Roughage Levels and Roughage Substitutes in High Concentrate Diets for Finishing Beef Cattle and Lambs

William M. Larson

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ROUGHAGE LEVELS AND ROUGHAGE SUBSTITUTES IN HIGH
CONCENTRATE DIETS FOR FINISHING
BEEF CATTLE AND LAMBS

BY
WILLIAM M. LARSON

A thesis submitted
in partial fulfillment of the requirements for the
degree Doctor of Philosophy, Major in
Animal Science, South Dakota
State University

1969

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ROUGHAGE LEVELS AND ROUGHAGE SUBSTITUTES IN HIGH CONCENTRATE DIETS FOR FINISHING BEEF CATTLE AND LAMBS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Doctor of Philosophy, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser / Date

Head, Animal Science Department / Date
ROUGHAGE LEVELS AND ROUGHAGE SUBSTITUTES IN HIGH
CONCENTRATE DIETS FOR FINISHING
BEEF CATTLE AND LAMBS
Abstract

WILLIAM M. LARSON

Under the supervision of L. B. Embry and R. M. Luther

Experiments were conducted with yearling beef cattle and feeder
lambs to determine the effects of adding 3% oyster shells or various
levels of hay to an all-concentrate diet of rolled corn grain
adequately supplemented with protein, minerals and vitamins A and E.
Criteria used for evaluating diets with varying amounts of roughage
included feedlot performance, carcass characteristics, rumen fermenta­
tion, digestibility and concentrate replacement value of hay.

In experiments with beef cattle, steers fed an all-concentrate
diet gained 1.30 kg. daily with 6.79 kg. feed required per kg. gain.
Adding 3% oyster shells to this diet resulted in only small effects on
daily gain, carcass characteristics or rumen fermentation. Concentrate
requirements were reduced slightly, resulting in the oyster shells
having a replacement value for concentrate equal to 0.5 unit per unit
of oyster shells. Digestion coefficients were generally higher with
the diet containing oyster shells.

Alfalfa hay was incorporated into the all-concentrate diet at
levels of 3, 10 or 20%. The addition of alfalfa hay resulted in a
15.4% improvement in gain with essentially no difference between levels
of hay. Total feed consumption increased with increasing levels of hay
and concentrate consumption was slightly higher in diets with hay in
comparison to the no-roughage diets. Concentrates required per unit of gain were about the same for the three levels of hay and lower than for the all-concentrate diet. Replacement values per unit of hay amounted to 3.2, 1.0 and 0.5 units of concentrates in the 3, 10 and 20% hay diets, respectively. Level of hay resulted in only small differences in the carcass characteristics studied. There was a tendency for concentration of total volatile fatty acids in the rumen fluid to be lower as the level of hay was increased from 0 to 20%. Acetate to propionate ratios became wider with increasing amounts of hay. Hay at 3 or 10% of the diet had only small effect on digestibility of the diet, but digestibility was some lower with 20% hay.

An experiment was conducted with lambs fed diets similar to those for the cattle. Lambs fed the all-concentrate diet gained 0.295 kg. daily and the feed to gain ratio was 4.67. Oyster shells offered little improvement in terms of gain and carcass characteristics. Feed consumption was slightly higher, but concentrate consumption was lower when 3% oyster shells were fed, resulting in a replacement value for concentrates of 0.57 unit per unit of oyster shells.

Lambs fed hay at levels up to 20% of the diet gained about the same as when fed the all-concentrate diet. There was a trend toward increased feed consumption with increasing levels of hay, but concentrate consumption was slightly lower. Concentrate requirements were relatively constant for all levels of hay up to 20% of the diet, resulting in low replacement values of hay for concentrates. Carcass characteristics were similar for all dietary treatments.
Another experiment with lambs was conducted similar to the first one except the diet with oyster shells was omitted and diets with 40 or 60% hay were added. Lambs fed all-concentrate diets in this experiment gained 0.262 kg. daily with a feed to gain ratio of 5.54. Inclusion of hay up to 20% resulted in slightly lower gains. When hay was included at 40 or 60%, rate of gain was 37 and 48% lower for the two diets, respectively, in comparison to the all-concentrate diet. There was a tendency toward increased feed consumption with increasing levels of hay, but concentrate consumption was lower. Concentrate requirements were relatively constant for all levels of hay up to 40%, resulting in little replacement value of hay for concentrates. Only at the 60% level did there appear to be an appreciable reduction in concentrates required per unit of gain. However, the increase in hay required relative to concentrates saved resulted in a low concentrate replacement value for hay even at this higher level. Levels of hay up to 20% resulted in only small effects on the carcass characteristics studied. Lambs fed 40 or 60% hay had lower carcass values, but they were slaughtered at lighter weights. Although variations between rumen samples taken from lambs were high, average volatile fatty acid concentrations were generally higher with the diets containing hay as compared to the one with all-concentrates.
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INTRODUCTION

Cattle and sheep can be grown and finished to desirable market weights and condition on a great variety of feedstuffs. Being ruminants, they are able to make use of high-fiber feeds having a low, if any, value for animals with a simple stomach. While ruminants are commonly considered to be forage consuming animals, they have been fed satisfactorily on diets devoid of roughage. However, the unique feature is not that ruminants can be fed diets without roughage but that they are able to utilize rather efficiently large quantities of roughage.

Diets containing both concentrates and roughages are more often fed to feedlot cattle than diets of either alone. Roughages are of lower digestibility than concentrates and produce more heat during fermentation and metabolism. An increase in roughage in the diet decreases its energy value. Animals consume more of a lower energy diet and thus will partially compensate for the lower energy concentrations by greater feed intake. However, there are limits on the ability to do this and variation in feedlot performance should be expected from diets which vary in proportions of concentrates and roughages.

Digestibility of diets and type of fermentation in the rumen are affected by the proportions of concentrates and roughages. Energy values for diets, therefore, are not simple additions of the energy contained in the concentrate and roughage portions. These facts
suggest that the ratio of concentrates to roughages may have an important influence on utilization of the diet.

Rumen microorganisms need some readily available source of energy for maximum efficiency in their fermentative and synthetic activity. However, additions of readily available carbohydrates to high-roughage diets have been shown to depress cellulose digestibility. While cellulose digestibility would be of only minor importance in high-concentrate diets, there is considerable evidence that such diets are benefited by some roughage, or perhaps a substitute for the roughage.

A large number of experiments have been conducted during the past several years to determine most efficient ratios of concentrates to roughages for growing and finishing beef cattle and sheep. Most ratios tested until recently would be considered intermediate ones by present standards. Recent research has indicated that such ratios of concentrates to roughages do not result in the most efficient utilization of either the concentrate or the roughage portion. More research is needed, especially to determine the value of small amounts of roughage, or roughage substitutes, in comparison to all-concentrate diets and of small amounts of concentrates in comparison to all roughages. Information obtained would be useful in selecting diets at various stages of growing and finishing for most efficient and economical feed utilization and livestock production.

The research reported in this thesis involved experiments to determine the value of adding low levels of roughage (alfalfa hay) or
a roughage substitute (oyster shells) to an all-concentrate diet for finishing beef cattle and sheep. Diets were compared on basis of feedlot performance, grain replacement value of the roughage, carcass characteristics, digestibility and rumen fermentation.
REVIEW OF LITERATURE

Early workers (Davenport, 1897; McCandish, 1923) were unsuccessful in feeding calves on diets devoid of roughage and concluded that fibrous materials were necessary in the diet. However, Huffman (1928) postulated that hay contained an unknown factor other than bulk which was necessary for maintaining health of cattle, and Mead and Regan (1931) successfully grew calves to 19 months of age on an all-concentrate diet supplemented with cod liver oil and alfalfa ash.

Since that time, several workers have successfully fed all-concentrate diets to cattle (Wise et al., 1961, 1963, 1965; Davis et al., 1963; Oltjen et al., 1965, 1966; Embry et al., 1967; Bushman et al., 1968). These diets have been shown to produce high rates of gain with low feed requirements which offer many advantages in large feeding operations.

While all-concentrate diets have been fed with good results, some questions remain as to the need for roughage for finishing cattle and its relative value at different levels. The literature review will be devoted largely to research concerned with various concentrate to roughage ratios in feedlot diets and factors that may affect results obtained from the different types of diets. For uniformity, data are reported in the metric system with proper conversions being made for data not originally presented in this system.
Factors That May Affect Results Obtained From Various Concentrate to Roughage Ratios

Varying the amount of concentrates and roughages in diets fed to ruminant animals has produced differences in digestibility, rumen fermentation products and performance of the animals. Several factors may affect the results obtained from various concentrate to roughage ratios. These include size, type and quality of the animal; stage of growth and fattening; frequency of feeding; protein, vitamin and mineral content of diet; various feed additives; environment; physical form of the diet and type of concentrates and roughages. Consideration should be given to these factors in evaluating results between experiments involving levels of concentrates and roughages and in selecting diets under various conditions.

**Size, Type and Quality of Cattle.** Mature body size, type and quality of cattle appear to have an effect on results obtained from diets varying in ratio of concentrates to roughages. In contradiction to common older feeding systems, lower grading feeder cattle with a large skeletal size as typified by the Holstein breed appear to respond at least as well to a high-energy diet as higher grading beef-type feeders. The effect of roughage level in diets fed for 216 or 265 days on the feedlot performance and carcass characteristics of Holstein and Hereford steers was studied by Larson (1967). Diets were composed of 20 or 50% haylage on an as-fed basis (15 and 39% air-dry basis) with corn as the concentrate. Average daily gains were increased and feed requirements decreased by the lower level of roughage and the shorter
feeding period for both types of cattle. Holsteins appeared to respond better to the higher energy diet in weight gain, feed efficiency and carcass traits than did Herefords. This is in agreement with earlier work reported by Burroughs et al. (1965).

Minish et al. (1966, 1967) studied the effects of adding various amounts of corn grain to high corn silage diets for steer calves representing the Standard, Common and Choice feeder grades. Levels fed were 0.0, 0.5, 1.0 or 1.5 kg. of total concentrates (corn and protein supplement) daily per 100 kg. of body weight along with a full-feed of corn silage. When the level of concentrates was increased, average daily gain increased for all feeder grades with the Standard grade feeders showing the most response to the higher concentrate levels. Carcass grade of the Choice feeders was improved by adding concentrate to the diet, but the higher concentrate diet had very little effect on the carcass grade of the Standard feeders.

Rate of gain and feed requirements vary at different stages of growth and with the amount of fattening. In a general discussion of growth, Tyler (1964) pointed out that growth occurs in different tissues at different times. The skeleton develops first, muscle next and fat last with these stages of development overlapping to a considerable extent. Increasing energy intake in young animals leads to increasing protein and fat deposition, but protein predominates at first and fat later. Since cattle with a large skeletal size would be physiologically younger than cattle of small skeletal size at the same body weight, it would be reasonable to assume that a larger
portion of the gain would be in the form of protein. Less energy is required for production of body protein than for fat deposition which would suggest that larger framed cattle should benefit more from high-energy diets than cattle with a lighter mature weight when both are finished at similar market weights.

**Stage of Growth and Fattening.** Since protein deposition predominates in younger animals while fat deposition becomes proportionately greater as the animal approaches mature weight, energy requirements increase with age and degree of fatness. Calves and yearlings represent animals in different stages of growth and fattening and they differ in growth rate and feed requirements. Their response to diets with various proportions of concentrates and roughages may also vary. Keith *et al.* (1952) fed 60 steer calves and 40 yearling steers diets containing concentrate to hay ratios of 1:3, 1:2, 1:1, 2:1, 3:1 and 4:1. Calves fed a 2:1 ratio of concentrates to hay made the most rapid daily gain. On the other hand, yearling steers made the most rapid gain when fed the 3:1 ratio of concentrates to roughages. In agreement with these results that calves use higher roughage diets more efficiently than yearlings are those by Embry *et al.* (1967). They reported that hay fed at 10 and 20% of finishing diets with barley had a greater barley replacement value for calves than for yearlings.

Diets with 50, 35 or 20% alfalfa hay plus corn grain and supplement were fed by McGillick (1964). The feeding trial was divided into three periods. Each of the three diets was fed to a
group of steers during the entire experiment and one group of steers received a different diet each period, starting with the highest level of roughage and finishing on the lowest level. Greater benefits in gain, feed efficiency and hay replacement value of corn were obtained during periods 2 and 3 than during period 1 for the 20% hay diet in comparison to those with 50% hay. Increasing the level of corn from 50 to 65 to 80% appeared more efficient than the constant level of 65%. These results would appear to support high-roughage diets during early stages of growing and finishing and high-concentrate diets during late stages for most efficient utilization of forage and grain. Results by Miller et al. (1966) are also in agreement with this system of feeding. Holstein steers were self-fed concentrate to roughage ratios of 11:1 or 1:3 from 182 kg. to 455 kg. or the 1:3 diet to 341 kg. and finished on the 11:1 diet. Steers fed the high-hay diet to 341 kg. and then finished on the high-grain diet gained fastest followed by those fed high-grain during the entire feeding period. The faster gaining steers also had higher carcass grades and significantly higher dressing percentages. Total feed requirements were higher for those receiving the most roughage, but calculated TDN per 100 kg. of gain was lowest for these diets.

It has been shown with swine that high-energy diets during early stages of growth with lower levels of energy thereafter are conducive to high rates of gain with less fat deposition in relation to lean than the reverse of this system (McMeekan, 1940). Whetzal et al. (1966) tried this system on cattle and reported that 218 kg. steers full-fed
a diet of high-moisture ear corn for 198 days followed by corn silage to a final weight of about 518 kg. gained at a lower rate and required more corn grain and corn silage per 100 kg. gain than steers fed the reverse of this system. Steers fed the corn silage during the latter part of the trial were fed 32 days longer. They did have more desirable carcasses from the standpoint of marbling and carcass grade, but they had a lower carcass yield. Higher feed requirements and a lower carcass yield resulted in the high-low system being less economical than the low-high one.

A study was reported by Oltjen et al. (1968) in which two groups of steer calves initially received an all-concentrate diet (90.6% cracked corn) and two groups received a pelleted all-roughage diet (98.5% alfalfa hay). After 77 days one all-concentrate group was switched to the all-roughage diet and one all-roughage group to the all-concentrate diet. All groups were then fed an additional 77 days. Steers fed the all-concentrate diet for the entire experiment gained faster with less feed than those fed only roughage. Those fed the all-roughage diet for 77 days and then changed to the all-concentrate diet were similar in gain and feed conversion as those fed the reverse of this system. Carcass grade and dressing percent were significantly higher (P < .05) for steers fed all-concentrates or all-roughages followed by all-concentrates than those fed under the other systems.

On the basis of gain and feed efficiency, results of these experiments show that liberal grain feeding is usually best for all ages and types of cattle. Higher roughage diets do appear to be
utilized better by cattle that are in the earlier stages of growth and fattening where requirements in relation to capacity are less than older cattle. Although fat deposition can be reduced by feeding low-energy diets during later stages of the feeding period, this practice does not appear economical on basis of total feed requirements for beef cattle.

**Frequency of Feeding.** An area of interest to researchers has been that of voluntary energy intake by ruminants. Feed intake is usually greater with high-roughage diets than with those high in concentrates. However, results may vary somewhat depending on the digestibility and physical form of the roughage. Feer and Campling (1963) concluded from experiments to determine factors affecting voluntary intake of feed by cattle that intake of hay and dried grass was directly related to digestibility and inversely related to mean retention time. On the other hand, intake of concentrates was not related to digestibility or retention time. From these results, benefits received from feeding more than once daily would likely vary with the amount and quality of roughage in the diet. Frequency of feeding would be a factor affecting results obtained from various ratios of concentrates to roughages.

