NUTRITIVE VALUE OF DRIED BEANS FOR GROWING AND FATTENING LAMBS

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NUTRITIVE VALUE OF DRIED BEANS FOR GROWING AND FATTENING LAMBS

By

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INTRODUCTION

The ability of the farmer to feed efficiently influenced net returns in fattening lambs more than any other factor according to a Michigan Farm Management study by Wright (1937). A thorough knowledge of the relative nutritive and dollar value of various concentrates and roughages enables the feeder to select the most efficient and economical ration for a given set of conditions.

During the development of the lamb feeding industry in the United States, many by-products and waste feeds were utilized in an effort to lower feed costs. Many lamb feeding enterprises were started in the Northwest near flour mills when wheat screenings and other by-products of the milling industry were found to be useful feeds for lambs.

Dry beans which include kidney, navy, pinto, Great Northern and similar beans are raised primarily for human food. During the processing and packaging of dry beans, discolored, shrunken, split and broken beans are sorted out. These waste products called "cull beans" are used as a livestock feed.

According to the Bureau of Agricultural Economics (1952) the United States produced 838,850 tons of dry beans in 1952. The clean yield of this crop was 779,700 tons. A large part of the 59,150 tons sorted out during the processing for human food was

cull beans available for livestock feeding.

The five leading states in 1952 dry bean production were California, 215,750 tons; Michigan, 195,500 tons; Idaho, 112,100 tons; Colorado, 108,500 tons; and New York with 82,500 tons. The production in Michigan and New York is of special interest because the studies being reported were carried out at the Cornell Agricultural Experiment Station by the writer while enrolled in the graduate school at Michigan State College. Michigan produced 176,150 tons or 94 per cent of the total clean navy bean crop in the United States. New York produced 57,550 tons or 82 per cent of the clean red kidney crop. The total 195,500 tons of beans produced in Michigan during 1952 had a clean yield of 187,700 tons. New York State produced 82,500 tons with a clean yield of 77,400 tons. The difference of 12,900 tons between the total yield and the clean yield of the combined Michigan and New York crops indicates that over ten thousand tons of cull beans are available annually in these two states. The average production figures for the 1941-1950 period are similar to 1952. The amount of beans available for livestock may be increased considerably during a wet harvesting season.

Morrison (1948) reports the following percentage values for raw red kidney beans with reference to total composition, digestible protein and total digestible nutrients: dry matter 89.0, protein 23.0, fat 1.2, crude fiber 4.1, mineral matter 3.9, nitrogen-free extract 56.8, digestible protein 20.2 and total digestible nutrients 77.8. The percentages of the various nutrients especially protein

are equal to or higher than many concentrates frequently fed. The feeding value, however, appears to be much lower. Feeding trials have shown that raw dry beans may be unpalatable and cause scours. Due to these and other limitations, cull beans have not been a popular feed for livestock.

The rise in prices of concentrates after World War II created renewed interest in greater utilization of low cost waste products for feeding livestock. At the Cornell University Agricultural Experiment Station raw red kidney beans were substituted for part of the corn in lamb fattening rations. During the course of these studies, which were initiated in 1946, (Willman 1953) found that the addition of small amounts of linseed oil meal to the ration and the cooking of the beans before feeding were beneficial and worthy of further study.

The study now being reported was carried out to learn more about the feeding value of cull red kidney beans for lambs and how this value may be improved. Digestion trials, feed lot trials, nitrogen utilization studies and amino acid composition analyses were used.

REVIEW OF LITERATURE

Cull Dry Beans for Feeding Sheep

Wilson and Lantow (1926) fed pinto beans to fattening lambs. They demonstrated that raw pinto beans were about 85 per cent as efficient as corn in a single trial with two lots of ten lambs each averaging approximately 85 pounds.

Working with lighter lambs, Maynard, Morton, and Osland (1931) found pinto beans to be worth only 44 per cent the value of corn. Fairly satisfactory gains were made, but the bean fed lambs were not fat enough at the end of the regular 120 day feeding period and had to be fed an additional 30 days in order to satisfy market demands.

Dry bean screenings consisting of split, shrunken, and small beans were fed by Miller (1927) to shorn grade Shropshire lambs averaging approximately 55 pounds. Three lots of 49 lambs each were fed to compare barley with bean screenings. The roughage for all lots was alfalfa hay. At the close of the first month of the trial, the lambs were getting a daily average of 1.2 pounds of concentrates and 1.75 pounds of alfalfa hay. Scouring was noticed in the bean lot, particularly at the beginning of the trial. After being on experiment 20 days, the lot on bean screenings alone refused part of their feed and scoured severely. The ration was reduced, and in a few days the lambs were back on feed. After 48 days

the cull bean lot again went off feed. The concentrate was reduced to 1.25 pounds daily until the lambs regained their appetite. In spite of some severe cases of scours, there were no noticeable after effects. The results of this feed lot trial indicated that beans were about equal to whole barley in feeding value, but slightly laxative.

Two years of work by Johnson, Rinehart, and Hickman (1931) did not fully support the above mentioned work of Miller (1927). They compared a mixture of 80 per cent barley and 20 per cent cull Great Northern beans with barley alone as a concentrate to be fed with alfalfa hay. The lambs receiving the beans made four per cent less average daily gain and the gain was more expensive. The authors concluded that cull beans of the Great Northern variety may be utilized where they are on hand and do not have market value. They found them objectionable to feed because they were not palatable and often caused such digestive disturbances as scouring and bloating.

The same workers, Rinehart, Hickman, and Johnson (1932) gave further support to their statements when they reported average data of six trials carried out at the University of Idaho Agricultural Experiment Station from 1926 to 1932. Under the conditions of their trials more hay was needed by the lambs when beans were substituted for 20 per cent of the barley. Since scouring and digestive troubles increased when the lambs were fed a concentrate mixture containing 30, 40, or 50 per cent beans, they concluded that beans should be

limited to no more than 20 per cent.

In other work with Great Northern beans, Quale (1932) found a better feeding value than Rinehart, Hickman and Johnson (1932). Quale compared beans to equal parts beans and barley and found 100 pounds of barley had a replacement value of 113 pounds of beans and 35 pounds of alfalfa hay. Even though the cull beans tended to scour the lambs severely at times, the lambs never refused to eat them. Cull beans were also compared with cottonseed cake when added to an alfalfa and barley ration. An average daily feed of 0.28 of a pound of cull beans added to a barley and alfalfa ration increased the daily gain very little. Their feeding value was about equal to the barley. Cottonseed cake added at the rate of 0.22 of a pound per lamb daily increased the rate of gain more than the beans. The lambs fed beans alone with alfalfa gained 0.25 of a pound and those fed barley, cottonseed, and alfalfa 0.30 of a pound daily.

