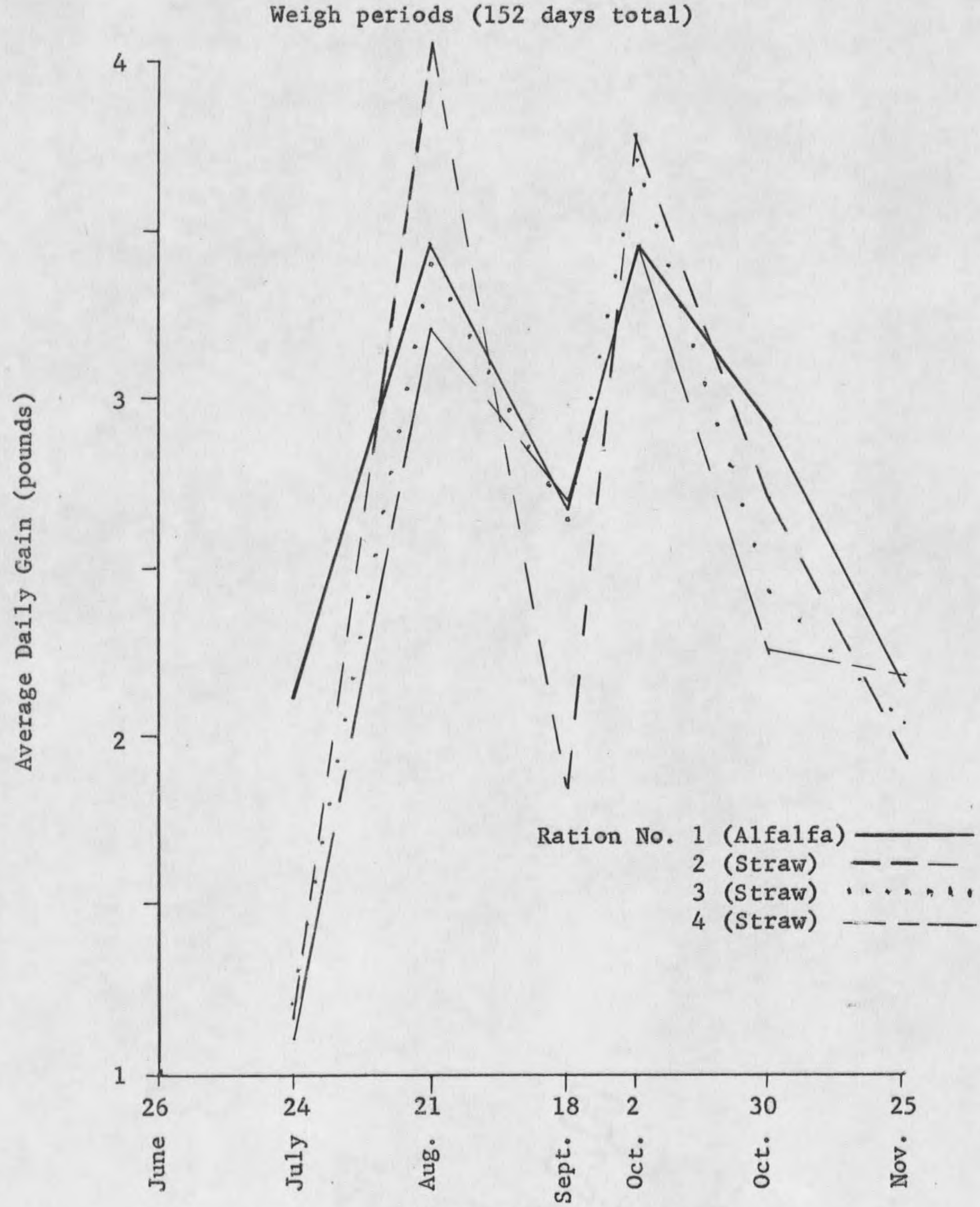

Figure 3. Average Daily Gain Per Weigh Period.