Theurer et al. (1964) conducted two trials using 20 heifer calves in each trial. They fed a diet with 67% concentrate or 67% roughage. The diets were offered to the cattle for either two 1-hour feeding periods or six 20-minute periods spaced over 9 hours during the day. Heifers fed the higher concentrate diet six times daily
consumed more feed and had greater gains than those fed twice daily. On the other hand, feed consumption and daily gain were not consistently altered by frequency of feeding of the high-roughage diet. Feed efficiency was not affected by frequency of feeding with either diet.

Comparative performance of cattle fed one and two times daily with diets differing in moisture content and level of roughage was studied by Larson et al. (1967). They fed dry (12% moisture) or high moisture (28%) corn grain with or without 6.8 kg. of corn silage once or twice daily to beef steers initially averaging about 352 kg. Feeding twice daily generally resulted in faster gains, a slight increase in feed consumption and a reduction in feed requirements. More frequent feeding appeared to benefit steers fed dry corn with silage and high moisture corn without silage the most.

**Protein, Vitamins and Minerals.** As the level of roughage is reduced in ruminant diets, several of the required nutrients and certain "physiological factors" may be reduced. A marked lower rumination will decrease salivary flow and thus may lead to an upset of the buffering system afforded the rumen by this mechanism.

The lower feed intake associated with high-concentrate diets will result in a decrease in intake of those nutrients supplied as a percent of the total diet. This may present problems when requirements of nutrients are presented as a percent of the diet. The National Research Council (N.R.C., 1963) lists the required protein content of diets for 182 to 364 kg. calves as being 11%. Some research has shown beneficial effects when higher than these
recommended levels of protein have been fed. Haskins et al. (1967) reported improved performance of steer calves fed an all-concentrate diet by increasing the level of protein from 11% to 14%. Woods and Tolman (1968) reported performance of 318 kg. yearling steers was improved by increasing the protein content of an all-concentrate diet from 11% to 14%. However, there were no benefits from the higher level of protein when the diet contained 15% roughage. Thrasher et al. (1967) showed higher levels of protein to be beneficial for calves fed diets containing 20% ryegrass pellets and 80% concentrates as well as in all-concentrate diets. Protein levels fed were 11% and 12.5% of the total diet. Calves fed diets with 12.5% protein gained significantly faster ($P < 0.05$) than those fed the 11% level and had consistently lower feed requirements. Source of protein did not appear to affect performance with these high-concentrate diets in that steers fed urea or soybean meal as the supplemental protein made similar rates of gain.

Questions are frequently raised concerning the need for various vitamins and minerals with high-concentrate diets. It would be reasonable to assume that high-concentrate diets would need to be supplemented with such major nutrients as vitamin A and calcium since most grains are known to contain a considerably lower level of these than established requirements for ruminants. There may be some question as to the need for other vitamins and minerals which normally appear adequate in diets containing considerable quantities of roughage. Burroughs et al. (1963) reported that supplementing a ground ear corn diet with vitamin E and K resulted in improved performance by beef
steers. The vitamin-supplemented cattle averaged 9% faster gains with an improvement in feed conversion. In another trial with similar diets, about the same response in weight gains was obtained from supplemental selenium as from the supplemental vitamins. A response in weight gain from supplemental vitamin E has also been reported by Ellis (1965). In contrast, Woods and LaToush (1968) failed to obtain any benefit from adding vitamin E, potassium or phosphorus to high-concentrate diets. All-concentrate diets have not been improved by supplementing with choline (Wise et al., 1964) or zinc (Wise and Barrick, 1963).

**Antibiotics and Buffers.** One of the problems associated with the feeding of high-energy diets is the rumen parakeratosis-liver abscess complex. An increased incidence of rumen parakeratosis and liver abscesses in ruminants fed high-energy diets has been reported by several workers (Beardsley et al., 1959; Cullison, 1961; Ward, 1962; McGinty, 1963). There appears to be a high correlation between the presence of ruminal lesions and liver abscesses in cattle. Smith (1944) examined the livers and rumens of 1,807 cattle at slaughter and found 322 with liver abscesses. Ruminal lesions were present in 62% of the cattle with affected livers in comparison to only 18% in cattle with normal livers. Jensen et al. (1954) have also reported a highly significant association between abscessed livers and ruminal lesions in cattle.

Two bacteria have been suggested as the causative agents of liver abscesses. *Sphaerophorus necrophorus* has been the predominant
organism isolated from abscessed livers (Newson, 1938; Madin, 1949). Smith (1944) cites Pellegrini (1939) as also isolating Corynebacterium pyogenes from abscessed cattle livers in Italy. These two bacteria have also been isolated from abscessed livers by workers at the North Carolina station (Wise et al., 1968). These organisms occur widely in nature and are probably on the skin and mucous membranes and can also be assumed to be present in the digestive tract of both healthy and diseased cattle. Normal, healthy mucous membrane is highly resistant to penetration by the organisms. Jensen (1960) suggested, however, that when ruminal inflammation occurs these organisms may penetrate the affected rumen epithelium, gain access to the portal blood system, become highly pathogenic and cause extensive necrosis and abscesses in the liver. Jensen et al. (1954) have produced liver abscesses experimentally in cattle and sheep by intraportal inoculation of viable S. necrophorus.

The causes of rumen parakeratosis which would favor access of the organisms to the portal system are not known. However, it has been established that diets high in energy increase the incidence of rumen parakeratosis. The absence of coarse roughage in the diet could thus be a contributing factor. Low levels of roughage in the diet are also associated with a narrowing of the acetate to propionate ratio in the rumen contents accompanied by an accumulation of normal fermentation products (Tyznik and Allen, 1951; Balch and Rowland, 1957; Brown et al., 1958; Eusebio et al., 1958; Raun et al., 1962; Bath and Rook, 1963; Hughes et al., 1964; Templeton and Dyer, 1967; Weiss et al., 1967).
Cornell workers (Flatt et al., 1958; Sander et al., 1959) have shown that rumen development is markedly affected by fermentation products of the rumen, especially propionate and butyrate. Dobson and Phillipson (1956) have further related tissue growth with increased blood flow from the rumen which is a result of increased fatty acid concentrations. The possibility exists that this rapid accumulation of normal fermentation products or abnormal fermentation products might be responsible for the observed effects in ruminal epithelial change. Vida.cs and Ward (1960) found that when acetic acid was added to a beet pulp diet known to produce severe rumen parakeratosis epithelial damage was arrested but not eliminated. These workers suggested that low acetate to propionate ratios associated with the beet pulp diet may be the causative agent of rumen parakeratosis.

Economic loss to packing companies due to condemnation of abscessed livers is not the only problem associated with this condition. Damaged livers can result in lowering of production. Bolsen et al. (1968) reported daily gain of heifers with abscessed livers at time of slaughter was significantly less than for heifers with clinically normal livers. Similar results have been reported by Wise et al. (1968) and Powell et al. (1968).

Attempts to combat the pathogenic bacteria thought to be responsible for increased incidence of liver abscesses in high-concentrate diets have been the subject of many investigations. Jensen (1960) reported that chlortetracycline fed at 70 mg. per head daily would significantly reduce, but not eliminate, abscesses of liver in
cattle. Ellis et al., (1963) and Ellis (1965) found a substantial reduction in incidence of abscessed livers when continuous low levels of chlortetracycline (70 mg. daily) were added to all-concentrate milo diets. A marked response from the antibiotic in gain and feed conversion was also observed by these workers. Harvey et al. (1968) obtained a 30% reduction in liver abscesses by feeding chlortetracycline at 75 to 85 mg. daily to steers receiving all-concentrate diets. A slight but nonsignificant improvement in gains and feed efficiency was noted from the antibiotic. Results from feeding a low level of chlortetracycline indicate that it is effective in reducing liver abscesses in steers fed high-concentrate diets.

While much of the work with antibiotics has been with chlortetracycline, others have been tested. Zinc bacitracin in barley diets was found to be beneficial in reducing liver abscesses as well as foot rot and founder (Dinusson et al., 1964). In contrast, Haskins et al. (1967) reported bacitracin (70 to 80 mg. daily) to be ineffective in preventing liver abscesses in steers fed all-concentrate diets.

The increase in total volatile fatty acid concentration and narrowing the acetate to propionate ratio when higher energy diets are fed are accompanied by a lower pH in the rumen (Balch and Rowland, 1957; Reid et al., 1957; Rhodes and Woods, 1962; Woods and Luther, 1962; Thompson et al., 1965; Oltjen and Davis, 1965; Luther and Trenkle, 1967). Buffering capacity of the rumen is dependent on the amount of saliva produced which in turn is highly dependent upon the
amount of time spent in ruminating by the animal (McDougall, 1948). On conventional hay-grain diets, sufficient saliva is produced which is high in bicarbonate for buffering the VFA's. However, diets high in readily fermentable starch and sugars are known to cause a marked reduction in ruminating (Balch et al., 1955; Matrone et al., 1959) which in turn reduces flow of saliva. This reduction in flow of saliva may cause the rumen buffering capacity to be reduced, allowing the pH to remain low.

Differences in rumen pH and buffering capacity of the saliva may influence results obtained when comparing diets which vary in amount of concentrates and roughages. Wise et al. (1962) reported on a series of four experiments in which potassium, sodium and calcium salts were added to all-concentrate diets. The addition of sodium and potassium bicarbonates as well as calcium carbonate at various levels resulted in no definite value for the buffers in all-concentrate diets.

Nicholson and Cunningham (1961) reported that adding 7.2% of a mixture of ground limestone and sodium bicarbonate to an all-concentrate diet significantly improved feed consumption with a trend toward improved gains and feed efficiency. However, performance was not equal to that obtained by feeding hay with the concentrates. A buffer mixture containing two parts limestone, two parts sodium bicarbonate and one part potassium carbonate added as 6% of the diet tended to give better results than a 9% level of the same buffer mixture. In another study, Nicholson et al. (1962) reported that 5.7%
of sodium bicarbonate in an all-concentrate diet composed of either
ground or rolled grains (barley and oats) did not improve gains, feed
efficiency or carcass grade. Adding 3.6% sodium propionate to the
bicarbonate containing diet did not have any significant effect on
animal performance. In a later study, Nicholson et al. (1963) found
that 3% sodium bicarbonate in a rolled barley basal diet resulted in a
significant increase in feed intake but no significant change in
average daily gain. Diets with 3% sodium bicarbonate, 2% ground
limestone and 1% potassium carbonate did not improve feedlot
performance over that obtained on the basal diet. Sodium bicarbonate
resulted in a lower molar proportion of acetic acid. The pH and
buffering capacity of rumen fluid were found to be considerably higher
for the two buffered diets.

Research reported to date on the use of buffering agents and the
effect of variations in rumen pH has shown variable results. Addi-
tional research is needed which would involve various types of diets
and levels and kinds of buffers.

Climatic Environment. Body temperature of warm-blooded animals
is maintained within narrow limits with varying environmental tempera-
ture. Heat is produced from reactions occurring in carrying on the
life processes. In addition, feed consumption increases body heat
through heat of fermentation and heat of cellular metabolism (heat
increment of the food). This heat is useful in maintenance of constant
body temperature when the environmental temperature is below body
temperature and must be dissipated from the body when the environmental
temperature is above body temperature. The usefulness or expense to the animal of this heat depends upon the environmental temperature and the amount of body heat produced. The importance of the heat increment in the economy of food utilization and in body-temperature regulation is discussed by Maynard and Loosli (1962) and by Kleiber (1961).

Roughages, or feeds high in fiber, undergo a longer period of fermentation in the digestive tract of ruminants and produce more heat of fermentation than do concentrates. In addition, a greater proportion of acetic acid than propionic acid is dissipated as heat in ruminants (Armstrong et al., 1957). Since roughages result in more acetic acid production in relation to propionic acid, this would be another basis for greater heat production with high-roughage diets.

Because of differences in heat production between roughages and concentrates, value of diets with various proportions of roughages and concentrates should be expected to vary somewhat with the environmental temperature and the level of intake. High-concentrate diets would appear to have more advantage in relation to high-roughage diets during summer months.

**Physical Form of Ingredients**

Various methods of feed preparation basically involve alterations in the starch, protein, particle size or moisture content of the feedstuff. These alterations may bring about changes in digestibility and/or rate of passage through the digestive tract. The nature and magnitude of the changes brought about may be influenced by the type of the feedstuff, level fed and the other ingredients in the diet. As
a result, feedlot performance from diets with various amounts of concentrates and roughages may be influenced by the type of preparation as well as the type of concentrates and roughages.

The value of a low level (6.8 kg) of corn silage in the diet of finishing steers was shown to be different for dry and high moisture corn by Larson et al. (1967). The corn silage had only a slight effect on corn grain requirements per unit of gain when fed with dry grain. However, when fed with grain at about 27% moisture, 100 kg of the air-dry silage saved an average of 41 kg of corn per 100 kg of gain.

Kuhlman et al. (1968) used 852 steers and 468 heifers initially weighing 290 kg in an experiment to determine the effect of dry rolling and steam flaking of milo when fed with 13 and 5% cottonseed hulls. Reducing the level of roughage from 13 to 5% significantly reduced feed consumption and daily gains but resulted in improved feed efficiency. The higher roughage level appeared to have a greater value when the milo was steam flaked than when dry rolled.

The value of grinding corn and hay when fed with two levels (4.5 or 6.8 kg) of corn silage to yearling steers was evaluated by Meiske et al. (1968). Ground corn in comparison to whole grain reduced daily gain and feed consumption and increased feed requirements with each level of silage fed, but differences were not statistically significant. Cattle fed ground hay ate more dry matter and gained faster than those fed long hay resulting in similar feed conversion ratios. Whether the cattle were fed 4.5 or 6.8 kg corn silage in their diets made little difference in daily gain, daily dry matter
consumption or dry matter required per unit of gain. No interrelationships between type of feed preparation and roughage level were shown in the experiment.

Pelleting of diets has been shown to alter the value of diets with various levels of concentrates and roughages. Generally, diets which contain a high proportion of roughage are improved by pelleting. However, as the roughage level is reduced, benefits received from pelleting become less. McCroskey et al. (1959) studied the effects of pelleting diets containing 1:4 and 4:1 concentrate to roughage ratios when fed to steers. Ground milo, cottonseed meal and molasses were the concentrates and chopped alfalfa hay and cottonseed hulls comprised the roughages. In two trials, rate and efficiency of gain were increased by pelleting the 1:4 diet. However, gains were either lower or not affected when the 4:1 mixture was pelleted. Similar results were obtained by Beardsley et al. (1959) when they fed finely ground and pelleted or coarsely ground and unpelleted diets composed mainly of ground snapped corn and Coastal Bermuda hay in ratios of 70:30, 55:45 or 40:60.

A number of experiments have shown an advantage for pelleting diets for lambs with the improvement being greater with higher levels of roughage. Six hundred ninety-eight feeder lambs were fed either pelleted or nonpelleted diets containing 29 or 59% alfalfa hay by Hartman et al. (1959). Pelleting the lower roughage diet gave no advantage in liveweight gain or feed efficiency while pelleting the higher roughage diet increased gain and feed consumption but not feed
efficiency over the unpelleted form. Ross and Pavey (1959) also showed no differences in gain or feed conversion by lambs from pelleting diets which contained as much as 60% concentrates.