Unpublished Work on Feeding Cull Beans to Lambs at Cornell University Agricultural Experiment Station

Cull beans had been fed to breeding ewes for many years in New York State, but lamb feeders had not been too successful in using cull beans in fattening rations. Willman (1953) had long recognized the need for practical feeding trials with cull beans and started work along this line in the fall of 1946. Summaries of his unpublished work may be found in appendix tables 15 through 21.

The feed lot performance over a period of six years by White Face Western lambs averaging about 66 pounds initial weight, fed cull beans, led to the following general conclusions. Beans were able to replace up to one-half of the corn in lamb rations if at least 0.10 of a pound of linseed meal was added for each lamb daily. Soybean oil meal in one trial was a satisfactory replacement for linseed meal, but brewers' dried yeast failed to be satisfactory in another trial. A commercial amino acid mixture fed on an equal protein basis was about equal to linseed meal. A commercial product containing aureomycin was added to the linseed meal for one trial. At a low level of intake it failed to produce any beneficial effect. If a protein supplement was not used, it was difficult to substitute beans for one-quarter of the shelled corn. When beans were fed as the only concentrate, very unsatisfactory results were obtained. The main difference between these studies and those reviewed where beans alone were quite satisfactory was the roughage fed. In the studies of Miller (1927), Quale (1932) and other earlier workers, alfalfa was the only roughage, but in the work of Willman (1953) hay was limited and corn silage was the main roughage. There was some indication in the studies by Willman (1953) that the lambs on a higher hay allowance and cull beans made better daily gains than those on a more limited hay intake. The 1950-51 trial demonstrated that cooking the beans with open steam and drying before feeding greatly improved their feeding value.

During four of the six years, raw beans and corn, equal parts by weight, and linseed meal were compared to corn and linseed meal. Table 1 gives the average data for this four year comparison.

The average value of beans was about seventy per cent that of shelled corn. One hundred pounds of cull beans replaced 95.8 pounds of corn less 5.8 pounds of linseed meal less 15.8 pounds of legume hay less 50.9 pounds of corn silage.

The highly significant benefit of adding small amounts of linseed meal to rations containing cull beans was demonstrated in the first studies started in 1946. The protein content of the cull bean rations was always above recommended protein allowances before the linseed was added. The average daily gains for lambs averaging 62 pounds for the first 70 days of the trial were 0.25, 0.15, 0.10, and 0.11 of a pound for the respective lots where one-fourth, one-half, three-fourths, and all of the corn was replaced by cull red kidney beans. During this same period, lambs receiving the control ration of corn, and linseed meal gained 0.31 of a pound daily. The gains were so low for the bean fed lambs that the rations were adjusted for the last 77 days of this first trial. Summaries of the first 70 days and last 77 days of this trial may be found in tables 15 and 16 in the appendix. An example of the benefit of linseed meal was the comparison of the early and late gains for lot IX which received the same cull bean and corn mixture (equal parts) throughout the trial but 0.17 of a pound of linseed meal was added

TABLE 1

FEEDING VALUE OF RAW KIDNEY BEANS *

	Shelled Corn Linseed Meal Hay Corn Silage Salt	Shelled corn Cull Beans Linseed Meal Hay Corn Silage Salt
Lambs per lot	23	23
Days fed	95	95
Av. initial wt. (lbs.).	68.8	69.1
Av. final wt. (lbs.)	100.6	98.1
Av. daily gain (lbs.)	.337	.310
Av. daily ration (lbs.):		
Sh. corn	1.12	.54
Cull beans		.50
Linseed oil meal	.097	.12
Legume hay	.82	.82
Corn silage	2.07	2.21
Salt	.015	.016
Amount of feed per 100 lbs. gain (lbs.):		
Sh. corn	334	176
Cull beans		165
Linseed oil meal	29	38.5
Legume hay	246	272
Corn silage	612	696

* Average data for four trials.

for each lamb daily during the last 77 days. The average daily gain for each lamb was 0.15 of a pound for the first 70 days and 0.40 of a pound for the last 77 days.

This early work was the basis of five more years of study summarized in tables 17 through 21 in the appendix. In addition to the linseed meal phase of the study, other factors and practices which might have a similar beneficial effect were investigated.

Cull Beans for Cows and Steers

Huffman and Baltzer (1929) indicated that beans were a valuable source of protein but were unpalatable. They concluded that 20 per cent of the total ration was the maximum amount of beans that could be used in a dairy cow ration. Steam cooked beans were found more palatable but difficult to feed. The additional cost of cooking did not appear to be economical. Beans gave the best results when fed with alfalfa or clover hay, however, additional protein was beneficial when the cows were fed timothy hay.

Ground cull beans, Great Northern, were fed to fattening yearling steers by Vinke and Pearson (1931). They compared the feeding value of cull beans with barley when fed with alfalfa hay. The bean content of the grain mixture had to be limited to 20 per cent because a mixture with a greater proportion of beans was too laxative. Oats were a much better replacement for barley than beans under the conditions of their trial. Beans had no value when fed with barley and alfalfa hay as 20 per cent of the grain mixture.

Hickman, Rinehart, and Johnson (1934) fed similar rations and found that beans could constitute up to 15 per cent of the grain mixture. Digestive disorders resulted if beans were fed in larger amounts. Each ton of cull beans replaced 2,341 pounds of alfalfa hay and 1,707 pounds of barley.

Feeding Cull Beans to Hogs

Beans were fed at the Michigan Station by Shaw (1906). He compared beans alone, which were steam cooked until soft, with a mixture of beans and corn where one-half of the corn was replaced by beans. Daily gains made by the hogs were 1.1 pounds on the bean ration and 1.52 pounds for the combination bean and corn ration. Due to the low cost of the cull beans, the hogs receiving beans alone made the most economical gains. The higher market value, however, for the hogs fed a combination of corn and beans made this lot more profitable. While trying to find the best supplements for hogs on pasture, Thompson and Voorhies (1922) compared cooked cull beans to barley and tankage. The gains obtained were fair compared to other rations, but the packer did not like the carcasses because they were too soft and flabby. The bean fed hogs had a very low dressing percentage of 63.8.

Four trials at the Michigan Station reported by Brown (1931) also demonstrated that soft and medium soft carcasses were produced by feeding cull beans. In this series of trials, fattening pigs were used to compare a ration of two parts of cooked cull beans

and one part of ground grain to a ration of corn and tankage. All bean fed lots gained slower and required more feed per 100 pounds of gain than the corn and tankage fed lots. The Michigan workers concluded that the bean ration was unpalatable.