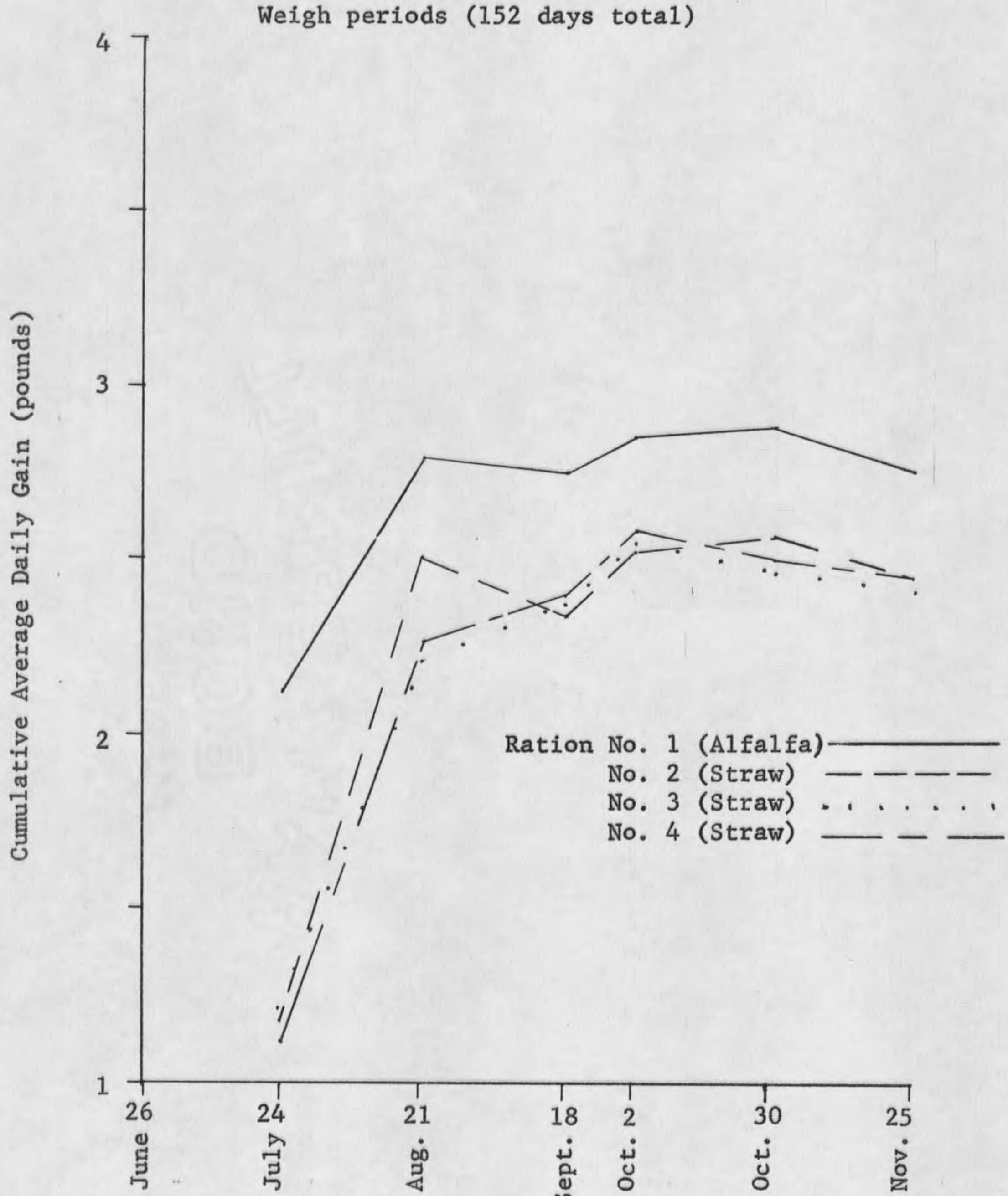

Figure 4. Cumulative Average Daily Gain Per Weigh Period.