Quality of the roughage has been shown to be a factor in the benefits obtained from diets with various amounts of roughages and concentrates. Pelleting appears to be more beneficial with lower levels of roughages when of low quality according to research by McClure et al. (1960). Improvement in gain from reducing the level of a low quality roughage from 70 to 40% of the diet was as much for a pelleted diet as for a ground one. With orchardgrass-alfalfa hay, maximum gains were obtained with a 60:40 ratio of grain to hay for an unpelleted diet. When the diet was pelleted, a 45:55 ratio of grain to roughage produced maximum gains.

Type of rumen fermentation has been shown to be affected by the preparation of feedstuffs. Shaw et al. (1960) showed a marked decrease in the molar proportion of rumen acetate from pelleted hay and flaked corn as compared to a diet with the hay and corn fed in the meal form. Pelleting a diet containing 60% concentrates decreased the molar proportion of acetate and increased propionate proportions in the rumen according to Luther and Trenkle (1967). Higher levels of rumen acids were associated with pelleting the roughage portion of diets containing 20 or 80% concentrates. Putnam et al. (1966) showed that rate of salivary secretion was less when equal amounts of a high-roughage diet were fed pelleted rather than as a coarsely ground mixture. This resulted in less buffering capacity by the saliva which resulted in
higher VFA concentrations and lower pH values in the rumen. The same phenomena occurred when the concentrate portion of the diet was increased. It is apparent from this work that the type of preparation of concentrates and roughages should be considered when evaluating rumen fermentation results from experiments involving various concentrate to roughage ratios.

Many of the effects of pelleting appear to result from the fine grinding of the feed rather than from the pelleting process itself. Balch and Rowland (1957) showed similar differences in VFA patterns in the rumen liquor between diets with finely ground and coarsely ground hay that other workers have shown between pelleted and unpellet ted hay. In their studies, the ratio of acetic acid to propionic acid decreased with a reduction in the ratio of fibrous to starchy feeds except with diets containing ground hay. Replacing long hay by finely ground hay also decreased the ratio of acetic acid to propionic acid.

Thompson et al. (1965) also showed changes take place in rumen fermentation when hay is ground as opposed to feeding it in the long form. They fed 1.82 kg. daily of either ground or long hay along with a full-feed of corn. Volatile fatty acid concentrations were highest and pH lowest when steers were fed ground hay. This was accompanied by a narrower acetate to propionate ratio and 0.1 kg. improvement in daily gain.

When fed at low levels, grinding of some types of roughage apparently does not affect rumen fermentation patterns or performance of ruminants. This was the conclusion of Harvey et al. (1968) when
they compared diets composed of 5% ground rice hulls or 5% whole rice hulls. However, severe rumen parakeratosis and an increase in the incidence of abscessed livers were noted when the rice hulls were ground. Wise et al. (1961) fed calves either an all-concentrate diet or diets with 1.14 kg. Coastal Bermuda grass hay either ground or in the long form. They also found only small differences in feedlot performance or carcass characteristics between the ground and unground hay.

**Type of Concentrate and Roughage**

The proportion of concentrate to roughage is not always an accurate indication of the energy content of the diet without describing the concentrates and roughages involved. Morrison (1956) listed several feeds as concentrates which have 25% or more fiber on an air-dry basis. On the other hand, several feeds with less than this amount of fiber are classified as roughages. Feeds with more than 18% fiber in the dry state are classified as roughages by the National Research Council (N.R.C., 1964). While this separated feeds into higher and lower energy groups, one could expect only small differences between some classified as roughages and some classified as concentrates. Wide differences also exist in energy content of feedstuffs within the concentrate and roughage classifications. For these reasons, it is necessary to define the type of roughages and concentrates fed when concentrate to roughage ratios are being evaluated.
A series of experiments were conducted by Conrad et al. (1966, 1967b) in which feed mixtures containing cottonseed hulls, rice hulls, ammoniated rice hulls, flax shives or alfalfa hay were fed at levels of 0, 10 or 20% of the diet. Results obtained with cottonseed hulls, rice hulls and flax shives were different from those with alfalfa. In all roughage mixtures, with the exception of those containing alfalfa hay, there was a decrease in gain as the roughage level was increased from 10 to 20%. This trend was reversed when alfalfa was used. Increasing the level of "low quality" roughages resulted in an increase in total feed but a decrease in concentrates per unit of gain. However, as the alfalfa was increased from 10 to 20%, both total feed and concentrate requirements decreased. The quality of roughage was also shown to affect the value of diets with various levels of roughage in work reported by White (1969). He fed diets containing rice straw, alfalfa hay or rice hulls as 0, 5 or 20% of the diet. Roughage had essentially no replacement value for concentrates in the cases of 5 and 20% rice straw and 20% rice hulls. However, one unit of roughage replaced 0.86, 1.73 and 1.74 units of concentrate in the cases of 20% alfalfa hay, 5% alfalfa hay and 5% rice hulls, respectively.

The effects on rumen fermentation when fistulated steers were fed either corn silage or Coastal Bermuda hay at four levels with flaked corn (20 to 80% of the diet) were studied by McCullough and Smart (1968). A decline in molar percent of acetic acid and a corresponding increase in molar percent of propionic acid with increasing amounts of grain were noted when corn silage was fed.
Increasing the amount of grain when hay was fed did not produce the same trend. Diets containing hay resulted in similar molar percentages of the three acids (acetate, propionate and butyrate) at all levels of grain. The pH changes followed closely the changes in total volatile fatty acid concentration, with a sharp drop in pH with increasing grain in silage diets but little change in pH with the hay diets.

Barley is a more fibrous feed than is corn or milo and should therefore possess more "roughage character" than these other grains. With this in mind, McCartor et al. (1964) conducted an experiment to study the effects of equalizing the fiber content of rolled barley and rolled milo diets by adding 8% cottonseed hulls to the milo diet. Milo was also fed without roughage and with 10% corn silage. Daily gains were equal for steers receiving all-milo or milo plus corn silage. Gains were higher for these treatments than for all-barley or milo plus 8% cottonseed hulls. Steers fed barley had slightly lower gains than those fed milo with 8% cottonseed hulls, but feed to gain ratios were higher for those fed the milo-cottonseed hull combination. Condemned livers due to abscesses were highest (30%) in the milo-cottonseed hull treatment and lowest (0.00%) in the barley group. Greater rumen damage was also observed in steers fed milo than in those fed barley.

It is evident from the results of experiments involving diets with various amounts of concentrates and roughages that the kind of concentrates and roughages involved must be considered. Fiber content
Proportions of Concentrate to Roughage

Digestibility, Energy Intake and Rumen Fermentation. Several workers have conducted experiments with ruminants to determine the effects of proportions of concentrates and roughages upon digestibility of the diet. In general, as the proportion of grain is increased, digestibility of the total diet is increased (Haynes et al., 1955; Kane et al., 1961; Brent et al., 1961; McGillick, 1964; Montgomery and Baumgardt, 1965). Digestibility of the crude fiber portion of the diet, however, is usually lowered by increasing the level of concentrates. Putnam and Loosli (1959) and Phillips et al. (1951) fed diets containing 20 to 60% concentrates. They found that as the amount of concentrates was increased the apparently digestibility of the total diet was increased for all the proximate nutrients except crude fiber. Parrot et al. (1968) found no decrease in cellulose digestibility by cattle fed diets with alfalfa hay with grain levels of 40% or less. However, at levels of 50% and above, cellulose digestibility was decreased by increasing increments of grain. In contrast, studies by Dowe et al. (1955) showed no effect on crude fiber digestibility when the level of corn in a corn-hay diet was increased from 50 to 80%.

One factor that can have an effect on the performance of ruminants fed diets varying in concentrate to roughage ratio is digestible energy intake. Blaxter et al. (1961) have demonstrated that the bulk contributed by a feed high in roughage is likely the
major factor in controlling its consumption. On the other hand, when ruminants were given a diet containing a sizable proportion of concentrates, it appeared that the animals ceased to eat before the rumen was completely full or distended. Montgomery and Baumgardt (1965) found that when rumen fill is not limiting intake, ruminants adjust voluntary intake in relation to physiological energy demand. They postulated that the decreased intake with higher concentrate levels may be due to a chemostatic or thermostatic process. This would offer an explanation as to why ruminants tend to consume less feed when fed diets high in concentrates. However, the relationship between roughage level and intake is not always linear. Consumption may be limited with high levels of roughage as a result of the "fill factor." This can also be affected by type of concentrate and roughage, their physical form and the ratio in which they are fed.

Parrot et al. (1968) conducted three trials to determine the effect of concentrate level on dry matter intake and digestible energy intake. Steers were fed diets which varied from all-alfalfa hay to all-steam processed milo in 10% increments. Digestible energy intake increased as the grain level increased up to 60% of the diet. Thereafter there was a decrease, being more pronounced at the higher levels of milo.

Holstein cows were used by Nelson et al. (1968) to study energy intake of pelleted diets composed of Coastal Bermuda grass and concentrates in ratios of from 100:0 to 0:100 in 25% increments. A highly significant increase in digestible energy intake was noted as the
proportion of concentrates were increased. The authors stated that apparently rumen load and rate of passage were the limiting factors on energy intake for the higher roughage diets.

Donefer et al. (1963) fed pelleted diets consisting of barley and alfalfa in ratios of 0:100 to 60:40 to ewes. As the level of barley increased, there was an almost linear increase in digestibility of energy accompanied by a similar decrease in relative intake. As a result, a constant digestible energy intake was maintained with all diets containing barley.

A narrower acetate to propionate ratio in the rumen fluid has been associated with higher concentrate diets. There is some controversy on the significance of changes in metabolism within the rumen as far as milk and meat production is concerned. However, from a review of published work, Van Soest (1963) concluded that diets which yield low ruminal acetate and high ruminal propionate often result in a milk fat test depression while causing the animal to gain body weight. This conclusion is consistent with calorimetric studies which indicate that propionate is more efficient than acetate as an energy source for lipogenesis (Swift, 1957; Blaxter, 1962).

These theories are supported by several experiments. Weiss et al. (1967) conducted an experiment in which three pelleted diets with concentrate to roughage ratios of 0:100, 40:60 and 80:20 were fed to produce variation in VFA levels. The means of the acetate to propionate ratios were 3.4:1, 2.8:1 and 1.3:1 from all roughages to high concentrates, respectively. Means for calculated digestible energy
intake did not differ significantly for the three diets. Carcass fat increased and protein decreased as the acetate to propionate ratio narrowed. The majority of the variance in body composition (58%) was accounted for by the acetate to propionate ratio. Daily gain was improved on the high-concentrate diet and total kilograms of feed required per unit of gain were lower. An increase in dressing percent and carcass grade was positively associated with the high-concentrate diet and negatively associated with the acetate to propionate ratio. Hironaka and Bailey (1968) showed similar results when digestible energy intake of diets varying in barley to hay ratio was equalized. Raun et al. (1962) did not associate a narrowing of the acetate to propionate ratio with a change in weight gains, but higher dressing percent and higher separable fat resulted from diets promoting narrow acetate to propionate ratios. In contrast to the above workers, Kromann and Meyer (1966) concluded from their studies with fistulated sheep that animal response and energy metabolism are due entirely to energy intake and not to a difference in rumen metabolism.

Feedlot Performance and Carcass Characteristics of Cattle.

Feed intake, its digestibility and the end products of rumen fermentation are the factors that determine performance of ruminants fed diets which contain adequate amounts of all essential nutrients. The proportion of concentrates and roughages in the diet influences these factors. Many growth and carcass studies have been conducted with varying concentrate to roughage ratios in an effort to determine which combination will produce the fastest, most economical gains and the most
desirable carcasses under specific conditions. Although one level of roughage in relation to concentrates may appear to produce the most favorable performance, other factors must be considered such as the cost per unit of gain and gain per unit of crop land.

No definite concentrate to roughage ratio appears to be superior under all conditions. Generally, feeding high-concentrate diets to cattle produces a faster rate of gain with a smaller amount of feed than do high-roughage diets (Stanley, 1953; Durham et al., 1963; Lane et al., 1966). These workers also suggested that carcasses of cattle fed high-concentrate diets often have more fat in relation to lean but may vary considerably depending upon days fed and market weight.

Alabama workers have reported superior gains for cattle fed high-roughage diets in comparison to high-energy diets (Anthony et al., 1961; Brown et al., 1964). The high-energy diets were composed principally of shelled corn with 10% or less hay while the high roughage mixtures consisted of either 30% hay, cottonseed hulls or peanut hulls and ground snapped corn plus supplement. Feed requirements were lower for steers fed the high-concentrate diets, but economic conditions were reported to favor feeding high-roughage. Slaughter grades were essentially equal between test groups.

Kansas workers fed steers (Richardson et al., 1953) and heifers (Richardson et al., 1961) on diets containing concentrate to hay ratios of 1:1, 3:1 and 5:1. Steers gained fastest when fed the 3:1 ratio of concentrates to hay while heifers gained faster on the 5:1 ratio.
Carcass grades and marbling scores obtained with the 5:1 and 3:1 ratios were not significantly different, but both were significantly higher than the 1:1 ratio. These studies show that steers and heifers may differ in response to diets varying in amounts of concentrates and roughages.

Conrad et al. (1967a) compared feed mixtures containing cottonseed hulls or chopped Coastal Bermuda grass hay at levels of 0 to 70%. The concentrate portion in all diets was composed primarily of dry sorghum grain and cottonseed meal. Average daily gain increased with increasing roughage levels, attaining maximum at 50% roughage and then decreasing. The same pattern was evident in daily feed intake. As the roughage level increased, total feed per 100 kg. gain also increased but concentrates required per 100 kg. gain decreased. Each unit of roughage replaced 0.72, 0.74, 0.48, 0.63 and 0.62 units of concentrate at the 10, 20, 30, 50 and 70% levels, respectively. Carcass grades were about the same through the 30% roughage level, then tended to decrease as the roughage level was further increased.

Keith et al. (1952) also reported hay had a higher replacement value for concentrates with increasing amounts of grain in the diet. On the other hand, Woods and Scholl (1962) showed a linear relationship between concentrate level in the diet and gains, with the level of concentrate having no effect on the replacement value of hay for grain.

Recently, considerable interest has developed in the feeding of all-concentrate diets to beef cattle because of low feed requirements associated with this type of diet. Several experiments have been
conducted to determine the effects of adding roughage or bulk to these diets and the relative value of the roughage when added at various levels.

The addition of low levels of alfalfa hay to ground ear corn diets has been studied with inconsistent results. Goodrich and Meiske (1966) improved gains of yearling steers by adding 1.82 kg. of alfalfa-brome hay daily to a ground ear corn diet. On the basis of feed efficiency, each unit of alfalfa-brome hay replaced 0.25 unit of soybean meal and 0.41 unit of ground ear corn, indicating an economic advantage for this amount of hay in the diet. On the other hand, Woods et al. (1967) found that hay had little replacement value for corn when 0.90 kg. was added daily to a ground ear corn diet.

Experiments comparing diets with low levels of hay versus all-concentrate diets have also shown varying results. Wise et al. (1963) found no difference in daily gain or feed requirements for steers when 5% alfalfa meal was added to an all-concentrate diet, indicating a 1:1 replacement value of the alfalfa meal for the concentrate. Albin and Durham (1967) also found no difference in gains from adding 5% dehydrated alfalfa meal to an all-concentrate diet. However, steers receiving the alfalfa meal required as much milo and supplement per unit of gain as those fed all-concentrate. Larger amounts of mixed hay (1.36 kg. daily) were added to an all-concentrate diet by Wise et al. (1965). Again, no significant differences were noted in gain. Concentrate requirements were actually higher as well as total feed
requirements per unit of gain when this level of mixed hay was added to the diet.