Some more recent work by Connell (1944) demonstrated that cooked pinto beans gave satisfactory results and the carcasses were not soft. The beans were cooked by soaking them 25 hours and then steam cooking for 3 hours. Raw pinto beans were very unsatisfactory because of high cost gains and the pigs were not fat enough to sell.

Raw Soybeans Compared to Heat Treated Soybean Oil Meal for Sheep

Inasmuch as a search of the literature failed to reveal any nitrogen utilization and digestion studies with ruminants fed dry beans, work with soybeans was reviewed.

Miller and Morrison (1944) conducted nitrogen balance experiments with lambs to determine the effect of heat treatment and oil extraction on the digestibility and utilization of soybean protein. The additional heat treatment of solvent process soybean oil meal resulted in no appreciable improvement in the protein for lambs. They did note, however, that the protein furnished by raw soybeans or unextracted soybean flakes had a significantly lower digestibility for lambs than the proteins furnished by solvent process soybean oil meal with or without special heat treatment. This dif-

ference in digestibility was due apparently to the heat treatment given the meal. The difference in percentage of total nitrogen stored between the raw and heat treated meals was due chiefly to the difference in digestibility. The differences in biological values were so slight that they were not significant.

Chemical Analysis, Coefficients of Digestibility and Amino Acid Content of Dry Beans

In a search of the literature, it was soon discovered that dry beans grown primarily for human food were among the first legumes analyzed to determine protein content and energy value. Ladd (1885) analyzed navy beans and found the total albuminoids were 25.51 per cent. He compared navy beans with various farm grains when digested in pepsin solution. He hoped that the albuminoid digestibility by pepsin would be an indication of food value. The 94.78 per cent digestibility of albuminoids for the navy bean was the highest value for any of the concentrates tested.

The digestibile nutrient content and composition of kidney beans as offered to sheep and goats has been reported by Schneider (1947) as follows:

Total dry matter	87.8%	Ash	3.6%
Digestible crude protein	13.6%	Crude protein	20.3%
Total digestible nutrients	68.0%	Crude fiber	4.2%
Nutritive ratio 1: 4		N-free extract	58.5%
		Ether extract	1.2%

The average digestion coefficients compiled by Schneider (1947) were 80 for organic matter, 67 for curde protein, 49 for crude fiber, 88 for nitrogen free extract, and 35 for ether extract. Morrison (1948) reporting data for all classes of livestock had similar determinations for kidney beans.

Osborne and Clapp (1907) studied the protein content of the white bean and kidney bean and found a globulin, phaseolin, formed nearly all of the protein of these beans. On a water and ash free basis, they found that phaseolin had the following composition:

glycocoll	0.55	serine	0.38
alanine	1.80	tyrosine	2.18
valine	1.04	arginine	4.89
leucine	9.65	histidine	1.97
proline	2.77	lysine	3.97
phenylalanine	3.25	ammonia	2.06
aspartic acid	5.24	"typtophane"	present
"glutaminic" acid	14.54		

No attempt was made to determine the cystine content because phaseolin was found to be less than 0.4 per cent sulphur.

Thirteen years later Finks and Johns (1920) compared the amino acid content of phaseolin obtained by Osborne and Clapp (1907) with results they obtained by using the VanSlyke method. They obtained a value of 0.84 per cent for cystine which was not determined by Osborne and Clapp. Their values for arginine, histidine and lysine were slightly higher than those obtained by Osborne and Clapp.

Protein Quality of Dry Beans

Studies by Mendel and Fine (1912) with a man and a dog showed the proteins of raw white beans to be very poorly utilized. They were unable to explain fully the poor results obtained. Work by McCollum, Simmonds, and Pitz (1917), with rats fed beans as the sole source of amino acids, demonstrated clearly that beans had a very low biological value for rats. Rats had a very high mortality and grew poorly when fed only white beans as a source of protein. The level of protein was 19.8 per cent. Rats fed so that 19 per cent of the ration was bean protein and 3 per cent was casein protein, had a marked improvement in growth and livability. They concluded that beans seemed to exert an injurious effect on rats which might be due to an unknown factor in the beans. They postulated, however, that because the beans were high in hemicelluloses the micro-organisms in the digestive tract attacked the hemicelluloses and considerable gas was liberated. This action was believed to cause swollen abdomens and injurious effects on the digestive tract.

Osborne and Mendel (1917a) reported that they had worked with phaseolin, the chief protein in kidney beans, for several years. Phaseolin extracted by sodium chloride and used as the only protein failed to maintain rats. It was non-toxic because animals that ate enough remained alive. If phaseolin was boiled, then dried and fed, rats were maintained without growth. Raw phaseolin was 55 per cent

utilized and cooked phaseolin 82 per cent utilized. This work was no doubt carried out at approximately the same time as the similar and well known work with soybeans by Osborne and Mendel (1917b).

The work by Johns and Finks (1920) with rats was similar to that reported by McCollum, Simmonds, and Pits (1917). They also reported no growth, but did not notice the swollen abdomens due to accumulation of gas. In an attempt to improve the nutritive value of navy beans, cystine was added to the diet because an analysis had indicated that beans were low in cystine. Rats fed phaseolin with added cystine maintained their weight, but still failed to grow satisfactorily. During the course of this study, phaseolin was digested with trypsin _in vitro_ and dried. Cystine was added to this dried digested phaseolin and fed to rats. The rats grew normally.If this particular part of the study had been developed more fully, the presence of an anti-trypsin factor in raw beans might have received attention several years before other workers suggested such a factor was the reason for poor growth obtained by feeding raw soybeans. In this same study, cooked bean meal with added cystine gave normal growth.

Biological values determined with rats, on a 10 per cent protein ration by Mitchell (1924) where cooked beans furnished all of the protein, were quite low and averaged 38.4. Hoagland and Snider (1927) also showed very poor growth when cooked navy beans were fed.

More recent work by Everson and Heckert (1944) again showed that rats fed raw navy, kidney, or pinto beans rapidly lost weight and died. Cooking the beans for 45 minutes at 15 pounds pressure in an autoclave resulted in slight, but not normal growth. Russell, Taylor, Mehrhoff, and Hirch (1946) demonstrated that white rats fed lima or snap beans as the only protein at a 10 per cent level grew slowly. The addition of 0.1 per cent methionine caused an immediate growth response, but even more growth was obtained when the methionine was raised to 0.6 per cent. This work supported previously discussed work showing that many varieties of beans are low in sulphur-containing amino acids. Jaffe (1949) reported that he felt raw kidney beans contained a toxic material, part of which was destroyed by cooking. He soaked kidney beans overnight and then autoclaved the beans at 10 pounds pressure for 30 minutes. Rats fed treated beans, at a 10 per cent protein level, made slight growth, but when methionine was added the growth was much better and equal to cooked soybeans plus methionine. He concluded that methionine was the limiting factor in all cases.