half pound greater than the other groups. During this period, steers receiving rations 2, 3 and 4 had accepted (in part) wheat straw as their roughage, making possible these abrupt stimulation in daily gains. It is not known why those steers fed ration 2 gained more than the other straw groups. They did eat somewhat less straw during the first period than those steers fed ration 3 and 4. Their pen was always wetter, because much water drained in that direction. It was especially wet during the first part of the feeding period, as that was during the rainy season. Their supplemental pellet did not contain a high amount of molasses, or ingredients designed to stimulate ruminant performance with low-grade roughage, as the pellets in ration 3 and 4.

At the end of the third 28-day period, all four groups had declined in average daily gain, as result of their going off feed. This will be explained more fully, later. Fourteen days later the steers were weighed again to collect data for a feeder-tour. During this shorter period, each group increased in daily gain. After this date (October 2), each group continually declined in rate of gain until the termination of the experiment, 60 days later.

Rate of gain was affected by animals scouring or becoming sick from any cause. One sick steer per lot may have appreciably affected the average daily gain for the entire group over a 28-day period. Several steers were isolated and treated for scours and for pink eye, while one steer was hurt while trying to jump a gate. Children may have been chasing the steers. Almost an identical decline in average daily rate of gain exists for those steers fed ration 1 and 3 during the weigh period August 22nd and September 18th. There is no apparent reason for such similarity in decline, however, there was one sick steer in each lot during this time. The steer fed ration 1 was sick for nine days and the steer fed ration 3 was sick for seven days.

Figure 4 presents the average daily gains in an accumulated form through each weigh period, showing no extreme variations. This cumulative information is most important economically; for regardless of how much gain is accrued during one period, any abnormal loss or gain in weight would alter the average daily gain for the entire experimental period. Steers fed rations containing alfalfa and wheat straw followed the same trend in cumulative average daily gains by weigh periods, however, those steers fed ration 1 presented a consistently higher average daily gain.

It was difficult for those steers fed straw to become accustomed to eating it. However, a group difference in attitude toward eating straw was soon noticed. Four days following initiation of the experiment, steers fed ration 4 were observed eating more straw than either of the other two groups. Table VI relates how these same steers continued eating more straw than the others throughout the remainder of the experiment. For periods of short duration only, their straw consumption was surpassed slightly by other groups. Yeast and bovirum were added constituents in these steer's rations (4). The presence of the constituents might have contributed to the additional intake of straw roughage. Hall et al. (1953, 1955) found yeast extract stimulated cellulose digestion greater than any combination of B-vitamins. He suggests yeast contains unidentified factors stimulatory to cellulose digestion. Bovirum may also have stimulated greater rumen activity; however, Williams and Jensen (1954) found no visible benefit from adding two per cent dried rumen contents to milk replacement rations for 24-day old calves. Their work carried on for ten weeks duration. It would also seem probable that a yearling animal would have matured enough to possess a fully-functioning rumen.

Straw used during this experiment came from various sources. It may have been of different quality because of variety, preparation, or nutrient content, as influenced by fertilizer. It is possible one group of steers could have received more of one source of straw than did the others.

Baird (1957) found improvement in weight gains of cattle fed barley straw that had been fertilized over cattle fed barley straw that had not been fertilized. This observation was noted while the cattle were running under the same conditions at the same time. Dent (1957) records greater nutritive value of oat straw when fertilizer is applied during its growth.

The daily straw consumption was inconsistent, although not nearly to such an extent as was the grain. The daily alfalfa hay consumption varied less abruptly than either straw or grain. The fluctuation of daily consumption of all feedstuffs is not obvious in Table VI because the data is presented as average figures. Initially, the straw consumption followed in descending order, those steers fed ration 4, 2 and 3. However, during the last 100 days of the experiment, those steers fed ration 3 ate greater amounts of straw, placing them second in order of consumption. These steers had more molasses in their ration than did those fed ration 2. This might have been an influencing factor stimulating greater cellulolytic activity by rumen microorganisms.