Embry et al. (1967) conducted two trials to study the effect of adding 15% hay to barley diets for finishing beef cattle. Feeding 15% prairie or bromegrass hay with rolled barley increased rate of gain, feed consumption and feed requirements. In the two trials hay had a replacement value of 45 to 50% for barley on the basis of feed required per unit of gain. They also compared an all-barley diet to diets containing 10 or 20% prairie hay. The hay had a higher replacement value for barley at the 10% level than at the higher level.

Nebraska workers have reported results of several feeding trials involved with the effects of various levels of roughage in high-concentrate diets composed mainly of corn grain (Woods et al., 1967; Woods and Tolman, 1968). Although these studies did not include all-concentrate diets, they indicated that alfalfa hay in excess of 1.0 to 1.5 kg. daily (10 to 15% of the diet) resulted in low values for the added roughage compared to high-concentrate diets.

Cottonseed hulls are a common source of roughage for ruminants in many southern states. Eudaly et al. (1967a) reported on the value of cottonseed hulls when added to a sorghum grain diet at levels of 0 to 10%. Average daily feed intake increased as roughage level increased. There appeared to be no clear influence of roughage level on gain, feed requirements, dressing percent or carcass grade within the limits of this study.
Small amounts of roughage added to all-concentrate diets appear to offer advantages in the management of feedlot cattle. However, when the level of roughage in the diet is over 15%, it has a low value in relation to grain unless there are substantial quantities of roughage in the diet. This suggests that either high-concentrate or high-roughage diets will result in the most efficient utilization of concentrates and roughages.

Only limited data are available as to the effects of concentrate to roughage ratios on composition of bovine fat. Since dietary unsaturated fatty acids are partially or completely hydrogenated by rumen microorganisms (Garton, 1960), effect of dietary fat on the degree of unsaturation of body fats in ruminants is not likely to be great. However, different end products of rumen metabolism associated with varying concentrate to roughage ratios may have an effect on altering composition of the fat. Cabezas et al. (1965) found diets containing mostly corn produced a higher degree of unsaturation of fat than diets containing mostly dried citrus meal. The higher unsaturation of fat in corn-fed steers was due to a higher oleic acid and a lower palmitic acid content. These changes were associated with a higher starch content in the higher corn diets which also narrowed the acetate to propionate ratio significantly. Significant correlation coefficients of 0.58 and -0.57 were found between acetate to propionate ratio in rumen fluid and palmitic acid and oleic acid, respectively.

Feedlot Performance and Carcass Characteristics of Lambs. Cox (1948) reported the optimum concentrate to roughage ratio for lambs
fed a nonpelleted diet to be 45% concentrate and 55% roughage. Morrison (1956) stated that it is very important to feed fattening lambs plenty of good roughage. He said that if a diet on the air-dry basis has more than about 50% corn or other heavy grain, the danger of death losses from enterotoxemia is increased; and even when this does not occur, the feed cost per 100 kg. of gain is apt to be higher when too large a proportion of grain is fed.

Most of the work concerned with concentrate to roughage ratios for sheep has been with concentrate levels of 60% or less. Montgomery and Baumgardt (1965) fed lambs ground shelled corn and alfalfa meal in ratios ranging from all-roughage to 40% roughage. Daily dry matter consumption decreased as corn was increased, but daily energy consumption was similar for all diets. No differences were reported for gain. Corn had a higher replacement value for hay when fed as 20% of the diet than when fed in larger proportions. Each unit of corn replaced 2.35, 2.08 and 1.91 units of hay for 80, 60 and 40% roughage, respectively, when compared to the all-hay diet. Carcass grade, loin fat and rib fat were not significantly different with varying amounts of grain and alfalfa.

Perry et al. (1959) conducted two feeding trials with lambs fed diets with concentrate to roughage ratios of 40:60 and 60:40. All diets contained 20% dehydrated alfalfa meal with the remainder of the roughage consisting of either corn cobs, oat mill feed, soy mill feed, sun-cured alfalfa, sugar cane bagasse or cottonseed hulls. Lambs fed pelleted diets with 40% concentrate and 60% roughage grew more rapidly
than those fed diets with 60% concentrate and 40% roughage. Similar results were obtained by Ross and Pavey (1959) when they fed pelleted diets containing 60, 50 or 40% concentrate. Daily gains were significantly higher for lambs fed 40 or 50% concentrate than for those fed 60% concentrate and total feed requirements were reduced as the roughage level was increased.

High-concentrate diets were included in studies with lambs by Ruttle and Sundt (1965) and Ruttle (1966). The diets were pelleted and consisted of grain sorghum and alfalfa hay in the ratios of 100:0, 90:10, 60:40 and 30:70. The two higher roughage diets produced better gains with less feed required per unit of gain. Dressing percent was higher for lambs fed the high-concentrate diets.

It is evident that much of the research supports the statements by Cox (1948) and Morrison (1956) that diets for lambs should contain no more than 50% roughage. However, the research that supports these conclusions appears to be largely with diets containing relatively high levels of roughage. Ruttle and Sundt (1965) and Ruttle (1966) worked with high-concentrate diets, but the grain source was milo. There are two other factors that should be considered when evaluating these results. Lambs fed the higher concentrate diets consistently dressed higher than those fed high-roughage diets, which would reduce differences in gain and feed requirements on a carcass basis. Also, most of the diets were pelleted which has been shown to benefit high-roughage diets and have little effect with high-concentrate diets.
When corn grain is used as the principal source of concentrate, results appear to be more favorable for high-concentrate diets for finishing lambs. Drake and Fontenot (1966) found no significant difference in average daily gain of early weaned lambs that were finished on diets containing 90, 75 or 60% concentrates (mainly corn grain). Feed requirements increased as the level of roughage was increased and the value of roughage in terms of concentrate replacement value was low for the two higher levels of roughage. Dressing percent and carcass grade tended to be higher for the 90% concentrate diet and loin-eye area was significantly greater for the lambs fed this diet.

Pelleted diets containing from 64 to 100% concentrates were fed to early weaned lambs by Cooper et al. (1968). Corn grain and soybean meal were the principal concentrate sources while corn cobs and alfalfa meal made up the roughage portion of the diets. Differences in average daily gain were not significant among diets. Feed conversion was significantly improved with the high-concentrate diets compared to the higher roughage diets. Each unit of hay in a diet containing 12% hay replaced 0.43 unit of concentrate. Higher levels of hay had very small replacement values for concentrate.

The effect of roughage level on the composition of ovine fat has been reported to be similar to its effect on bovine fat. Miller et al. (1967) compared a chopped alfalfa hay diet to a high-concentrate diet consisting mainly of ground corn and soybean meal. The composition of serum lipid and depot fat closely followed the trends in
composition of fat in the diets fed to the lambs, indicating that the ruminal microorganisms did not play much of a role in altering the fatty acids entering the rumen in this experiment. In another trial, Miller and Rice (1967) fed diets with ground corn and alfalfa hay in ratios of 25:75 and 75:25. These diets were fed at fattening levels which produced slightly different results. Stearic acid (18:0) was significantly higher and oleic acid (18:1) slightly lower when high roughage was fed while other acids were affected only slightly by roughage level.

Ziegler et al. (1967) also studied the effect of roughage on the composition of ovine depot fat. One group of lambs had access to alfalfa hay ad libitum while a like group was fed an all-concentrate diet. The addition of roughage to the ration in this experiment, as well as the others cited with either cattle or sheep, resulted in a higher content of total saturated fatty acids in the depot triglycerides. Although significant differences have been produced between the fatty acid content of depot fat of ruminants fed high-roughage diets and those fed high-concentrate diets, the magnitude of these differences does not appear to be of practical significance at this time.

**Roughage Replacers**

The high cost of transporting bulky feeds, the advent of mechanized feeding systems and the supposition that ruminants do not perform satisfactorily without roughage in their diet have led to interest in roughage replacers. Polyethylene, sawdust, oyster shells,
wood shavings and clay have been investigated as possible roughage substitutes.

Most of the work involving the value of roughage replacers has been concerned with oyster shells. Several experiments reported have indicated that the addition of from 2 to 4% oyster shells to diets already containing small amounts of roughage is of little value for beef cattle (Woods et al., 1967; Goodrich et al., 1968; Karr and Hodge, 1968; Williams et al., 1968). However, Matsushima and co-workers (1968) reported a response in gain and feed efficiency with steers when 0.23 kg. oyster shells was added to a daily diet containing 1.36 kg. beet pulp and a full feed of concentrates.

Perry et al. (1968) fed 227 kg. calves to slaughter weight on either a diet composed of ground shelled corn and ground corn cobs in their approximate natural proportion in ear corn or a diet in which 2.5% crushed oyster shells substituted for ground corn cobs. The calves fed ground corn cobs gained significantly faster than those fed the diet with oyster shells. Total feed consumption was 13% less for the cattle fed oyster shells as a roughage. However, when the respective roughage portion of the diets was deducted, cattle fed ground corn cobs required 8.7% less corn and supplement per kilogram of gain than the cattle fed oyster shells. Carcasses from cattle fed corn cobs graded higher than those fed oyster shells. Consistent rumen damage was observed in those animals fed oyster shells which was characterized by gross hyperkeratosis and rumenitis. More liver condemnations were also noted in these cattle. Data presented by
Williams et al. (1968) also indicated no benefits were derived as a result of including oyster shells in either ground ear corn or ground shelled corn diets.

Average daily gains were significantly lower for yearling steers fed diets containing no roughage or 2.5% oyster shells than for steers fed 7.5% hay or 15% hay in a study reported by Goodrich et al. (1968). When compared to the all-concentrate diet, 2.5% oyster shells or 15% hay replaced very little corn and supplement. Each unit of hay in the 7.5% hay diet replaced 0.5 unit of corn and supplement. McElroy (1968) reported reduced gains when cattle were fed 0.23 kg. oyster shells per day as compared to 1.36 kg. hay daily. Grain and supplement requirements were higher when oyster shells were fed than when hay was fed. Budaly et al. (1967b) and Karr and Hodge (1968) also concluded from their work that oyster shells did not appear to be of any benefit as a substitute for roughage.

Rations containing 15% alfalfa hay were compared with diets containing 2.5% oyster shells or no roughage (Woods and LaToush, 1968). These studies showed a more favorable response than other workers have shown for oyster shells as a roughage replacer in terms of corn replacement. Average daily gain for steers fed oyster shell-containing diets was lower than for steers fed diets containing 15% roughage. Oyster shell-fed steers consumed less concentrate per day which could account for their slower gain. Feeding of oyster shells reduced feed requirements when compared to 15% roughage, with 6.6 kilograms of roughage being replaced per kilogram of oyster shells.
Compared to the all-concentrate diet, 15% roughage replaced 0.61 kg. of concentrates and 2.5% oyster shells replaced 3.9 kg. of concentrates per kilogram. Cattle fed an all-concentrate diet did not gain as rapidly as those fed oyster shells and required more feed per 100 kg. of gain. In another experiment (LaToush and Woods, 1968), concentrates or estimated net energy intake was equalized between treatments containing 15% roughage, 5% roughage or 2.5% oyster shells to that of an all-concentrate diet. When this was done, gains were not significantly different, indicating difference in net energy intake is often a major factor in results obtained from diets varying in type or levels of concentrate and roughage.

The effects of incorporating low levels of wood by-products into all-concentrate diets have been studied. Dinius et al. (1968) found that these materials added at a level of 10% of the diet had no effect on digestible energy intake by sheep as compared to all-concentrate or 10% corn cob diets. In a growth study (Anthony and Cunningham, 1968), improved rates of gain were observed when 2.5% hardwood sawdust was incorporated into an all-concentrate diet and fed to lambs and steers. A mixture containing 10% sawdust supported gains equal to gains of cattle fed the basal all-concentrate diet.

Small additions of blasting sand (2%) improved performance of completely mixed high-concentrate diets fed to yearling beef cattle during three feeding trials (Cooley and Burroughs, 1962). The improvement was consistent among trials but the degree of improvement
was small averaging about 5% as measured by liveweight gains and feed conversion per kilogram of gain.

Hughes et al. (1964) included 20% ground polyethylene (inert bulk) to an all-concentrate diet and improved consumption and caloric intake as well as rate of gain. When 13% polyethylene was added to a 74% concentrate diet, caloric intake was reduced, accompanied by a reduction in average daily gain. Conrad et al. (1967b) reported polyethylene pellets, when included as 10% of the diet, increased concentrate requirements and reduced daily gain in comparison to an all-concentrate diet.

Most of the products investigated as possible roughage replacers have, at best, promoted performance of ruminants only slightly superior to all-concentrate diets. In many of the experiments reported, no actual test has existed as to the value of roughage replacers in comparison to roughages. Level of roughage has been reduced and roughage replacers added, resulting in more of a test on levels of substitute for roughage. In experiments where roughage replacers have been used as a complete substitute for roughage, they have generally shown less favorable results than a corresponding level of natural roughage in the diet.
LEVEL OF ROUGHAGE AND OYSTER SHELLS IN HIGH
CONCENTRATE DIETS FOR BEEF CATTLE

Considerable interest has been shown in high-concentrate diets and in the use of roughage replacers such as oyster shells for beef cattle. These diets appeal to many cattle feeders because they produce high rates of gain with low feed requirements which offer many advantages in large feeding operations.

While all-concentrate diets or those with oyster shells have been fed with satisfactory results, some questions remain as to the need for roughage for finishing cattle and its relative value at different levels. These experiments were conducted to study the effects of the addition of small amounts of hay or oyster shells to an all-concentrate diet in terms of digestibility, rumen fermentation, growth and carcass characteristics and to determine their replacement value for grain and supplement with beef cattle.

Experimental

Composition of the diets fed in the feeding and digestion trials is shown in table 1. Treatments consisted of mixed diets which contained 0, 3, 10 or 20% alfalfa hay or 3% hen-size oyster shells. The hay was ground in a hammer mill through a 2.54 cm. screen. Dry, coarsely rolled shelled corn was used as the grain source and soybean meal provided the supplemental protein. All diets were calculated to contain 12% protein and 0.3% calcium, disregarding the calcium in oyster shells.
TABLE 1. PERCENTAGE COMPOSITION OF DIETSa

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>0 hay</th>
<th>3% hay</th>
<th>3% O.S.</th>
<th>10% hay</th>
<th>20% hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolled shelled corn</td>
<td>89.5</td>
<td>86.0</td>
<td>87.0</td>
<td>81.8</td>
<td>74.0</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>9.0</td>
<td>9.5</td>
<td>8.5</td>
<td>7.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Oyster shells</td>
<td>--</td>
<td>3.0</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>--</td>
<td>--</td>
<td>3.0</td>
<td>10.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Ground limestone</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Trace mineral salt</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Potassium chloride</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

a All diets contained 3,300 I.U. vitamin A, 660 I.U. vitamin D, 17.6 I.U. vitamin E and 8.8 mg. chlortetracycline per kg.

Feeding Trial. This trial involved 120 Hereford yearling steers initially averaging about 308 kg. They were fed in outside paved lots without bedding. At the outset of the experiment, the steers were implanted with 36 mg. of diethylstilbestrol. Each of the 5 dietary treatments was replicated 3 times, giving 15 pens with 8 steers each. All cattle were started on feed with a daily allowance of 4.5 kg. of the appropriate feed mix and 2.3 kg. of alfalfa hay. Hay was gradually reduced until eliminated after 10 days and the feed mix was increased to full feed over a period of 28 days.