It must be concluded from these studies on protein quality that raw dry beans are not a satisfactory protein for rats but may be improved either by the addition of sulphur-containing amino acids, cystine and methionine, or by heating. The maximum effect may be obtained by both heating and adding methionine.

Effect of Heat on Protein Quality of Legumes

The unique beneficial effect of heat on the nutritive value of legumes has been of theoretical and practical interest to research workers since Osborne and Mendel (1917) demonstrated that cooking soybeans greatly improved their value for growth in rats. The development of how this is accomplished has been well reviewed by Liener (1950), Griswold (1951) and Norris (1951). Various reasons have been given on how cooking improves the protein quality of legumes. Proposed explanations include improved palatability and greater food intake, higher digestibility of protein, greater utilization of the nitrogen, making the amino acids more available, destruction of a trypsin inhibitor, changing the site of nitrogen absorption in the digestive tract, and destruction of a growth inhibitor. Most of this work has been done with soybeans, but much of it should apply to dry beans, such as the kidney bean. Everson and Heckert (1944) demonstrated that the beneficial effect of heat on navy, kidney and pinto beans was more pronounced than on soybeans. A review of these theories follows.

Palatability and intake. Rats fed by Osborne and Mendel (1917) had greater growth on cooked soybean oil meal than on raw meal. The meal was cooked on a steam bath for three hours. They concluded that the failure of the rats to grow was mainly due to insufficient food intake. The cooking improved the palatability. Hoagland and Snider (1927) working with navy beans felt that low

food intake might be the main reason for poor growth on navy beans alone because intake varied considerably.

Digestibility, nitrogen utilization and role of amino acids. Pepsin digestion work, *in vitro*, by Waterman and Johns (1921) demonstrated that cooking improved digestion (pepsin followed by trypsin). They used the protein phaseolin from the common bean. In one study only 28.8 per cent of the total nitrogen in raw phaseolin was digested by pepsin followed by trypsin. Phaseolin, which was cooked for 45 minutes, had 44.07 per cent of the nitrogen digested. As a result of these studies, Waterman and Johns (1921) suggested that the main reason for greater growth with cooked dry beans was due to the increase in digestibility of the protein. Recent work by Jaffe (1950) with rats showed that the proteins of autoclaved kidney beans, soybeans, and lima beans were 12 to 15 per cent better digested than raw beans. Greatest improvement was with red kidney beans where a digestive coefficient of 56 per cent was obtained for raw and 79.5 per cent for the autoclaved beans.

Work by Johns and Finks (1920) demonstrated both the value of cooking and adding cystine to phaseolin. Approximately normal growth was obtained by cooking the phaseolin and adding cystine. Unpublished work by Osborne and Mendel using phaseolin and navy bean meal cited in the review of literature by Johns and Finks (1920) supported these results. Hayward, Steenbock, and Bohstedt (1936) working with soybeans found that the addition of 0.3 per cent cystine practically doubled the nutritive value of soybeans for rats. When the

soybeans were autoclaved for one hour under 15 pounds of steam pressure, similar results were obtained. When cystine was added to the cooked soybeans, no increase in nutritive value was noted. This is in contrast to the earlier work of Johns and Finks (1920) with navy beans where they had an increase in growth when cystine was added to cooked phaseolin. This might indicate a difference in the proteins found in soybeans and navy beans. Hayward, Steenbock and Bohstedt (1936) concluded that cystine in raw soybeans must be in a form which is not available and that heating makes this cystine available.

Working with both rats and chicks, Hayward and Hafner (1941) found that methionine was a more effective supplement to raw soybeans than cystine. They suggested that this could be due to the fact that methionine may be converted to cystine, and that both are needed. Their results showed that raw soybeans with added methionine and cystine were still not equal to cooked soybeans with either cystine or methionine added. This work was in disagreement with the earlier work of Hayward, Steenbock and Bohstedt (1936). Hayward and Hafner felt that all increased growth from heated soybeans was not explained by making cystine and methionine more available. Sulphur and nitrogen balance work with rats by Johnson, Parsons and Steenbock (1939) had also shown the nutritive value of soybeans improved by heating. They felt that a complex containing sulphur and nitrogen might be absorbed but was not available unless properly heated.

A slightly different approach was offered by Melnick, Oser, and Weiss (1946). Their work showed that raw and heated soybeans had approximately the same protein digestibility, but heated soybeans had a much higher biological value. By using enzymic digestion, they found that the methionine was released much faster in heated than in raw soybeans. The release of leucine and lysine was also faster in the heated beans. They concluded that the actual amount of methionine released was not changed by heating, but the time of release was changed. They felt that the methionine was released from heated beans at a time when it was most needed, and therefore better growth resulted.

Work reported later by Geiger (1950) gave some support to such a theory. Geiger reported that all of the essential amino acids for the rat must be available at one time in sufficient quantities for maximum protein tissue synthesis. Work with swine by Eggert, Brinegar, and Anderson (1953) did not fully support this theory for swine. Growth was as rapid and nitrogen utilization as efficient when the protein supplement to a corn ration was fed at a 24 hour interval as when it was available at all times. Delaying the supplementation to 36 and 48 hour intervals decreased the gains by 7 and 14 per cent.

Riesen, Clandinin, Elvehjem, and Cravens (1947) demonstrated that the amount of each of the essential amino acids liberated by acid hydrolysis from soybean meal was not changed by heat treatment.

The amount of amino acids liberated by pancreatic hydrolysis, however, was increased by proper heat treatment.

Later work by Clandinin and Robblee (1952) used the amino acid values obtained by enzymatic hydrolysis to determine the relative nutritive value of various soybean meals. They found that meals processed at various temperatures and for different lengths of time which were equal in actual feeding tests were not equal in amino acids values obtained by enzymatic hydrolysis.

Riesen, Clandinin, Elvehjem, and Cravens (1947) demonstrated the destructive effect of over heating soybeans. Lysine, arginine and tryptophane were destroyed by over heating. Evans and Butts (1948) showed by enzymatic digestion _in vitro_ that 40 per cent of the lysine was destroyed and 60 per cent less lysine was available in soybean oil meal after autoclaving four hours. Sucrose apparently caused the lysine destruction because very little loss occurred in the absence of sugar. Part of the lysine, however, was converted to a form not liberated by enzyme digestion. When 20 per cent sucrose was added to the meal,50 per cent of the lysine was destroyed by over heating. Dry heat was not nearly as destructive as the moist heat in the autoclave.