Table VI. Average Daily Feed Consumption Per Steer by Weigh Periods.

Ration No.	1		2		3		4	
Roughage	Alfalfa		Straw		Straw		Straw	
	Feed Consumed (pounds) 1/							
	Grain	Alfalfa	Grain	Straw	Grain	Straw	Grain	Straw
June 26 to July 24	6.4	8.7	7.9	5.2	7.9	4.6	7.9	6.5
July 25 to Aug. 21	12.7	9.2	13.3	6.3	13.3	6.6	13.3	6.7
Aug. 22 to Sept. 18	19.1	6.0	19.0	3.0	19.1	4.1	19.1	4.3
Sept. 19 to Oct. 2	18.9	4.8	18.7	3.5	18.9	4.1	18.9	4.7
Oct. 3 to Oct. 30	17.7	5.5	20.1	4.1	20.0	4.3	20.1	4.1
Oct. 31 to Nov. 25	20.3	2.9	20.3	2.4	20.4	1.8	20.5	2.1
Avg. for all periods	15.8	6.2	16.6	4.1	16.6	4.2	16.6	4.7

1/ Figures include the supplemental pellet which was fed each steer at the rate of 2 pounds per day.

Results from Table VI show that the steers fed alfalfa as roughage generally consumed less grain than those receiving straw. No doubt this was because alfalfa furnished a greater proportion of their dietary needs, which in turn decreased their desire for more grain.

As indicated by Table IV, the grain consumption averaged as high as 18.5 pounds per day, for one 28-day period in each lot. Here again, because of data compiled in average figures, a total consumption of 22 pounds of concentrates per steer, per day is hidden.

Table IV reveals average daily consumption of all feedstuffs to be about 21 pounds for the steers fed ration 2, 3 and 4. Almost two pounds greater consumption per day was observed for steers fed ration 1. This increase in total consumption came about because of their greater roughage consumption. Weather certainly affected the consumption of each roughage. Whenever it was wet (rain or snow) there was little intake of hay and no intake of straw.

Table VII reflects the efficiency of grain and roughage utilization for each group of steers during weigh periods. Generally, all four groups of steers followed the same trend for conversion of feed to meat. Initially, these records show inefficient utilization of both grain and roughage for steers fed all rations, except ration 1. This inefficiency is a result of steers experiencing great changes in feedstuffs when first placed on this experiment. Steers fed ration 1 did show efficient use of grain for this period. However, this interpretation is not valid, in that these steers went off feed five days after the experiment began. For two days they ate no grain and very little roughage. The third day their appetite

Table VII. Feed Required Per Hundredweight Gain Per Steer by Weigh Periods[1/]

Ration No.	1		2		3		4	
	Feed Per Hundredweight Gain (pounds)							
Period:	Grain	Alfalfa	Grain	Straw	Grain	Straw	Grain	Straw
June 26 to July 24	210.2	418.6	553.7	520.8	532.3	502.6	471.4	543.0
July 25 to Aug. 21	308.7	270.4	278.0	155.6	328.6	191.4	352.5	209.6
Aug. 22 to Sept. 18	640.9	228.6	925.0	162.1	645.3	155.7	632.5	161.2
Sept. 19 to Oct. 2	489.2	161.0	441.1	92.1	456.3	109.6	489.2	135.9
Oct. 3 to Oct. 30	598.2	186.6	669.6	153.0	742.6	177.4	802.4	181.1
Oct. 31 to Nov. 25	842.4	170.4	942.5	152.2	909.1	115.9	846.0	115.8
Average for all periods	514.9	239.3	635.0	206.0	602.4	208.8	599.0	224.4
Supplemental pelleted feed per cwt. gain	72.9	---	81.6	---	81.6	---	82.8	---
Total (Avg. for all periods plus sup. pellet feed per cwt. gain	587.8	239.3	716.6	206.0	684.0	208.8	681.8	224.4

1/ These figures include the amount of supplemental pellets fed.

for alfalfa appeared normal, although 27 days passed before they were again eating the same amount of grain fed the other steers. The gain made by those steers during that period was mostly due to their large consumption of alfalfa hay.