The steers were marketed when each treatment group reached an average filled weight of about 523 kg., resulting in feeding periods of 139 to 152 days (July 12 to November 28 or December 11). At slaughter a sample of rumen contents was collected from each steer for
volatile fatty acid (VFA) and ammonia analyses. A 25 ml. sample of fluid was obtained by straining the sample of rumen contents through 8 layers of cheesecloth into a centrifuge tube containing 1 ml. of saturated mercuric chloride solution. The samples were stored in ice while being transported to the laboratory and were then centrifuged in a Sorvall RC-2 centrifuge at 9,750 x gravity for 30 minutes. Ten milliliters of supernatant were transferred to polyethylene storage bottles containing 2 ml. of meta-phosphoric acid (25% w/v) as described by Erwin et al. (1961) and frozen. For analysis, the samples were thawed, allowed to come to room temperature and centrifuged as before to remove precipitated protein. Total VFA was determined by steam distillation and the proportion of individual VFA's was determined by gas chromatography as described by Bushman et al. (1968). Procedures of Conway (1950) were used for ammonia analysis.

Livers were observed for abscesses and rumens were scored for condition of papillae, lining thickness, hair accumulation and color. Sections approximating 15 cm. in diameter were taken from the heavily papillated anterior dorsal area of the rumen from two randomly selected steers in each lot. The sections were preserved in a 10% formalin solution.

After the carcasses had been chilled for 24 hr., various carcass data were collected and a subcutaneous fat sample was taken from each carcass directly above the longissimus costarum muscle between the 12th and 13th ribs. A 2 gm. sample was extracted with chloroform-methanol by the procedure of Folch et al. (1957). An
aliquot was evaporated to dryness under nitrogen and esterified by the procedure of Morrison and Smith (1964). Fatty acid esters were determined by gas chromatography as outlined by Bushman et al. (1968).

Statistical analyses for comparison among treatment means for incidence of liver abscesses were made by the chi-square method (Cochran and Cox, 1966). Feed data were analyzed by analysis of variance and other performance and carcass data by least squares. A general factorial analysis of variance with appropriate transformations was used to analyze the VFA data. Comparisons between treatment means were made by Dunnet’s procedure (Steel and Torrie, 1960).

**Digestion Trial.** Ten Hereford steers averaging about 500 kg. were used in the digestion study. The cattle were kept indoors in individual pens without bedding. Prior to the experiment all steers were gradually adapted to the all-concentrate diet and brought to full feed over a period of 24 days. Two steers were then randomly assigned to each of the five dietary treatments. A period of 21 days was allowed to adjust the animals to the diets, which were fed twice daily in amounts so they would be nearly consumed by the next feeding. Following each collection period, the steers were randomly reallocated without regard to previous treatment. Two steers were fed each of the 5 diets over 4 collection periods, giving 8 replications per diet.

After each 21-day adjustment period, total fecal collections were made for 5 days using the collection bag technique. A 2% sample of the feces was taken at each collection and was frozen until the end of each 5-day collection period. At this time the accumulated samples
were thawed and subsamples were taken and refrozen until chemical analyses could be performed. A 250 gm. sample of the feed mixes was obtained at each feeding during the collection period after which the accumulated samples were dried in a forced-air oven at 88°C. The dried samples were ground in a Wiley mill and subsampled in preparation for chemical analyses. Chemical analyses of the dry feed and wet feces for the proximate nutrients were performed in accordance with A.O.A.C. (1960) methods.

The steers were maintained on the same diets for 2 additional days following each collection period. On each day a 25 ml. sample of rumen fluid was obtained from all steers 4 hr. after the morning feeding using a stomach tube-suction strainer apparatus described by Raun and Burroughs (1962). The pH of the rumen fluid was determined immediately using a Bechman H-2 pH meter. Other procedures for handling the samples and determining total and individual VFA content were as described for the feeding trial.

Upon completion of the final collection period, the steers were slaughtered and a 3.8 liter sample of rumen contents was taken from each steer. A 500 gm. subsample was washed through a fine sieve and oyster shells were sorted out for observation and weight determination. Similar procedures were employed for fecal samples obtained during the last collection period except a 250 gm. subsample was used. A 50 gm. sample of the dried rumen contents and feces from each steer was analyzed for calcium content.
Digestibility data were analyzed by analysis of variance and a comparison of treatment means was made by Dunnet's procedure (Steel and Torrie, 1960). VFA data were analyzed as in the feeding trial.

Results and Discussion

Feeding Trial. Data pertaining to feedlot performance, carcass characteristics and liver abscesses are presented in table 2. One steer fed 3% oyster shells and one fed 10% hay died during the experiment with overeating suspected as being the cause in both cases. Results are presented for cattle completing the experiment with an average feed consumption being deducted to adjust feed data.

There was apparently no advantage in daily gain when oyster shells were added to the all-concentrate diet. Total feed consumption and requirements per unit of gain were slightly greater for the 3% oyster shell diet. Concentrate consumption was slightly less, resulting in each unit of oyster shells replacing 0.5 unit of corn and protein supplement. Carcass characteristics and incidence of liver abscesses were not significantly affected by oyster shells. However, dressing percent was slightly lower for the steers fed oyster shells and they had a greater incidence of abscessed livers.

Other researchers (Woods et al., 1967; Goodrich et al., 1968; Karr and Hodge, 1968; Williams et al., 1968) showed no advantage in adding oyster shells to diets already containing roughage. On the other hand, Matsushima et al. (1968) reported an improvement in gain and feed efficiency when 0.23 kg. oyster shells was added to a diet containing 1.36 kg. beet pulp. However, oyster shells were inferior to
## TABLE 2. FEEDLOT PERFORMANCE, CARCASS CHARACTERISTICS AND LIVER ABSCESSSES OF BEEF CATTLE AS AFFECTED BY LEVEL OF HAY AND OYSTER SHELLS IN HIGH-CONCENTRATE DIETS

<table>
<thead>
<tr>
<th>Item</th>
<th>0% hay</th>
<th>3% hay O.S.</th>
<th>3% hay</th>
<th>10% hay</th>
<th>20% hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of steers</td>
<td>24</td>
<td>23</td>
<td>24</td>
<td>23</td>
<td>24</td>
</tr>
<tr>
<td>Days fed</td>
<td>152</td>
<td>152</td>
<td>139</td>
<td>139</td>
<td>139</td>
</tr>
<tr>
<td>Wt. data, kg.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial wt.</td>
<td>307</td>
<td>308</td>
<td>310</td>
<td>308</td>
<td>308</td>
</tr>
<tr>
<td>Final wt.</td>
<td>505</td>
<td>507</td>
<td>518</td>
<td>520</td>
<td>516</td>
</tr>
<tr>
<td>Av. daily gain</td>
<td>1.30</td>
<td>1.31</td>
<td>1.50*</td>
<td>1.52*</td>
<td>1.50*</td>
</tr>
<tr>
<td>Feed data, kg.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Av. daily ration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentrate</td>
<td>8.84</td>
<td>8.78</td>
<td>9.26</td>
<td>9.30</td>
<td>8.94</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>--</td>
<td>--</td>
<td>0.29</td>
<td>1.03</td>
<td>2.23</td>
</tr>
<tr>
<td>Oyster shells</td>
<td>--</td>
<td>0.27</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>8.84</td>
<td>9.05</td>
<td>9.55</td>
<td>10.33</td>
<td>11.17*</td>
</tr>
<tr>
<td>Feed/100 kg. gain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>607</td>
<td>593</td>
<td>554</td>
<td>555</td>
<td>553</td>
</tr>
<tr>
<td>Supplement</td>
<td>72</td>
<td>76</td>
<td>64</td>
<td>56</td>
<td>45</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>--</td>
<td>--</td>
<td>19</td>
<td>68</td>
<td>150</td>
</tr>
<tr>
<td>Oyster shells</td>
<td>--</td>
<td>21</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>679</td>
<td>690</td>
<td>637</td>
<td>679</td>
<td>748</td>
</tr>
<tr>
<td>Units grain and suppl. replaced per unit O.S. or hay</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dressing percent</td>
<td>61.1</td>
<td>60.0</td>
<td>59.8</td>
<td>60.6</td>
<td>60.4</td>
</tr>
<tr>
<td>Marblinga</td>
<td>5.9</td>
<td>5.8</td>
<td>5.2</td>
<td>5.6</td>
<td>5.3</td>
</tr>
<tr>
<td>Carcass gradeb</td>
<td>19.8</td>
<td>19.7</td>
<td>19.0</td>
<td>19.5</td>
<td>19.1</td>
</tr>
<tr>
<td>Fat covering, cm.</td>
<td>1.92</td>
<td>1.93</td>
<td>1.66</td>
<td>1.73</td>
<td>1.81</td>
</tr>
<tr>
<td>Abscessed livers</td>
<td>12</td>
<td>16</td>
<td>4*</td>
<td>2**</td>
<td>3**</td>
</tr>
</tbody>
</table>

a Modest, 6; Small, 5.
b Choice, 20; Choice -, 19.

* Significantly different (P < .05) from 0 hay.
** Significantly different (P < .01) from 0 hay.
beet pulp when each was included as the only source of roughage. Oyster shells have been shown to be inferior to corn cobs (Perry et al., 1968), alfalfa hay (Goodrich et al., 1968; McElroy, 1968) and cottonseed hulls (Karr and Hodge, 1968) as a source of roughage in high-concentrate diets. Eudaly et al. (1967b) and Goodrich et al. (1968) obtained a negative response in daily gain and no concentrate replacement value for oyster shells when added to an all-concentrate diet. In contrast, Woods and LaToush (1968) reported that oyster shells had a high replacement value for concentrate when included as 2.5% of an otherwise all-concentrate diet.

Average daily gain was improved (P<.05) by including hay in the diet with essentially no difference between levels of hay, amounting to about 15.4% faster gain than for the all-concentrate control. Each increase in level of hay resulted in an increase in feed consumption. Total feed intake was enough greater than for steers fed the all-concentrate diet to result in more concentrates being consumed by steers fed hay. This increase in feed consumption associated with higher levels of roughage has been a common observation in past research. However, these data would indicate a reduction in intake of concentrates at levels of hay above 10% of the diet in comparison to lower levels.

The grain required per unit of gain for the three levels of hay was essentially the same and lower than for the all-concentrate diet. Since all diets were calculated to contain the same percent protein, less protein supplement was used with increasing levels of hay. Hay
had the greatest replacement value when included at 3% of the diet with 1.0 unit replacing 3.2 units of corn and supplement in comparison to the all-concentrate diet. With 10% hay the ratio was 1:1, and with 20% it was 1:0.5. The addition of 3% hay to the diet was more beneficial than 3% oyster shells in terms of gain and feed requirements. Research by others also appears to support a need for some roughage in the diet for finishing beef cattle (Wise et al., 1963, 1965; Goodrich et al., 1968; Woods and Tolman, 1968). A level of 10% or less has been shown to have a high replacement value in terms of concentrates and to largely eliminate digestive problems frequently associated with feeding all-concentrate diets. Higher levels have resulted in somewhat lower replacement values for concentrates and reduced weight gains. However, Albin and Durham (1967) observed 5% alfalfa meal in the diet had no replacement value for milo and supplement.

Although steers fed all-concentrates had a slightly higher dressing percent, marbling score, carcass grade and fat covering than those fed hay, none of the differences were statistically significant. Numerous other workers have reported only small effects on carcass traits when varying levels of hay were fed and final weight was constant.

Twelve of the steers, or 50%, fed the all-concentrate diet had abscessed livers even though chlortetracycline was fed at 70 mg. daily. A high incidence of this condition is associated with high-concentrate diets and broad spectrum antibiotics have been shown to be effective
in reducing the problem (Jensen, 1960; Ellis et al., 1963; Ellis, 1965; Harvey et al., 1968). Incidence of this condition was greatly reduced ($P < 0.05$) when hay was included in the diet with little difference between levels of hay.

The rumen epithelium of steers fed hay appeared to be healthier than when all-concentrate or $3\%$ oyster shell diets were fed as suggested by the higher scores for papillae matting, lining thickness and hair accumulation for those fed all-concentrates or $3\%$ oyster shells (table 3). As level of hay increased from 3 to 20%, the condition of rumen epithelial tissue appeared to be improved. No definite trends in color were observed except that rumens of steers fed all-concentrates tended to be darker than those fed oyster shells or hay. The extensive clumping of the papillae and accumulation of hair in rumens of steers fed diets of all-concentrates or with $3\%$ oyster shells is illustrated in figure 1. Very little of either of these conditions was noted in the rumen sections taken from steers fed hay at the 10 or 20% levels while a moderate amount of papillae clumping and hair was evident in sections from steers fed $3\%$ hay diets. The conditions of rumens from steers fed all-concentrate or $3\%$ oyster shell diets were similar to those described by others when all-concentrate diets were fed to beef cattle (Oltjen and Davis, 1965; Haskins et al., 1967; Bushman et al., 1968).

Ruminal abnormalities and liver abscesses in cattle appeared to be highly associated in this study which is in agreement with Smith (1944) and Jensen et al. (1954). Several others (Beardsley et al.,
TABLE 3. CHARACTERISTICS OF RUMEN EPITHELIAL TISSUE

<table>
<thead>
<tr>
<th>Criterion</th>
<th>0 hay</th>
<th>3% O.S.</th>
<th>3% hay</th>
<th>10% hay</th>
<th>20% hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Papillae matting</td>
<td>3.00</td>
<td>3.04</td>
<td>2.58</td>
<td>1.87</td>
<td>1.67</td>
</tr>
<tr>
<td>Epithelium lining</td>
<td>2.87</td>
<td>2.70</td>
<td>2.67</td>
<td>2.00</td>
<td>1.50</td>
</tr>
<tr>
<td>Hair accumulation</td>
<td>2.17</td>
<td>2.17</td>
<td>1.42</td>
<td>1.04</td>
<td>1.00</td>
</tr>
<tr>
<td>Color</td>
<td>1.21</td>
<td>1.04</td>
<td>1.12</td>
<td>1.04</td>
<td>1.00</td>
</tr>
</tbody>
</table>

a No matting = 1, slightly matted = 2, moderately matted = 3, heavily matted = 4.
b Normal = 1, slightly thickened = 2, moderately thickened = 3, heavily thickened = 4.
c None = 1, slight = 2, moderate = 3, heavy = 4.
d Light = 1, medium = 2, dark = 3.

1959; Cullison, 1961; Ward, 1962; McGinty, 1963) have shown a high incidence of rumen parakeratosis and liver abscesses in ruminants fed high-energy diets. The possibility exists that some of the lower energy intake and gains by steers fed all-concentrate or 3% oyster shell diets could be attributed to the rumen parakeratosis-liver abscess condition. Bolsen et al. (1968) reported lower gains by heifers that had abscessed livers at time of slaughter when compared to heifers with clinically normal livers. Similar results have been reported by Wise et al. (1968) and Powell et al. (1968).