Trypsin inhibitor. Independently, Ham and Sandstedt (1944) and Bowman (1944) showed that extracts of raw soybeans inhibited digestion of protein _in vitro_ by trypsin. Bowman studied the effect of this trypsin inhibitor obtained from soybeans and navy beans on the digestion of casein with trypsin, _in vitro_. His results showed

that the extract of navy beans decreased the digestibility of casein protein from approximately 94 to 13 per cent while the extract of soybeans decreased the digestibility from 94 to 43 percent.

Studies by Ham, Samstead, and Mussehl (1945) demonstrated that partially purified solutions of this trypsin inhibitor would decrease growth. They also found that the intestinal contents of chicks fed raw soybeans would inhibit trypsin digestion, in vitro. Their work gave further proof that a trypsin inhibitor might be the reason for the poor utilization of raw soybeans by living animals.

Kunitz (1946) crystalized the trypsin inhibitor which he isolated from de-fatted soybean meal. A difference between the soybean trypsin inhibitor and the navy bean fraction was pointed out by Bowman (1948). He found the navy bean preparation much more active. Westfall and Hauge (1948) found by several observations that the trypsin inhibitor found in raw soybeans was probably the major cause for their poor utilization. Further importance of this inhibitor was shown by Chernick, Lepkovsky, and Chaikoff (1948) when they fed chicks raw and cooked soybean meal and then examined their pancreas. They found that the pancreas of chicks fed raw soybeans was greatly enlarged and also contained a greater amount of trypsinogen. They proposed that this increased size and enzyme content of the pancreas was due to acinar tissue stimulation by the inhibitor or a product of incomplete protein digestion.

One of the first indications that the beneficial effect of heating soybeans might not be due entirely to the destruction of an anti-trypsin factor was suggested by Riesen, Clandinin, Elvehjem and Cravens (1947). In their work when excessive pancreatin was used to overcome any possible anti-trypsin activity in raw meal, the amino acid liberation was still below that of heated meal. Jaffe (1950) was unable to find any definite correlation between the growth depressing effect of crude legume seeds studied and their trypsin inhibitor action. About the same time, Borchers and Ackerson (1950) were unable to find any correlation between the improved nutritive value after autoclaving and the presence or absence of a trypsin inhibitor in raw legume seeds.

Further work by Borchers and Ackerson (1951) found that trypsin powder would counteract the growth inhibitor in raw soybeans, but its action did not depend on its trypsin activity because autoclaved trypsin powder had the same effect as powder not autoclaved. Autoclaving the trypsin powder should destroy its trypsin activity.

Site of nitrogen absorption. Carroll, Hensley, and Graham (1952) determined that all, or nearly all, of the nitrogen to be absorbed from properly heated meal was absorbed in passage through the small intestine of the rat. They found the nitrogen of raw meal, however, was absorbed primarily from the large intestine or cecum. They found by conventional methods the protein of raw soybeans 77 per cent digested and the protein of heated soybeans 82 per cent digested. By using the contents of the terminal 20 per

cent of the small intestine instead of the feces, they obtained coefficients of protein digestibility of 79 per cent for the heated meal and 33 per cent for the raw meal. As a result of this work, the authors suggested that the nitrogen absorbed from the large intestine had little growth promoting ability. They also felt that when proteins escaped to the large intestine substantial pancreatic and intestinal secretions also escaped. They suggested that this loss might be related to the hypertrophy of the pancreas and the concentration of trypsinogen in pancreatic tissue reported by Chernick, Lepkovsky and Chaikoff (1948).

Borcher (1953), determining digestibility by a similar procedure, was unable to confirm the work of Carroll, Hensley and Graham (1952). Borcher did not find that the apparent digestibility of raw soybean nitrogen was significantly different from autoclaved soybean nitrogen in the terminal 20 per cent of the small intestine of the rat. These conflicting reports leave this explanation to be confirmed or rejected.

Toxic substance - "soyin". A protein toxic to rats and devoid of anti-triptic activity has been found in raw soybeans. This protein which shows a marked hemagglutinating action was called "soyin" by Liener (1953). He estimated that one-half of the growth inhibiting effect of raw soybeans was due to the soyin content and one-half to something which may be counteracted by crude trypsin powder. It is interesting to note that Liener (1953) feels that the growth impairment due to "soyin" is probably due mainly to the decrease in food intake which was the reason given by Osborne and Mendel (1917) when they first discovered the benefits of heating.

Methods of Determining Protein Quality

The work of Mitchell (1924a), (1924b), (1942), (1944) has had considerable influence on the development of various methods for determining the value of food proteins. Three methods of measuring protein value were outlined and discussed by Mitchell (1944). They were the amino acid content of the protein, the ratio of gain in weight to a unit of protein intake, and a measure of gain in nitrogen by the animal when fed the protein to be tested.

Mitchell (1944) felt that amino acid content was a valuable measure of protein quality for monogastric animals especially where the essential amino acids are known. The digestibility of proteins, however, is largely independent of the amino acid make-up and the effect of heat and storage on protein quality does not seem to be shown by an amino acid analysis.

The correlation of the amino acid composition of proteins and their nutritive value has been well discussed by Block and Mitchell (1947).

In discussing the evaluation of protein feeds by their growth promoting ability for each unit of intake, Mitchell (1944) gave simplicity as the main advantage. This method does not give full account to the maintenance requirements for protein which are prob-

ably not constant and are influenced by age, size, rate of growth and the quality of protein. He also pointed out that weight gain varies widely in its make-up and is not all protein. When a rapid gain was made more of the increased weight was fat.

Mitchell (1924) described the Thomas-Mitchell method of determining biological value of proteins. The formula for this method may be stated as:

$$\text{B.V.} = \frac{\text{Absorbed Nitrogen Retained by Body}}{\text{Absorbed Nitrogen}} \times 100$$

OR

$$\text{B.V.} = \frac{\text{N intake} - (\text{fecal N} - \text{metabolic N}) - (\text{urinary N} - \text{endogenous N})}{\text{N intake} - (\text{fecal N} - \text{metabolic N})} \times 100$$

This measure of protein quality was more fully described by Mitchell (1943). The fecal nitrogen is divided into two fractions, one which is of dietary origin and the second which is of body origin and is called metabolic nitrogen. The urine nitrogen is divided into exogenous and endogenous nitrogen, the exogenous nitrogen is the result of part of the absorbed dietary nitrogen being formed into compounds which are not synthesized into body protein. The other fraction is the endogenous nitrogen which is the constant nitrogen excretion due to catabolism related to body size and other factors. Schoenheimer and Rittenberg (1940) challenged this distinction between the two types of nitrogen catabolism on which the conception of biological value is based. They demonstrated by the use of isotopes that a state of dynamic, not static, equilibrium

existed between the tissue proteins and the amino acids of the blood plasma and intercellular fluid. Maynard (1951), commenting on endogenous and exogenous catabolism, stated that only a small fraction of the protein appears to be involved in the dynamic state and the endogenous nitrogen is the excess left over as anabolic and catabolic processes come into balance. Mitchell (1943), commenting on the effect the work of Schoenheimer and Rittenberg (1940) had on his method of determining biological values, stated that there was nothing in this work that denied the existence of a constant type of catabolism in the tissue of nitrogen containing compounds. He felt the theory of protein metabolism upon which the calculation of biological values are based was still sound. Mitchell (1944) pointed out that proper nitrogen metabolism studies should give the most information on protein value. Both protein digestibility and protein utilization may be determined. He pointed out the disadvantage that all determinations were based on nitrogen so that sources of non-protein nitrogen as well as the proteins were included.