The second 28-day period, efficiency of utilization increased for both grain and roughage throughout all rations, except for the grain in ration 1. Because of the false implications drawn from the previous weigh period data, these steers appear to be making less efficient use of their grain, this also is not true. They are merely eating more grain as a result of partial recuperation from being sick.

The third 28-day period, efficiency of utilization for both feedstuffs declined again for each group of steers, because they had all gone off feed and lost weight. The following period was fourteen days in duration. Having recuperated from the past slump in daily gain and showing increase in gain, this data shows an increase in utilization for all steers concerning both feedstuffs. After this date, their rate of gain was slowly decreasing. Efficiency of utilization followed this same decreasing pattern for each group of steers and for both grain and roughage, to termination of the experiment.

Two of the groups fed straw in their ration had very similar utilization of total feedstuffs, they also had similar cumulative weight gains (steers fed rations 3 and 4). Steers fed ration 2 (also straw roughage) showed less efficient utilization of grain and greater utilization of roughage than the previous two groups. Their cumulative rate of gain was also slightly lower.

The steers receiving ration 1 showed a greater efficiency for grain for the experimental period than the other groups; requiring 19, 14 and 14 per cent less grain than steers fed rations 2, 3 and 4, respectively. Meanwhile, the control steers receiving alfalfa ate more roughage per hundredweight gain than did the animals receiving straw. These results show the animals apparent dislike for straw.

Table VIII tabulates the salt and mineral record. As might be expected the steers fed alfalfa, as roughage, consumed much less salt and minerals (presented to them free choice in the feed lot) than did any of the other groups of steers fed straw as their roughage. Alfalfa contains sufficient calcium and phosphorus, while wheat straw is deficient in both of these (Morrison 1956). This fact may suffice for reason of such a negative consumption of salt and minerals by those steers fed ration 1. Chappel _et al_. (1955) and Bentley and Klosterman (1953) support the theory that plenty of good alfalfa hay furnishes sufficient trace minerals.

Of the three groups of steers fed straw as roughage, steers fed ration 3 consumed much more salt and minerals. Their consumption seemed greatest at the termination of the experiment. Reason for this greater consumption is not known, unless the additional amount of molasses in the supplemental pellet might have had some effect. The possibility exists here also of a nutritional difference in straw fed these steers, particularly at that time.

Table IX represents the carcass data which was obtained at Great Falls, Montana. When the steers were weighed off the trucks, it was impossible to obtain individual weights, therefore individual shrinkage

Table VIII. Salt and Mineral Record of the Steers During the Experiment.

Ration No.	1		2		3		4	
Roughage	Alfalfa		Straw		Straw		Straw	
Period:	Record (pounds)							
	Salt	Min.	Salt	Min.	Salt	Min.	Salt	Min.
June 26 to July 24	40	0	40	0	37.5	0	40	0
July 25 to Aug. 1	10*	5	15	5	20	5	20	5
Aug. 2 to Sept. 18	0	0	10	0	15	15	15	0
Sept. 19 to Oct. 2	0	0	0	0	5	10	0	0
Oct. 3 to Oct. 30	0	20	15	10	35	55	5	30
Oct. 31 to Nov. 25	0	0	4	1.75	6.75	47	8	10.5
Total Consumption	30	35	84	16.75	119.25	132	88	45.5
Average daily consumption	0.20	0.16	0.55	0.11	0.78	0.87	0.58	0.30

*This amount of salt was removed from these steers box.