Fatty acid composition of subcutaneous fat is shown in table 4. The fat from steers fed diets with 3% oyster shells had slightly more palmitic acid (16:0) and significantly (P < .05) less oleic acid (18:1) than all-concentrate-fed steers, resulting in a slightly higher proportion of saturated fatty acids from steers fed oyster.
Figure 1. Sections approximately 15 cm. diameter taken from the anterior dorsal area of the rumen. Note the extensive hair accumulation and papillae matting when cattle received no hay in their diets.
TABLE 4. PERCENT FATTY ACID COMPOSITION OF SUBCUTANEOUS FAT

<table>
<thead>
<tr>
<th>Fatty acid</th>
<th>0% hay</th>
<th>3% hay</th>
<th>3% hay</th>
<th>10% hay</th>
<th>20% hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:0</td>
<td>4.1</td>
<td>4.5</td>
<td>4.1</td>
<td>3.9</td>
<td>3.4*</td>
</tr>
<tr>
<td>16:0</td>
<td>26.4</td>
<td>27.6</td>
<td>26.6</td>
<td>26.6</td>
<td>25.3*</td>
</tr>
<tr>
<td>16:1</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
<td>3.9</td>
<td>4.0</td>
</tr>
<tr>
<td>18:0</td>
<td>12.7</td>
<td>12.5</td>
<td>13.3</td>
<td>13.7</td>
<td>14.0*</td>
</tr>
<tr>
<td>18:1</td>
<td>44.6</td>
<td>43.5*</td>
<td>44.0</td>
<td>44.7</td>
<td>47.2**</td>
</tr>
<tr>
<td>18:2</td>
<td>3.3</td>
<td>2.9</td>
<td>2.8</td>
<td>2.1</td>
<td>1.9</td>
</tr>
<tr>
<td>Other a</td>
<td>5.1</td>
<td>5.2</td>
<td>5.4</td>
<td>5.1</td>
<td>4.2</td>
</tr>
<tr>
<td>Saturated acids</td>
<td>44.4</td>
<td>45.7</td>
<td>45.2</td>
<td>45.3</td>
<td>43.6</td>
</tr>
</tbody>
</table>

* Significantly different (P<.05) from 0 hay.
** Significantly different (P<.01) from 0 hay.
a Includes 14:1, 15:0, 16:2 and 17:0.

shells. Calcium content of the oyster shell and all-concentrate diets was about 1.50 and 0.3%, respectively. Bushman et al. (1968) observed an increase in the 16:0 fatty acid content and a tendency toward an increase in total saturated fatty acids when calcium level was increased from 0.3% to 0.6% in an all-concentrate diet. They also found a reduction in fat thickness by increasing the calcium content of the diet, but this was not observed in the present study.

The addition of 3 or 10% hay had no significant effect on the composition of the fat. The fat from steers fed diets with 20% hay contained significantly less myristic acid (14:0) and palmitic acid (16:0) and more stearic acid (18:0) and oleic acid (18:1) than
all-concentrate-fed steers. Level of hay had no consistent or significant effect on proportion of total saturated fatty acids. The differences in fatty acid content of subcutaneous fat produced by the treatments in this study are of small magnitude and of little practical significance. When wider concentrate to roughage ratios were studied by Cabezas et al. (1965) with cattle and Miller et al. (1967), Miller and Rice (1967) and Ziegler et al. (1967) with sheep, high-concentrate diets produced a larger portion of total unsaturated fatty acids than high-roughage diets.

Oyster shells did not appear to affect VFA or ammonia levels (table 5). Although increasing levels of hay appeared to reduce total VFA concentration, differences were not significant. As the level of hay was increased to 3%, the proportion of acetic acid was increased (P<.05) accompanied by a decrease (P<.01) in the proportion of propionic acid which caused the acetate to propionate ratio to become wider (P<.05). The addition of 10 or 20% hay to the diet resulted in even greater differences (P<.01) for these parameters when compared to all-concentrates. Dietary treatments had little effect on butyric and valeric acids and their isomers. Ammonia concentration appeared to be considerably higher in the rumen fluid of steers fed all-concentrates or 3% oyster shells than those fed hay. These differences were not statistically significant, however.

The small amount of coarse roughage provided by the 3% hay diet may explain the apparently healthier ruminal epithelium and reduction of liver abscesses; however, volatile fatty acids may also be involved.
**TABLE 5. Rumen Fermentation Data, Feeding Trial**

<table>
<thead>
<tr>
<th>Item</th>
<th>0 hay</th>
<th>3% O.S.</th>
<th>3% hay</th>
<th>10% hay</th>
<th>20% hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total VFA, uM/ml.</td>
<td>126.7</td>
<td>133.0</td>
<td>108.2</td>
<td>98.5</td>
<td>84.7</td>
</tr>
<tr>
<td>VFA, molar %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetic</td>
<td>34.5</td>
<td>35.2</td>
<td>38.0*</td>
<td>41.0**</td>
<td>47.6**</td>
</tr>
<tr>
<td>Propionic</td>
<td>48.3</td>
<td>45.0</td>
<td>40.5**</td>
<td>38.9**</td>
<td>31.8**</td>
</tr>
<tr>
<td>Butyric</td>
<td>11.5</td>
<td>14.1</td>
<td>13.6</td>
<td>11.8</td>
<td>13.9</td>
</tr>
<tr>
<td>Other a</td>
<td>5.7</td>
<td>5.7</td>
<td>7.9</td>
<td>8.3</td>
<td>6.7</td>
</tr>
<tr>
<td>A/P ratio</td>
<td>0.71</td>
<td>0.78</td>
<td>0.94*</td>
<td>1.05**</td>
<td>1.50**</td>
</tr>
<tr>
<td>Ammonia, mg. %</td>
<td>22.9</td>
<td>25.2</td>
<td>12.0</td>
<td>13.2</td>
<td>14.6</td>
</tr>
</tbody>
</table>

*Includes isobutyric, isovaleric and valeric acids.  
*Significantly different (P<.05) from 0 hay.  
**Significantly different (P<.01) from 0 hay.

Vidacs and Ward (1960) suggested that low acetate to propionate ratios, as was the case with the all-concentrate and 3% oyster shell diets, may be the causative agent for rumen paraphysetosis.

Diets which yield low ruminal acetate and high ruminal propionate have been shown to promote gains in body weight superior to diets yielding wider acetate to propionate ratios when digestible energy intake was equalized (Weiss et al., 1967; Hironaka and Bailey, 1968). The apparently more desirable acetate to propionate ratio for the all-concentrate and 3% oyster shell diets did not result in better gains in this study, however, because of the lower energy intake with these diets as compared to those with hay.
Digestion Trial. Dry matter intake, proximate composition of the diets and apparent digestion coefficients are presented in table 6. Although the diets were fed ad libitum, daily dry matter intake was about the same for all diets, except consumption of the 10% hay diet was somewhat lower. This was different from the feeding trial in which consumption increased with increasing levels of hay.

Digestibility appeared to be higher for all the proximate nutrients in diets with 3% oyster shells in comparison to all-concentrates and were significant (P<.10) for organic matter and protein. Although digestibility was higher with oyster shells, this was not reflected in improved gains in the feeding trial. The lower consumption of concentrates with the oyster shell diet in the feeding trial resulted in similar calculated TDN intake and gain for steers fed all-concentrate and 3% oyster shell diets.

Apparent digestibility of the proximate nutrients tended to be less for diets which contained hay than for all-concentrate diets; however, when diets contained 3 or 10% hay, differences were small and only significant (P<.10) for organic matter in the case of 3% hay and for protein in 10% hay diets. Somewhat lower digestion coefficients were obtained with 20% hay diets but only organic matter and protein were significantly lower (P<.01) than 0 hay. The general trend of these results is in agreement with other workers (Haynes et al., 1955; Kane et al., 1961; Brent et al., 1961; McGillick, 1964; Montgomery and Baumgardt, 1965). These researchers have reported improved digestibility as the concentrate portion of the diet increases. They studied
### TABLE 6. DIGESTIBILITY DATA

<table>
<thead>
<tr>
<th>Item</th>
<th>0% hay</th>
<th>3% o.s.</th>
<th>3% hay</th>
<th>10% hay</th>
<th>20% hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of steers</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Av. daily dry matter intake, gm.</td>
<td>6807</td>
<td>6728</td>
<td>6867</td>
<td>6466</td>
<td>6782</td>
</tr>
<tr>
<td>Proximate composition of diets, %&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude protein</td>
<td>14.2</td>
<td>13.6</td>
<td>14.3</td>
<td>14.0</td>
<td>14.2</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>3.1</td>
<td>2.8</td>
<td>3.4</td>
<td>5.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Ether extract</td>
<td>3.1</td>
<td>2.6</td>
<td>2.7</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Ash</td>
<td>3.6</td>
<td>6.8</td>
<td>3.8</td>
<td>3.6</td>
<td>4.6</td>
</tr>
<tr>
<td>N.F.E.</td>
<td>76.0</td>
<td>74.2</td>
<td>75.8</td>
<td>74.1</td>
<td>70.9</td>
</tr>
<tr>
<td>Apparent digestion coefficients</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter</td>
<td>81.8</td>
<td>83.7</td>
<td>78.9</td>
<td>80.2</td>
<td>74.3</td>
</tr>
<tr>
<td>Organic matter</td>
<td>82.6</td>
<td>86.7*</td>
<td>79.3*</td>
<td>81.1</td>
<td>75.2**</td>
</tr>
<tr>
<td>Crude protein</td>
<td>75.1</td>
<td>78.0*</td>
<td>73.0</td>
<td>72.5*</td>
<td>67.2**</td>
</tr>
<tr>
<td>Ether extract</td>
<td>76.7</td>
<td>79.5</td>
<td>74.0</td>
<td>77.1</td>
<td>72.1</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>84.1</td>
<td>88.5</td>
<td>80.7</td>
<td>82.7</td>
<td>76.8</td>
</tr>
</tbody>
</table>

<sup>a</sup> Dry matter basis.

* Significantly different (P<.10) from 0 hay.

** Significantly different (P<.01) from 0 hay.
much wider ranges in concentrate to roughage ratios and obtained correspondingly larger differences in digestibility of the diets.

The higher digestibility of the all-concentrate and 3% oyster shell diets was not enough to compensate for their lower intake in the feeding trial which explains the poorer gains with these diets than with those containing hay. Intake of the 20% hay diet was enough greater than the other diets with hay to compensate for its lower digestibility, resulting in similar TDN intake and gains for the three levels of hay.

Rumen fermentation data from the digestion trial are shown in table 7. Oyster shells had little effect on rumen fermentation. As the level of hay increased, pH of the rumen fluid tended to be slightly more alkaline. However, only small differences were observed in total VFA concentration between levels of hay. The molar percent of acetic and propionic acids was similar for steers fed the all-concentrate or 3% hay diets. When 10 or 20% hay was fed, acetic acid concentration increased (\( P < .01 \)) and propionic acid decreased (\( P < .05 \)), causing acetate to propionate ratios to be wider (\( P < .05 \)) than when the all-concentrate diet was fed, with the differences being greatest with 20% hay. No significant trends were observed in butyric and valeric acids and their isomers. These results were similar to those obtained in the feeding trial.

Several workers have shown that when wide ranges in the concentrate to roughage ratio have been studied, high-energy diets usually result in higher concentrations of total VFA (Balch et al., 1955;
### TABLE 7. RUMEN FERMENTATION DATA, DIGESTION TRIAL

<table>
<thead>
<tr>
<th>Item</th>
<th>0 hay</th>
<th>3% O.S.</th>
<th>3% hay</th>
<th>10% hay</th>
<th>20% hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ruminal pH</td>
<td>6.42</td>
<td>6.30</td>
<td>6.37</td>
<td>6.54</td>
<td>6.72</td>
</tr>
<tr>
<td>Total VFA, uM/ml.</td>
<td>79.4</td>
<td>86.0</td>
<td>80.9</td>
<td>78.1</td>
<td>72.0</td>
</tr>
<tr>
<td>VFA, molar %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetic</td>
<td>41.9</td>
<td>41.2</td>
<td>42.1</td>
<td>46.6**</td>
<td>50.6**</td>
</tr>
<tr>
<td>Propionic</td>
<td>41.9</td>
<td>45.0</td>
<td>45.2</td>
<td>36.0*</td>
<td>33.8*</td>
</tr>
<tr>
<td>Butyric</td>
<td>11.3</td>
<td>10.3</td>
<td>8.4</td>
<td>12.7</td>
<td>11.7</td>
</tr>
<tr>
<td>Other&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.9</td>
<td>3.5</td>
<td>4.3</td>
<td>4.7</td>
<td>3.9</td>
</tr>
<tr>
<td>A/P ratio</td>
<td>1.00</td>
<td>0.92</td>
<td>0.93</td>
<td>1.29*</td>
<td>1.50*</td>
</tr>
</tbody>
</table>

<sup>a</sup> Includes isobutyric, isovaleric and valeric acids.

* Significantly different (P < .05) from 0 hay.

** Significantly different (P < .01) from 0 hay.

Reid <sup>et al.</sup>, 1957; Brown <sup>et al.</sup>, 1958; Shaw <sup>et al.</sup>, 1960; Thompson <sup>et al.</sup>, 1965) and Balch and Rowland (1957) observed that pH varied inversely with the concentration of VFA's. Others have associated a reduction in the level of roughage in the diet with a narrow acetate to propionate ratio (<sup>Eusebio et al.</sup>, 1958; Bath and Rook, 1963; Templeton and Dyer, 1967; Weiss <sup>et al.</sup>, 1967). The present studies indicate the same trends in rumen fermentation; however, a much narrower range in concentrate to roughage ratio is involved so in some instances significant differences have not been obtained.

Apparent absorption of the calcium in oyster shells as compared to that in all-concentrate is shown in table 8. Calcium level in the all-concentrate diet was in excess of recommended requirements so the
TABLE 8. APPARENT ABSORPTION OF CALCIUM IN OYSTER SHELLS

<table>
<thead>
<tr>
<th>Item</th>
<th>All concentrate&lt;sup&gt;a&lt;/sup&gt;</th>
<th>3% oyster shells&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca content of diet, %&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.37</td>
<td>1.50</td>
</tr>
<tr>
<td>Ca intake, gm./day</td>
<td>32.0</td>
<td>117.7</td>
</tr>
<tr>
<td>Concentration of Ca in dried rumen contents, %</td>
<td>0.6</td>
<td>11.7</td>
</tr>
<tr>
<td>Apparent digestibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent</td>
<td>32.6</td>
<td>8.5</td>
</tr>
<tr>
<td>Gm./day</td>
<td>10.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

<sup>a</sup> Average of the 2 steers fed these rations during period 4.<br>
<sup>b</sup> 12% moisture basis.

study would not be suitable for determining percent utilization of calcium from oyster shells. Oyster shells tended to accumulate in the rumen as indicated by the high calcium concentration in rumen contents of steers fed oyster shells as compared to those fed all-concentrates. After an initial build-up of calcium in the rumen when oyster shells were fed, the calcium apparently began to disintegrate and pass through the digestive tract. This is suggested by the apparent absorption of calcium of 10 gm. per day regardless of the amount of calcium in the diet or in the rumen. Also, very few intact oyster shells were observed in the feces while considerable numbers were found in the rumen contents which would indicate degradation of the shells in the digestive tract.

**Summary**

Experiments were conducted to determine the effects of adding 3% oyster shells or 3, 10 or 20% alfalfa hay to an all-concentrate diet based on rolled shelled corn. Oyster shells had no large effect on
daily gain, rumen fermentation, carcass characteristics, condition of rumen epithelium or incidence of abscessed livers. Organic matter and protein digestibility were improved (P<.10) by oyster shells and feed requirements, along with feed consumption, were increased slightly. Each unit of oyster shells replaced 0.5 unit of corn and supplement.