Evaluating proteins for ruminants. At the present time, there is fairly good agreement among research workers on the advantages and disadvantages of the various methods for evaluating proteins for non-ruminants. There does not, however, seem to be such good agreement among workers on the method of evaluating proteins for ruminant animals, such as sheep. The value of various protein supplements has been studied by feed lot trials. The value of the protein supplements is estimated mainly by the rate of gain and economy of gain made by the animals.

Swanson and Herman (1943) have shown that biological values of feed proteins secured with rats may not be correlated with biological values of the same feeds secured with ruminants due to the activity of the rumen flora in the utilization of protein. They decided that the digestibility of the protein and of the non-nitrogenous nutrients were the most important factors to consider in evaluating feed proteins. Johnson, Hamilton, Mitchell and Robinson (1942) demonstrated that biological values determined with ruminants were always near 60 for crude protein regardless of the ration fed. They suggested the slight differences in biological values were obtained because ruminants ultimately used micro-organismal protein rather than food protein. The reason for this nearly constant biological value of proteins for ruminants has been further explained by McDonald (1952). Working with sheep, he studied the role of ammonia which is readily released in the rumen by the action of micro-organisms on proteins. The formation of this ammonia leads to two opposing nutritional tendencies. Non-protein nitrogen, such as ammonia, may be acted upon by micro-organisms to form protein used by the animal. Ammonia may be lost, however, by absorption through the rumen wall. It is believed that this ammonia enters the blood stream and eventually may be lost as urea in the urine. Small amounts may be returned to the rumen through the saliva. McDonald (1952) believes that the interaction of these two opposing

forces is probably the reason for a nearly constant biological value of protein for ruminants. Synge (1952) also discussed the two opposing forces in the use of nitrogen by ruminants. He states that we must know which process predominates when a certain protein is fed in order to properly evaluate its food value. For this reason he states that regular digestibility studies are unsatisfactory for rating proteins for ruminants. Growth studies and nitrogen balance studies are more acceptable measures according to Synge (1952).

Determining biological values of proteins for sheep. A number of workers have used sheep to determine the biological value of proteins for ruminants. Swanson and Herman (1943) reviewed several such studies. Harris and Mitchell (1941) while working with sheep determined endogenous nitrogen to be 0.033 grams per kilogram of body weight and metabolic nitrogen to be 0.55 grams per hundred grams of dry matter intake. Miller and Morrison (1944), also working with sheep, obtained similar values of 0.037 grams of endogenous nitrogen daily per kilogram of body weight and 0.55 grams of metabolic nitrogen per hundred grams of dry matter intake.

EXPERIMENTAL PROCEDURE

Digestion Trial 1951-1952

Animals used. Eighteen native wether lambs with weights ranging from 69 to 97 pounds were selected for the trial from the Cornell University flock.

Design of the experiment. The digestibility of three rations, raw red kidney beans and alfalfa hay; cooked red kidney beans and alfalfa; and shelled corn, linseed meal and alfalfa were compared. Six lambs were fed each ration.

The lambs were alloted by selecting six trios with similar individual weights within each trio. Two trios were selected for each of three collection periods by average weight. Heaviest trios were placed on collection first. Individual lambs within a trio were assigned test rations by randomization. The allotment of the lambs has been listed in table 2.

Equipment. During each seven day collection, one trio was placed in collection cages as illustrated in Morrison (1948) page 84, and one trio was placed in collection stanchions where movement was restricted. The allotment of trios to collection equipment was also by random.

TABLE 2

ALLOTMENT OF LAMBS

Digestion Trial 1951-52

Lamb No.	Wt.	Concentrate*	Collection Equipment	Collection Period
273	96	Raw beans	Stanchion	1
286	97	Corn and L.O.M.	Stanchion	1
1034	97	Cooked beans	Stanchion	1
1045	94	Cooked beans	Cage	1
1014	90	Corn and L.O.M.	Cage	1
672	90	Raw beans	Cage	1
161	89	Corn and L.O.M.	Cage	2
250	93	Raw beans	Cage	2
257	93	Cooked beans	Cage	2
671	76	Raw beans	Stanchion	2
181	76	Cooked beans	Stanchion	2
34	76	Corn and L.O.M.	Stanchion	2
128	71	Corn and L.O.M.	Stanchion	3
166	74	Cooked beans	Stanchion	3
256	75	Raw beans	Stanchion	3
41	69	Corn and L.O.M.	Cage	3
126	70	Cooked beans	Cage	3
190	71	Raw beans	Cage	3

* Beans were cull red kidney

Feeds used. Raw red kidney beans - Cull beans consisting primarily of split, shrunken and discolored beans obtained from a New York State bean plant.

Cooked red kidney beans - The same lot as the raw beans but cooked by steam without pressure for two hours and then oven dried (80° to 90° C.) for about 60 hours.

Shelled corn - A composite sample of the corn purchased on the open market for the feed lot lamb trials.

Linseed oil meal - Purchased on open market.

Alfalfa hay (chopped) - Second cutting purchased near Ithaca, N. Y.

The composition of the feeds was obtained from composite samples taken during the weighing of the feeds for each collection period. Separate analyses were made of the alfalfa for each collection period. Beans were cooked at two different times so two samples were analyzed.

All composite feed samples were prepared for analysis by grinding in a Wiley mill and obtaining a sub-sample.

Methods of analysis. All the analyses were made in the Animal Nutrition Division laboratory. The methods employed, except nitrogen, were those suggested by Association of Official Agricultural Chemists (1948). The nitrogen was determined by the Kjeldahl modification using boric acid suggested by Scales and Harris (1920).