Table IX. Average Carcass Data for Steers on the Experiment

Ration No.	1	2	3	4
Avg. warm carcass wts., pounds	582.0	520.6	544.9	527.7
Avg. chilled carcass wts., pounds	564.6	505.1	528.6	511.9
Avg. chilled shrink pounds	17.4	15.5	16.3	15.8
Avg. chilling shrink per cent	2.99	2.98	2.99	2.99
Avg. dressing per cent 1/	59.12	55.59	58.52	56.02

1/ Dressing percentages were figured by dividing the chilled carcass weights by liveweights at Bozeman (minus 3.61 per cent trucking shrink).

data from Bozeman to Great Falls could not be calculated. An average shrink for the entire forty steers was figured (3.61 per cent) and used to obtain some of the remaining data.

The average chilled shrink per group did not appear greatly different and the chilling shrink expressed as per cent seemed to show even less difference. However, a more noticeable difference between dressing per cent did appear. Those steers, fed rations 1 and 3, having the highest dressing per cent, brought the greatest monetary return (Table IV). Ration 1, containing alfalfa hay as one of its constituents, offers ample explanation for the higher dressing per cent obtained by those steers fed this ration. Ration 3 contained twice as much molasses as any other group fed straw in their ration. Klosterman _et al_. (1956) found that one pound per head, daily, of cane molasses improved the carcass grade of finished cattle as well as their rate of gain. Similar action might have been the influence here.

Table X presents the carcass grades of those steers fed each ration. Animals on ration 1, containing alfalfa as a roughage, graded higher (8 choice and 2 good) than those on the straw rations. This higher degree of finish is very likely attributed to the alfalfa roughage because of the beneficial effects from the protein, phosphorus, calcium, ash and carotene therein. All of these nutrients were found to exist in greater amounts in the alfalfa as compared to the wheat straw. The steers fed ration 1 also ate more alfalfa than the other steers ate straw, in this experiment. Three weeks previous to this date, finished steers sold to the same company, under the same conditions, graded high-good and required the federal

Table X. Carcass Grades of the Steers on the Experiment.

Ration Number	1	2	3	4
Carcass grades:				
Choice	8	0	1	1
Good	2	10	9	9
Standard	0	0	0	0

grader to breakdown the carcass and observe the marbling of the loin-eye muscle in passing final judgment as to their grade.

In reference again to Table IV, the financial results are presented as the concluding data for this experiment. Steers fed ration 1 showed, on the average, a positive financial increase of $5.79 per animal. Those fed ration 2, 3 and 4 showed, on the average, a loss of $16.85, $9.26 and $15.82, respectively, per animal.

The time of year the steers were sold may have been a detriment to the financial return. When the steers were sold late in the fall, the price of beef had declined because of the numerous cattle sold coming off summer range. Three weeks earlier, finished steers brought $6.00 more per hundredweight. Had the experimental steers been sold for this price, the return from those fed straw in their ration, would have also been positive.

It is believed that positive financial returns may be realized when wheat straw is utilized as roughage in ruminant's rations. Further incentive toward this feeling arises from the fact that if the $32.65 and $30.65 per hundredweight received for the steer carcasses are converted to liveweight selling prices, each average return per hundredweight from the steer groups fed straw, would be greater than the feed cost per hundredweight gain. Liveweight selling prices (converted from carcass price) for steers receiving rations 1, 2, 3 and 4 were $19.06, $17.04, $18.06 and $17.28 per hundredweight, respectively, while the feed cost per hundredweight gain was $13.44, $14.24, $14.70 and $14.54 for the same groups of steers.

SUMMARY

Forty yearling Hereford steers were used as experimental animals during a 152-day fattening trial in which wheat straw was utilized as roughage. The objective of this experiment was to determine whether wheat straw could be used economically as roughage in a fattening program of beef animals. It was also the objective to observe the effects of adding bovirum (dried rumen contents from mature animals), yeast, and molasses to the protein supplements which were designed to supplement the deficiencies of straw. Resulting data from this experiment was measured by weight gains and feed utilization.