The addition of alfalfa hay improved (P<.05) weight gains with essentially no difference in gain between levels of hay. There was a progressive increase in feed consumption with levels of hay, but only steers fed diets with 20% hay had higher total feed requirements than those fed all-concentrates. Hay had a high replacement value for corn and supplement at the 3% level (3.2:1) and decreased with 10% hay (1.0:1) and 20% hay (0.5:1). No statistical differences were found between treatments in the carcass traits studied. Addition of hay resulted in a healthier rumen epithelium accompanied by a reduction in abscessed livers. Total volatile fatty acid concentration was highest when all-concentrate was fed and decreased as increasing levels of hay were added. Hay increased the molar percent acetic and decreased propionic acid proportions in the rumen. In general, all-concentrate, 3% hay and 10% hay diets had similar digestion coefficients while 20% hay tended to reduce the digestibility of all nutrients. Although some differences were found between treatments in the individual fatty acids in subcutaneous fat, total saturation was not significantly affected.
Feeders have traditionally fed relatively high-roughage diets to lambs. Cox (1948) and Morrison (1956) stated that diets for lambs in the order of 50% concentrates resulted in optimum performance and less problems from enterotoxemia. High-concentrate diets have proven desirable in large cattle feeding operations because they produce high rates of gain with low feed requirements. Many lamb feeders could also benefit from feeding high-concentrate diets if results similar to those with cattle could be obtained with lambs. Hoar et al. (1968) have shown that all-concentrate diets can be fed to lambs with satisfactory results. Little research, however, has been reported on the relative value of all-concentrate diets and those with low levels of roughage or roughage replacers such as oyster shells. These experiments were conducted to study the effects on lambs when fed diets containing various levels of hay or oyster shells.

**Experimental**

**Experiment 1.** One hundred eighty wether lambs and an equal number of ewe lambs from western South Dakota were used for the experiment. Five dietary treatments were involved in this study, including an all-concentrate diet and diets which contained 3% oyster shells or 3, 10 or 20% alfalfa hay. Lambs of each sex were allotted into 3 weight groups, giving 6 pens with 12 lambs per pen for each of the 5 treatments. Average initial weights for the three weight groups
were 31.1, 35.2 and 38.5 kg. for the light, medium and heavy groups, respectively.

Composition and processing of the diets were the same as in the previously discussed cattle experiments (see table 1). All diets were calculated to contain 12% protein and 0.3% calcium, disregarding calcium in oyster shells, and each diet contained about 0.25% phosphorus. Rolled shelled corn was the grain source and soybean meal provided the supplemental protein. Hen-size oyster shells were used in the oyster shell diet while good quality second-cutting alfalfa ground in a hammer mill through a 2.54 cm. screen was used in diets containing hay.

Lambs in all treatment groups were started on feed with 227 gm. of the appropriate feed mix and 681 gm. of hay per head daily. The hay was gradually reduced until eliminated over a 10-day period and the experimental diets were increased by 90 gm. per head daily until full feed was reached. Thereafter, feed was fed in amounts to be available at all times. All lambs were drenched with thiabendazole, vaccinated for control of enterotoxemia and implanted with 3 mg. of diethylstilbestrol.

The lambs were marketed when each weight group reached an average weight of about 60 kg., resulting in feeding periods of 70 to 100 days (November 9 to January 20, February 3 or February 19). Kidneys and bladders were collected from all lambs at slaughter and examined for incidence of calculi deposits. Carcass data were obtained the day following slaughter.
Statistical analysis for comparisons among treatment means for incidence of urinary calculi was made by the chi-square method (Cochran and Cox, 1966). Feed data were analyzed by analysis of variance and other data by least squares. Comparisons of treatment means were made by Dunnet's procedure (Steel and Torrie, 1960). Results are presented for lambs completing the experiment with an average feed consumption being deducted to adjust feed data for lambs which died or were removed during the experiment.

**Experiment 2.** Three hundred twenty-four lambs initially averaging 31.8 kg. were used in this experiment. The lambs were divided into three equal groups which consisted of ewe lambs from Texas and ewe and wether lambs from western South Dakota. Replicated pens of the 3 groups were assigned to each of 6 dietary treatments on basis of weight, giving 6 pens of 9 lambs per pen for each treatment. Dietary treatments were the same as for experiment 1 except oyster shells were omitted and two higher levels of hay (40 and 60%) were added.

Source of the ingredients and preparation of the diets were as in experiment 1. All diets were formulated to contain at least 0.5% calcium in an attempt to reduce the problem from urinary calculi which was encountered in experiment 1 (table 9). Lambs in all treatments were started on feed with 454 gm. of the appropriate feed mix and 681 gm. of hay per head daily. The hay was gradually reduced until eliminated over an 8-day period and the experimental diets were increased by 90 gm. per head daily until full feed was reached. Other feeding and management procedures were similar to experiment 1.
TABLE 9. PERCENT COMPOSITION OF DIETS FOR LAMBS, EXPERIMENT 2

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>0% hay</th>
<th>3% hay</th>
<th>10% hay</th>
<th>20% hay</th>
<th>40% hay</th>
<th>60% hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolled shelled corn</td>
<td>88.6</td>
<td>86.3</td>
<td>80.6</td>
<td>72.9</td>
<td>56.9</td>
<td>39.1</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>9.2</td>
<td>8.6</td>
<td>7.5</td>
<td>5.5</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td></td>
<td>3.0</td>
<td>10.0</td>
<td>20.0</td>
<td>40.0</td>
<td>60.0</td>
</tr>
<tr>
<td>Ground limestone</td>
<td>1.3</td>
<td>1.2</td>
<td>1.0</td>
<td>0.7</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Trace mineral salt</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Potassium chloride</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

* All diets contained 2,200 I.U. vitamin A, 17.6 I.U. vitamin E and 22 mg. chlortetracycline per kg.

Because of severe weather conditions, all lambs were marketed after being on experiment for 102 days (October 3 to January 13), resulting in some variation between treatments in final weight. Samples of rumen fluid were taken at slaughter from three lambs in each lot and were processed and analyzed for total VFA concentration as in the cattle feeding trial. Other data collected at slaughter, statistical analyses performed and adjustments for death loss were the same as in experiment 1.

**Results**

**Experiment 1.** Data pertaining to feedlot performance, carcass characteristics and incidence of urinary calculi are presented in table 10. The experiment was initiated with 72 lambs in each dietary treatment group. Three lambs died from enterotoxemia in each of the 3% oyster shell, 10% hay and 20% hay treatments. Two losses occurred
TABLE 10. EFFECT OF OYSTER SHELL OR LEVEL OF HAY IN DIETS FOR LAMBS, EXPERIMENT 1

<table>
<thead>
<tr>
<th>Item</th>
<th>0% hay</th>
<th>3% O.S. hay</th>
<th>3% hay</th>
<th>10% hay</th>
<th>20% hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of lambs</td>
<td>69</td>
<td>69</td>
<td>61</td>
<td>63</td>
<td>66</td>
</tr>
<tr>
<td>Av. days fed</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>Initial wt., kg.</td>
<td>34.7</td>
<td>35.1</td>
<td>34.8</td>
<td>34.8</td>
<td>35.1</td>
</tr>
<tr>
<td>Final wt., kg.</td>
<td>59.6</td>
<td>60.4</td>
<td>60.0</td>
<td>59.6</td>
<td>59.1</td>
</tr>
<tr>
<td>Av. daily gain, kg.</td>
<td>0.295</td>
<td>0.305</td>
<td>0.300</td>
<td>0.295</td>
<td>0.286</td>
</tr>
<tr>
<td>Av. daily ration, kg.</td>
<td>1.39</td>
<td>1.43</td>
<td>1.43</td>
<td>1.50*</td>
<td>1.59**</td>
</tr>
<tr>
<td>Feed/kg. gain, kg.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>4.03</td>
<td>3.92</td>
<td>4.00</td>
<td>4.02</td>
<td>3.98</td>
</tr>
<tr>
<td>Supplement</td>
<td>0.47</td>
<td>0.50</td>
<td>0.46</td>
<td>0.40</td>
<td>0.32</td>
</tr>
<tr>
<td>Alfalfa hay a</td>
<td>0.17</td>
<td>0.17</td>
<td>0.31</td>
<td>0.66</td>
<td>1.26</td>
</tr>
<tr>
<td>Oyster shell</td>
<td>--</td>
<td>0.14</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>4.67</td>
<td>4.73</td>
<td>4.77</td>
<td>5.08*</td>
<td>5.56**</td>
</tr>
<tr>
<td>Dressing percent</td>
<td>48.5</td>
<td>48.5</td>
<td>49.2</td>
<td>48.4</td>
<td>49.3</td>
</tr>
<tr>
<td>Finish b</td>
<td>6.1</td>
<td>6.3</td>
<td>5.8</td>
<td>6.2</td>
<td>6.0</td>
</tr>
<tr>
<td>Carcass grade c</td>
<td>21.2</td>
<td>21.9</td>
<td>21.2</td>
<td>21.6</td>
<td>21.2</td>
</tr>
<tr>
<td>Urinary calculi incidence, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clinical d</td>
<td>1</td>
<td>0</td>
<td>11</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Total e</td>
<td>22</td>
<td>7*</td>
<td>43*</td>
<td>26</td>
<td>25</td>
</tr>
</tbody>
</table>

a 4.5 kg. hay per lamb fed in all treatment groups during first 10 days.
b Small, 5; modest, 6.
c Choice, 20; prime, 23.
d Death due to urine blockage.
e Includes losses due to urine blockage and animals having mineral deposits in kidneys and bladder at termination of the experiment.
* Significantly different (P<.05) from all-concentrate mean.
** Significantly different (P<.01) from all-concentrate mean.

from this cause in the all-concentrate group but none occurred in the group fed diets with 3% hay. The remaining death losses were diagnosed as resulting from urinary calculi.

The lambs gained exceptionally well on all diets with only small and nonsignificant differences between dietary treatments. Feed consumption was slightly higher when 3% oyster shells or 3% hay were included in the diets and was significantly higher when 10% (P<.05)
or 20% (P<.01) hay was fed. Total concentrates (corn and supplement) required per kg. of gain varied only slightly between treatment groups. Therefore, the hay fed at levels of 3, 10 or 20% resulted in relatively small savings of concentrates. Since rate of gain varied slightly with level of hay, total feed requirements increased with increasing levels of hay, being significant for 10% hay (P<.05) and 20% hay (P<.01). Oyster shells resulted in a slight saving of concentrates equal to 0.57 unit per unit of oyster shells.

Only small and nonsignificant differences were observed between treatments for any of the carcass traits studied. Incidence of urinary calculi was high in the all-concentrate group, amounting to 22% of the lambs. The incidence of this condition was less (P<.05) in the presence of 3% oyster shells and higher (P<.05) in lambs fed diets with 3% hay. In groups fed higher levels of hay, incidence of calculi was about the same as for those fed all-concentrates.

Data pertaining to weight groups and sex are presented in table II. When live weights were used as the basis for calculating average daily gain, lambs with heavier initial weights appeared to gain more rapidly during the experiment. Because of differences in dressing percent, gains were adjusted to an equal carcass yield. When this was done, medium and heavy lambs gained at essentially the same rate and not significantly greater than light lambs. There was a significant (P<.05) diet by weight interaction. The heavier group gained at a faster rate when fed the all-concentrate or 3% oyster shell diets while light lambs gained at lower rates on these diets in comparison
TABLE 11. EFFECT OF INITIAL WEIGHT AND SEX ON FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS OF LAMBS FED HIGH-CONCENTRATE DIETS, EXPERIMENT 1

<table>
<thead>
<tr>
<th>Item</th>
<th>Light</th>
<th>Medium</th>
<th>Heavy</th>
<th>Ewes</th>
<th>Wethers</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of lambs</td>
<td>114</td>
<td>115</td>
<td>113</td>
<td>169</td>
<td>159</td>
</tr>
<tr>
<td>Av. days fed</td>
<td>100</td>
<td>84</td>
<td>70</td>
<td>82</td>
<td>87</td>
</tr>
<tr>
<td>Initial wt., kg.</td>
<td>31.1</td>
<td>35.2</td>
<td>38.5</td>
<td>33.5</td>
<td>36.3</td>
</tr>
<tr>
<td>Final wt., kg.</td>
<td>59.3</td>
<td>59.6</td>
<td>60.4</td>
<td>56.6</td>
<td>62.9</td>
</tr>
<tr>
<td>Av. daily gain, kg.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed live</td>
<td>0.282c</td>
<td>0.291c</td>
<td>0.314d</td>
<td>0.286**</td>
<td>0.309</td>
</tr>
<tr>
<td>Adjusted</td>
<td>0.282</td>
<td>0.291</td>
<td>0.290</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Av. daily ration, kg.</td>
<td>1.45</td>
<td>1.45</td>
<td>1.50</td>
<td>1.42*</td>
<td>1.51</td>
</tr>
<tr>
<td>Feed/kg. gain, kg.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed live</td>
<td>5.14a</td>
<td>4.98a,b</td>
<td>4.78b</td>
<td>5.01</td>
<td>4.92</td>
</tr>
<tr>
<td>Adjusted</td>
<td>5.14</td>
<td>4.98</td>
<td>5.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dressing percent</td>
<td>49.3</td>
<td>49.2</td>
<td>47.9</td>
<td>48.8</td>
<td>48.7</td>
</tr>
<tr>
<td>Carcass grade</td>
<td>20.9</td>
<td>21.8</td>
<td>21.5</td>
<td>21.3</td>
<td>21.5</td>
</tr>
</tbody>
</table>

a, b Means with different superscripts are significantly different (P < .05).
c, d Means with different superscripts are significantly different (P < .01).
e Gain adjusted to 49.2% carcass yield.
f Choice, 20; prime, 23.
* Difference between ewes and wethers significant (P < .05).
** Difference between ewes and wethers significant (P < .01).
to the diets containing hay. There were only slight differences in average daily feed consumption between weight groups and when gains were adjusted to an equal dressing percent feed requirements were not significantly different. The heavy group had the lowest dressing percent but graded as high as the lighter lambs.

Wether lambs averaged 2.8 kg. more than ewe lambs initially and gained at an 8% faster rate (\(P < .01\)). There was also a significant \((P < .05)\) diet by sex interaction, with wethers gaining best on the all-concentrate diet while ewes did not perform as well on this diet as on those containing oyster shells or hay. Wethers consumed more \((P < .05)\) feed than ewes, resulting in small differences in feed conversion between ewes and wethers. Dressing percent and carcass grade were about the same for the two sexes.