TABLE 3

DIGESTION TRIAL DAILY RATIONS 1951-52

Period No.	Lamb No.	Equipment(1)	Alfalfa	Corn	L.O.M.	Raw Beans	Cooked Beans	Ratio Concentrate Roughage
				gm.	gm.	gm.	gm.	
1	273	S	450			350		1: 1.28
1	286	S	450	175	175			1: 1.28
1	1034	S	450				350	1: 1.28
1	1045	C	450				350	1: 1.28
1	1014	C	450	175	175			1: 1.28
1	672	C	450			350		1: 1.28
2	161	C	500	350	50			1: 1.25
2	250	C	500			400		1: 1.25
2	257	C	500				364(3)	1: 1.37
2	671	S(2)	450			300		1: 1.5
2	181	S	450				270(3)	1: 1.66
2	34	S	450	250	50			1: 1.5
3	128	S	400	250	50			1: 1.5
3	166	S	400				270(3)	1: 1.48
3	256	S	400			300		1: 1.33
3	41	C	500	350	50			1: 1.25
3	126	C	500				364(3)	1: 1.37
3	190	C	500			400		1: 1.25

(1) S - Stanchion C - Cage
(2) Collection made in cage with 3rd group
(3) Dry matter equal to corresponding raw bean diet

Feed intake. The intake on all groups of three lambs was limited to the amount of raw beans consumed by the lamb on this concentrate. Total intake on an air dry basis was only 60 to 70 per cent of the recommended daily nutrient allowance as given by National Research Council (1949). After the first period, the cooked and raw beans were fed on an equal dry matter basis. The daily ration for each lamb has been listed in table 3.

Fecal collection. Feces were collected daily and placed in large glass jars. A preservative (95% alcohol and 3% HCL) was used in small amounts on the feces during the collection period.

The total seven day collection was weighed, and mixed well. Representative samples of 400 or 500 grams were taken and placed in the drying oven at approximately 85° C for 48 hours. After drying, the samples were allowed to stand for at least 48 hours in the open at room temperature before being weighed to determine dry matter content on an air dry basis. The air dry feces sample was ground in a Wiley mill and sub-sampled for use in making moisture, protein, ether extract, crude fiber and ash determinations.

Orts. Orts were handled similar to the feces except no preservative was used.

Calculations made. Apparent digestibilities for dry matter, protein, ether extract, crude fiber and nitrogen free extract were determined.

The total digestible nutrients in the ration for each lamb was calculated based on the various digestibility coefficients ob-

tained, with digestible ether extract multiplied by 2.25. The design of this trial did not allow values for raw or cooked beans alone to be determined by difference.

Feed Lot Trial

Lambs used. The 105 ewe lambs used in this trial were part of a carload of 294 white faced lambs from Utah. The average weight at the start of the trial was approximately 54 pounds.

Treatment of lambs previous to the start of the trial (October 25 to November 14). Upon arrival the lambs were given low grade grass hay and water and allowed to rest. Good quality mixed grass and legume hay was soon substituted for the poor grass hay and small amounts of bran and oats were fed. The roughage was gradually changed so that by the end of the adjustment period the lambs were receiving the proposed limited alfalfa hay allowance of 0.75 pound daily and about 1.5 pounds of corn silage. Shelled corn was gradually added to the wheat bran and oats mixture. The cull red kidney beans were not fed until the start of the experiment.

External parasites were controlled by hand dusting all lambs with a one per cent rotenone dust. Each lamb received $1\frac{1}{2}$ ounces of a one per cent copper sulfate and nicotine sulfate solution for internal parasites. Each lamb was vaccinated for "over eating" disease. The heads were clipped to prevent any wool blindness. Metal ear tags were inserted for identification.

Design of experiment. Five lots of 21 ewe lambs were used with one lot for each ration to be tested. Each lot was fed ad libitum to reach an average weight of 90 to 95 pounds. Lambs were assigned to each lot as follows: the 105 lambs were listed in order according to weight, heaviest to lightest; outcome groups were selected by placing the five heaviest lambs in group one, the next five heaviest in group two, and in like manner until twenty-one outcome groups had been selected; the five lambs within each outcome group were assigned by random to the five test rations.

Weight records. One day weights were used for initial, biweekly, and final weights as suggested by Bean (1948). The various lots were weighed in the same order and at approximately the same time each weigh day.

Feed records included the weight of the daily allowance of each feed and the total refused feed.

Equipment. Each lot of 21 lambs was fed in a pen 12 feet wide and 18 feet long in the barn with an outside exercise lot 12 feet wide and 20 feet long. The pens and the feed rack were illustrated by Willman, Morrison, Klosterman (1946) and Morrison (1948). Sufficient feed rack space was provided for all lambs to eat at one time.

Test rations.

Lot XI - Shelled corn and cull red kidney beans, raw, equal parts
Linseed oil meal, 0.10 lb. per head daily
Corn silage, full fed
Alfalfa hay, limited 0.75 pound daily
Plain salt

Lot XII - Shelled corn and cull red kidney beans, raw, equal parts
Corn silage, full fed
Alfalfa hay, limited 0.75 pound daily
Plain salt

Lot XIII - Shelled corn and cull red kidney beans, cooked, equal parts
Linseed oil meal, 0.10 pound per head daily
Corn silage, full fed
Alfalfa hay, limited 0.75 pound daily
Plain salt

Lot XIV - Shelled corn and cull red kidney beans, cooked, equal parts
Corn silage, full fed
Alfalfa hay, limited 0.75 pound daily
Plain salt

Lot XV - Shelled corn and cull red kidney beans, raw, equal parts
Brewers' dried yeast, 0.08 pound per head daily
Corn silage, full fed
Alfalfa hay, 0.75 pound daily
Plain salt

Feeds used. Raw red kidney beans - Cull beans from the 1951 crop were purchased from a local bean plant. They consisted of split, shrunken, and discolored beans relatively free from dirt.

Cooked red kidney beans - They were from the same shipment as the raw beans but cooked in a laboratory autoclave at 15 pounds of steam pressure for 30 minutes. Raw beans were placed in trays with hardware cloth bottoms at a depth of 2½ to 3 inches. The trays

were placed in the autoclave with 1/4 of an inch space between trays. Eighty-five pounds of beans were cooked at one time. The exhaust valve was left open for six minutes for air escape. The beans were cooked for 30 minutes after 15 pounds of pressure (250° F.) was reached. At the conclusion of the cooking time the steam was released, the beans removed and placed in large chick incubator trays to cool and dry. Electric fans were used to cool and dry the beans at first. The use of fans was discontinued, however, when still air was found to be effective. After the beans were cool and dry (12 hours) they were placed in feed bins at the experimental barn. Beans were cooked throughout the trial but it was planned not to feed beans until after two weeks in the bins for moisture stablization.

Shelled corn - Number 2 dent corn purchased on the open market.

Linseed oil meal - Purchased on the open market.

Corn silage - Made from well eared corn grown on the Cornell University farm.

Alfalfa hay - First cutting alfalfa purchased locally graded U. S. No. 2.