The steers were assigned to four groups of ten. One group of steers received alfalfa hay as roughage and two pounds per steer, per day of a 14 per cent protein pellet. The remaining three groups received straw as roughage and two pounds per steer, per day of a 32 per cent protein pellet, designed to supplement the deficiencies of straw. Of the three pellets fed the steers receiving wheat straw, one was designated as the control. One pellet fed the other two groups contained additional molasses and the other pellet contained yeast and bovirum. All supplements contained stilbestrol.

Steers receiving straw were slow in accepting it. Steers receiving alfalfa went off feed early in the experiment and took longer than the straw-fed steers to regain a full feed of concentrates. Steers ate more alfalfa roughage than straw roughage. Those steers receiving straw ate more concentrates than the other steers. The roughage intake reached its peak, for all steers, (9 pounds per steer, per day, for those steers fed

alfalfa and 6.5 pounds for those receiving straw) about 45 days after the beginning of the experiment. It then gradually declined until the end of the experiment (3 pounds for those steers fed alfalfa and 2 pounds for those fed straw).

Some steers in each lot went off feed intermittantly throughout the experiment. Those steers receiving straw roughage showed preference to the concentrates (wheat mixed feed, rolled barley, and supplemental pellets), while the remaining steers preferred alfalfa to the concentrates. As a result, steers receiving straw showed less efficient use of the concentrate portion of the ration, similarly, steers receiving alfalfa showed less efficiency of utilization for alfalfa.

The feed required per hundredweight gain (pounds) for rations 1, 2, 3, and 4 was 825.1, 845.1, 858.0 and 885.4 pounds and the rate of gain was 2.75, 2.46, 2.46, and 2.42 pounds, respectively.

The feed efficiency was slightly less for those steers receiving additional molasses (ration 3) when compared to the control (ration 2); however, their rate of gain was about the same. There was no apparent benefit from this increased level of molasses in the supplement.

The addition of yeast and bovirum (ration 4) appeared to be responsible for the greater consumption of straw and grain; however, this resulted in less efficiency of feed utilization and thus increased the cost per hundredweight gain. There was no increase in rate of gain for those steers receiving yeast and bovirum as compared to the other two groups of steers receiving straw. If significant rates of gain and feed efficiency had been observed from these steers, further research would be necessary to determine which ingredient had been responsible for this influence or whether it was a result of the combination of the two.

Steers in all four groups followed the same general trend in rate of gain. Steers receiving alfalfa hay maintained a slightly greater daily gain throughout the experiment; however, results showed no statistical differences in average daily gain between animals receiving straw (2.46, 2.46, and 2.42 pounds per steer, per day) and alfalfa (2.75 pounds per steer, per day). Groups receiving molasses or yeast and bovirum in the protein supplement showed no increase in daily gain as compared to the straw control animals.

Animals fed the ration containing alfalfa graded higher at slaughter than those fed the rations containing straw.

Negative monetary returns ($9.26 to $16.87) resulted from all steers receiving wheat straw as roughage. A positive return ($5.79) was shown by those steers receiving alfalfa. Closer evaluation of circumstances and data, suggest that under favorable conditions, straw might replace alfalfa if alfalfa sold for $25.00 per ton or more and straw sold for $10.00 per ton or less and 32 per cent protein pellets were $60.00 per ton or less. Straw roughage showed little or no deleterious effects upon weight gain or feed utilization; however, for straw-fed steers to arrive at the same degree of finish as alfalfa-fed steers, it would be necessary to feed a greater length of time (about 30 days).

A greater basic understanding is needed of the ruminant and its function. Adequate background in this field precurses further work with straw roughage, such as, varietal differences in straw, influence of fertilizer upon straw, environmental influence (climate, soil, moisture, etc.) upon the quality of straw, additional supplemental ingredients fed with straw rations, and some preparation of straw before its use as a feed.

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