**Experiment 2.** There were initially 54 lambs in all treatment groups in experiment 2 (table 12). Some losses occurred in each treatment, all of them being diagnosed as resulting from enterotoxemia with level of hay having no significant effect on the incidence of this disease. Lambs fed the all-concentrate diet had the highest average daily gain. Weight gains were reduced slightly by including hay at 3, 10 or 20% of the diet but with only small differences between levels of hay. However, differences between the 10 and 20% level and the all-concentrate diet were significant \((P < .05)\). Weight gains were further reduced by increasing the level of hay to 40% and 60% of the diet \((P < .01)\). This effect appeared progressively greater as the hay level was increased from 0 to 20 to 40 to 60% of the diet.
TABLE 12. EFFECT OF LEVEL OF HAY IN DIETS FOR LAMBS, EXPERIMENT 2 (102 DAYS)

<table>
<thead>
<tr>
<th>Item</th>
<th>0% hay</th>
<th>3% hay</th>
<th>10% hay</th>
<th>20% hay</th>
<th>40% hay</th>
<th>60% hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of lambs</td>
<td>49</td>
<td>53</td>
<td>49</td>
<td>51</td>
<td>51</td>
<td>50</td>
</tr>
<tr>
<td>Initial wt., kg.</td>
<td>31.6</td>
<td>31.5</td>
<td>31.6</td>
<td>31.5</td>
<td>31.5</td>
<td>31.5</td>
</tr>
<tr>
<td>Final wt., kg.</td>
<td>58.3</td>
<td>56.6</td>
<td>56.2</td>
<td>56.4</td>
<td>48.2</td>
<td>45.5</td>
</tr>
<tr>
<td>Av. daily gain, kg.</td>
<td>0.262</td>
<td>0.246</td>
<td>0.241*</td>
<td>0.244*</td>
<td>0.164**</td>
<td>0.137**</td>
</tr>
<tr>
<td>Av. daily ration, kg.</td>
<td>1.44</td>
<td>1.42</td>
<td>1.46</td>
<td>1.57**</td>
<td>1.51*</td>
<td>1.55**</td>
</tr>
<tr>
<td>Feed/kg. gain, kg.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>4.81</td>
<td>4.89</td>
<td>4.81</td>
<td>4.64</td>
<td>5.10</td>
<td>4.43</td>
</tr>
<tr>
<td>Supplement</td>
<td>0.62</td>
<td>0.61</td>
<td>0.57</td>
<td>0.46</td>
<td>0.29</td>
<td>0.11</td>
</tr>
<tr>
<td>Alfalfa hay a</td>
<td>0.11</td>
<td>0.29</td>
<td>0.71</td>
<td>1.40</td>
<td>3.76</td>
<td>7.02</td>
</tr>
<tr>
<td>Total</td>
<td>5.54</td>
<td>5.79</td>
<td>6.09</td>
<td>6.50**</td>
<td>9.15**</td>
<td>11.56**</td>
</tr>
<tr>
<td>Dressing percent</td>
<td>50.5</td>
<td>51.2</td>
<td>50.5</td>
<td>49.9</td>
<td>50.4</td>
<td>49.1*</td>
</tr>
<tr>
<td>Finish b</td>
<td>5.7</td>
<td>5.9</td>
<td>5.9</td>
<td>5.2</td>
<td>4.7**</td>
<td>4.4**</td>
</tr>
<tr>
<td>Carcass grade c</td>
<td>20.5</td>
<td>20.8</td>
<td>20.9</td>
<td>20.7</td>
<td>19.8**</td>
<td>19.3**</td>
</tr>
<tr>
<td>Urinary calculi incidence, % d</td>
<td>12.2</td>
<td>13.2</td>
<td>18.4</td>
<td>13.7</td>
<td>5.9</td>
<td>16.0</td>
</tr>
<tr>
<td>Ruminal volatile fatty acids</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total VFA, uM/ml.</td>
<td>64.5(18)e</td>
<td>82.1(18)</td>
<td>71.3(14)</td>
<td>68.7(16)</td>
<td>70.9(17)</td>
<td>71.7(15)</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>31.2</td>
<td>27.5</td>
<td>25.1</td>
<td>17.4</td>
<td>18.2</td>
<td>27.4</td>
</tr>
</tbody>
</table>

a 3.0 kg. hay per lamb fed in all treatment groups during first 8 days.

b Slight, 4; Small, 5; Modest, 6.

c Choice, 20; prime, 23.

d Percent of animals yielding calculi after 102 days on treatment.

e Number in parenthesis designates number of samples analyzed.

* Significantly different from 0 hay (P<.05).

** Significantly different from 0 hay (P<.01).
Feed consumption was essentially the same for diets with 0, 3 or 10% hay but increased with the higher levels. Total feed requirements increased with increasing levels of hay in the diets being significant (P < .01) for levels of 20% and above. Levels of hay up to 40% of the diet appeared to have only a slight effect on concentrates (corn and supplement) required per unit of gain. With hay at 60% of the diet, there was a reduction in concentrate requirements. However, the higher hay requirement resulted in a low concentrate replacement value even for this level of hay.

Dressing percentages were not significantly different except lambs fed 60% hay dressed lower (P < .05) than lambs fed the all-concentrate diet. Degree of finish and carcass grade were not significantly different between lambs fed 0 to 20% hay diets but were lower (P < .01) for those fed 40 or 60% hay. These carcass differences were probably a reflection of slaughter weight rather than treatment as such. No clinical cases of urinary calculi were observed in this experiment and incidence of calculi deposits at slaughter was low in all treatments. VFA concentration in the rumen fluid did not appear to be influenced largely by dietary treatment.

**Discussion**

Death losses from enterotoxemia amounted to 3.0 and 6.5% in experiments 1 and 2, respectively. The incidence of this disease was not associated with level of roughage in the diet in either experiment. Although all lambs were vaccinated against enterotoxemia and fed chlortetracycline, it is possible that immunity had not developed
sufficiently and that antibiotic intake had not reached high enough levels the first few days of the experiment when most of the losses occurred. Ruttle (1966) reported difficulty in keeping lambs fed all-concentrate diets from going off-feed, but no problems of that nature were encountered in these studies. It would appear from the results of these two experiments that lambs can be fed diets with low levels or even no added roughage with no more problems from enterotoxemia than when fed diets having more conventional levels (40 to 60%) of roughage.

While oyster shells did not appear to affect weight gains, there was a slight saving of concentrates equal to 0.57 unit per unit of oyster shells when included as 3% of the diet. This agrees closely with the results of the feeding trial with cattle as to the effects on weight gain and concentrate replacement value. It would appear that oyster shells offer little if any benefit as an addition to all-concentrate diets for lambs.

Lambs fed the all-concentrate diet gained at least as well as those fed diets with hay. Levels of hay up to 20% had only a slight effect on rate of gain in comparison to all-concentrate diets. However, there was a pronounced reduction in gain with higher levels of hay. These results are in contrast to earlier research and commonly recommended levels of roughage in diets for growing and finishing lambs. Drake and Fontenot (1966) found no differences in average daily gain of early-weaned lambs fed diets containing from 10 to 40% roughage. Cooper et al. (1968) also reported equal gains for lambs
when 0, 12, 24 or 36% roughage was included in their diets. However, diets in both of these studies were pelleted. Hartman et al. (1959) and McClure et al. (1960) showed that pelleting high-roughage diets improved consumption and gain but had little effect on low-roughage diets. Ruttle and Sundt (1965) and Ruttle (1966) reported reduced gains when lambs were fed all-concentrate or 10% alfalfa hay diets as compared to diets containing 40 or 70% hay, but again these diets were pelleted and the grain source was milo.

Lambs with heavier initial weights appeared to respond to the all-concentrate diet better than lighter lambs in experiment 1. On the other hand, the lighter lambs gained faster than the heavy lambs when the diets containing hay were fed. Wether lambs also gained best on the all-concentrate diet while the lighter ewes did not perform as well on this diet as on those containing hay. These results would be in agreement with cattle research involving steers and heifers and cattle of different sizes. Large animals lacking in finish or those maturing at heavier weights appear to be benefited more by high-energy diets. Weight groups were not involved in experiment 2 and a diet by sex group interaction was not evident.

There was little effect on concentrate requirements per unit of gain with up to 20% hay in the diet in experiment 1. Therefore, the hay had low replacement value for concentrates. In experiment 2, gains were lower and feed requirements higher, but results were in general agreement with experiment 1 as to the effect of roughage level on feed consumption and feed requirements with levels of hay up to 20% of the
diet. This is also in agreement with Drake and Fontenot (1966) and Cooper et al. (1968) who reported little replacement value of roughage for concentrates in high-concentrate diets for lambs. At the two higher levels of hay fed in experiment 2 where gains were substantially reduced, feed requirements were markedly higher. Only with the 60% hay diet were concentrate requirements per unit of gain reduced to any extent, but the much higher hay requirements with this diet resulted in a low replacement value of hay for concentrates.

Rate of gain was higher and feed requirements lower with the all-concentrate diet and with the diets with low levels of roughage in comparison to values reported in older work. With more conventional levels of roughage as in the diets with 40 or 60% hay, gains and feed requirements were more similar to values reported in much of the older research. It is commonly considered that diets for finishing lambs should contain more roughage than diets for finishing cattle. However, results of these lamb experiments indicate a lower concentrate replacement value for roughage in diets for lambs than for cattle.

Level of roughage up to 20% had little effect on carcass characteristics. Apparently there was little difference in amount of carcass fat with roughage levels up to 20% as measured by finish score and carcass grade. Lambs fed higher levels of roughage had lower scores for finish and grade, but they were slaughtered at lighter weights. Montgomery and Baumgardt (1965) observed no differences in carcass traits of lambs fed diets containing 40 to 100% alfalfa hay when all lambs were slaughtered at similar weights.
In experiment 1, diets were calculated to contain 0.3% calcium, excluding calcium in oyster shells. Incidence of urinary calculi was high in all treatments except in the one containing 3% oyster shells, indicating the elevated calcium level in this diet was effective in reducing calculi formation. Calcium levels were increased to 0.5% in experiment 2 and no death losses were attributed to this condition. The calculi found in kidneys of these lambs at slaughter were primarily silicious in nature and were considered to have been formed prior to the start of the experiment. Other work has shown that incidence of silicious calculi in these lambs has been as high as 25%. Lambs fed 3% hay in experiment 1 had a higher (P<.05) incidence of calculi than those fed 0, 10 or 20% hay. This apparent difference between various levels of hay in diets of equal calcium content needs further investigation. However, it appeared that 0.5% calcium in the diet effectively controlled phosphatic urinary calculi under all dietary treatments in this experiment with phosphorus levels of about 0.25%.

Ruminal VFA concentrations differed somewhat from those of the cattle trial. Little or no change in VFA's above the 3% roughage level was observed with lambs. Increasing the level of roughage has usually been associated with lower concentrations of VFA's, but in some instances there have either been no changes or higher concentrations with increasing roughage levels. Average VFA concentrations were generally higher in this study with the diets containing hay as compared to the no-hay diet. Average VFA levels were about 21% higher for the 3% hay diet than for the no-hay diet. Although the variations between
lambs fed these diets were about the same, the standard deviations indicated considerable variation within all treatments. The reasons for this are not apparent but may be attributed to differences in eating habits prior to slaughter. However, feed was removed from all lambs 15 hr. before slaughter and rumen contents were collected over a 2-hr. period.

**Summary**

Two feeding trials involving 684 lambs were conducted to study the effects of adding 3% oyster shells or 3, 10, 20, 40 or 60% alfalfa hay to an all-concentrate diet based on rolled shelled corn. Death losses from enterotoxemia were not related to level of hay. Weight gains were similar in experiment 1 for lambs fed diets with 0 to 20% hay. In experiment 2, gains decreased slightly with increasing levels of hay up to 20% and were markedly reduced with 40 and 60% hay. Feed requirements increased with increasing levels of hay while concentrate requirements remained relatively constant, resulting in a low value for alfalfa hay in terms of concentrate replacement value. Carcass characteristics were not affected by level of hay up to 20% of the diet. However, finish and grade were lower for lambs fed 40 to 60% hay and with lighter slaughter weights.

Oyster shells offered little improvement over the all-concentrate diet in terms of gain and carcass characteristics. They did reduce concentrate requirements somewhat, resulting in a replacement value of 0.57 unit of concentrate per unit of oyster shells.
Incidence of urinary calculi was high for lambs fed diets with 0, 10 or 20% hay in experiment 1 when these diets were calculated to contain 0.3% calcium. Higher calcium levels provided by oyster shells reduced calculi formation while the presence of 3% hay increased its incidence, although calcium content of this diet was the same as the all-concentrate diet. Calcium was increased to 0.5% of all diets in experiment 2 which effectively controlled formation of calculi with all levels of hay.

Concentration of total volatile fatty acids in rumen fluid was not largely affected by level of roughage in these studies with lambs.
SUMMARY AND CONCLUSIONS

Experiments were conducted with yearling beef cattle and feeder lambs to determine the effects of adding 3% oyster shells or various levels of hay to an all-concentrate diet of rolled shelled corn grain adequately supplemented with protein, minerals and vitamins A and E. Criteria used for evaluating diets with varying amounts of roughage included feedlot performance, carcass characteristics, rumen fermentation, digestibility and concentrate replacement value of the roughage.

Cattle fed the all-concentrate diet gained 1.30 kg. daily and required 6.79 kg. of feed per kg. gain. When 3% oyster shells were included in the diet, there was essentially no change in the rate of gain while total feed consumption was slightly higher. Cattle consumed less grain and supplement with this diet resulting in a concentrate replacement value for oyster shells of 0.50 unit per unit of oyster shells. Lambs fed the all-concentrate diet gained 0.295 and 0.262 kg. daily in experiments 1 and 2, respectively. Corresponding values for feed to gain ratio were 4.67 and 5.54. As with the cattle, the oyster shells did not influence gain but increased feed consumption slightly. Concentrate consumption was lower when 3% oyster shells were fed, resulting in a replacement value for oyster shells of 0.57 unit per unit of oyster shells which was similar to the cattle trial.

Inclusion of alfalfa hay at 3, 10 or 20% of the diet resulted in a 15.4% improvement in gain with essentially no difference between levels of hay. Total feed consumption increased with increasing levels of hay and concentrate consumption was slightly higher in diets with hay
in comparison to the no-roughage diets. Concentrates required per unit of gain were about the same for the three levels of hay and lower than for the all-concentrate diet. Replacement values per unit of hay amounted to 3.2, 1.0 and 0.5 units of concentrates in the 3, 10 and 20% hay diets, respectively. Lambs fed these levels of hay gained about the same as when fed the all-concentrate diet in experiment 1 and slightly lower in experiment 2. There was a trend toward increased feed consumption with increasing levels of hay, but concentrate consumption was slightly lower. Concentrate requirements were relatively constant for all levels of hay up to 20% of the diet, resulting in little replacement value of hay for concentrates. When hay was included at 40 or 60% for lambs, rate of gain was markedly reduced and feed requirements increased. Only at the 60% level did there appear to be an appreciable reduction in concentrates required per unit of gain. However, the increase in hay required relative to concentrates saved resulted in a low concentrate replacement value for hay even at this higher level.

Oyster shells in the diet had no apparent effect on carcass traits for either cattle or lambs. Levels of the hay up to 20% of the diet resulted in only small and nonsignificant effects on the carcass characteristics studied. Carcasses of cattle and lambs fed all-concentrate diets appeared to contain no more fat, as indicated by marbling or finish scores and carcass grades, than animals fed diets with as much as 20% hay. Lambs fed 40 or 60% hay had lower carcass values, but they were slaughtered at lighter weights.
Volatile fatty acid concentrations in the rumen fluid were not affected by including oyster shells in the diet. There was a tendency for concentration of total VFA in the rumen fluid of cattle to be lower as the level of hay was increased from 0 to 20% of the diet. Acetate to propionate ratios became wider with increasing amounts of hay in the diets. Although variations between rumen samples taken from lambs were high, average VFA concentrations were generally higher with the diets containing hay as compared to the all-concentrate diet. Relationships between the VFA data and feedlot performance for either cattle or lambs were not evident.

The diet with 3% oyster shells was of slightly higher digestibility than the all-concentrate diet. Hay at 3 or 10% of the diet had only small effects on digestibility of the diet, but digestibility was some lower with 20% hay.

The results of these experiments show that small amounts of alfalfa hay are beneficial in high-concentrate diets for beef cattle in terms of gain and concentrate replacement. Contrary to commonly recommended feeding systems for lambs, roughage resulted in little savings of concentrates at levels up to 40%. Even at levels up to 60%, replacement value of hay for concentrates was low.

The lower replacement value of hay for concentrates with increasing levels of hay in diets for cattle would indicate low values for hay at levels higher than 10 to 15% of the diet. However, diets with limited amounts of concentrates have been fed with satisfactory and economical production. These results would tend to support diets
either of high-concentrate or of high-roughage with limited concentrates rather than intermediate levels for most efficient utilization of concentrates and roughages.


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