Salt - Plain salt was fed free choice.

Methods of feed analysis. All routine analyses except the nitrogen determination, were conducted by methods suggested by the Association of Official Agricultural Chemists (1948). The Kjeldahl

determinations were carried out by the boric acid modification suggested by Scales and Harris (1920). All methods were standard for the Animal Nutrition Division feed analysis laboratory.

Feeding procedure. The lambs were fed twice daily, about 8:00 a.m. and 4:00 p.m. Full time employees fed the experimental lambs so the feeding schedule had to conform to their regular working hours. The concentrate mixture was fed first followed by the corn silage and hay. The amount of feed offered was regulated by keeping the refused feed less than 10 per cent of the total offered. The total amount of feed offered, however, was charged to each lot and considered as the amount consumed. No attempt was made to keep the various lots on an equal intake after the first part of the trial.

Calculations and measurements to be used. The average daily rate of gain and amount of various feeds consumed for each one-hundred pounds of gain were the most important measures used to determine the relative value of the test rations. Economy of gain, live market grade of lambs, and net return per lamb (selling price less initial cost of lamb, feed costs, services and mortality charge) were other factors considered.

The differences in daily rate of gain were analyzed statistically.

Nitrogen Utilization Studies - Trial I

A nitrogen utilization study was made of four rations similar to those fed in the feed lot.

Animals used. Four white faced ewe lambs from the same carload as those fed in the 1952-53 feed lot trial were used.

Design of experiment. A latin square design (4 x 4) was used so that each lamb would receive each of the four rations and in a different order. Lambs were assigned to the four series of rations by chance. The organization of the trial may be diagramed as follows:

	Lamb 1046	Lamb 406	Lamb 485	Lamb 323
Period 1	D	A	B	C
" 2	A	B	C	D
" 3	C	D	A	B
" 4	B	C	D	A

Daily ration.

A	-	Raw red kidney beans	160 grams
		Shelled corn	206
		Alfalfa hay (chopped)	340
		Corn silage	300
		Salt (block)	
B	-	Raw red kidney beans	160 grams
		Shelled corn	160
		Linseed meal	46
		Alfalfa hay (chopped)	340
		Corn silage	300
		Salt (block)	

Daily ration (continued)

C	-	Cooked red kidney beans	160 grams
		Shelled corn	206
		Alfalfa hay (chopped)	340
		Corn silage	300
		Salt (block)	
D	-	Cooked red kidney beans	160 grams
		Shelled corn	160
		Linseed meal	46
		Alfalfa hay (chopped)	340
		Corn silage	300
		Salt (block)	

The estimated daily dry matter intake for all of the rations was 704 grams. This was 86 per cent of the minimum, Morrison (1948), standard for a sixty pound lamb. These intakes based on an air dry basis were 82 per cent of the National Research Council (1949) suggested air dry feed allowance for a fifty pound lamb fed to gain 0.25 pound daily.

The maintenance requirement determined by Armsby of .72 therms of net energy for each one-hundred pounds of body weight as reported by Maynard (1951) was met, although the intake was below accepted feeding standards for fattening lambs. By using Morrison's (1948) tables to estimate the net energy value, the rations furnished about 1.09 therms daily for these 60 to 70 pound lambs compared to the maintenance requirement of .72 therms for one-hundred pounds of body weight. The concentrate to roughage ratio was 1 to 1.3 on an air dry basis.

Feeds used. The alfalfa hay, shelled corn, linseed meal, raw red kidney beans and cooked red kidney beans were selected from the supplies used in the feed lot study. The alfalfa hay, however, was fed chopped instead of whole. The corn silage was from a different silo which was necessary because the lambs on the nitrogen balance study were not housed at the experimental sheep barn. Salt blocks were available at all times.

Feeding and management. The lambs were kept in digestion cages as illustrated in Morrison (1948) at all times. A preliminary period of six weeks was required to get the lambs accustomed to the cages and on a constant intake for two weeks before collection started. The first attempted collection had to be terminated because one lamb injured a foot and refused to eat for three feedings. After this lamb recovered and all lambs had been on a constant intake for two weeks, the first recorded collection was made. Each collection period was for ten days with at least a fourteen day adjustment period between collections. The first collection started April 13 and the last collection was terminated July 9.

Lambs were weighed at the start and finish of each period. All feeds except the corn silage were weighed and sub-sampled for each collection period before collection started. The corn silage was weighed daily and a composite sample made for the entire period.

Feeds, except corn silage, were prepared for analysis by grinding samples in a Wiley mill. The corn silage composite sample was oven dried (85° C.) and allowed to stand in the open air at least

48 hours to gain moisture equilibrium before grinding. Total orts were saved and handled during analysis the same as the corn silage.

Collection of feces and urine. The feces were collected daily and placed in a large glass jar in the laboratory freezer. At the end of each period, the total feces were weighed and a 10 per cent sample placed in the oven (85° C.) for drying. One quart of fresh feces was placed in the freezer for possible future use. The dried sample was allowed to stand at room temperature in the open air for at least 48 hours before grinding and sampling for analysis (dry matter, protein, crude fiber, ether extract and ash). Five per cent samples of the total urine production were saved and stored in a refrigerator for analysis. The samples were preserved by acidifying with HCL and using a few drops of toluene.

Methods of analysis. The feed and feces samples were analyzed in the same manner as for the digestion and feed lot studies. Nitrogen determinations of the urine were made by the Kjeldahl modification suggested by Scales and Harris (1920) using 5 and 10 gram samples. Samples were pipetted into a small beaker for weighing. After pouring the sample into the Kjeldahl flask, the beaker was washed twice with distilled water and the washings were also poured into the Kjeldahl flask. The pipette was washed with the next urine sample before pipetting the sample into the beaker.

Shearing. All of the lambs were shorn at the end of the third collection period.

Ration evaluations. Apparent digestibility of dry matter, protein, crude fiber, ether extract and nitrogen free extract were calculated.

Estimated true digestibilities of the protein and the biological values of the rations (Thomas-Mitchell method) were calculated using the values for metabolic and endogenous nitrogen suggested by Miller and Morrison (1944). (Metabolic nitrogen estimated at 0.55 grams per 100 grams of dry matter intake. Endogenous nitrogen estimated at 0.037 grams daily for each kilogram of live weight).

The nitrogen data was calculated as total grams retained, per cent of dietary nitrogen retained and per cent of absorbed nitrogen retained.

Nitrogen Utilization - Trial II

In order to obtain more information on the digestibility and utilization of red kidney beans, a second nitrogen balance study was conducted using raw and cooked red kidney beans as the only concentrate and alfalfa hay as the only roughage. Trial I was based on the complete rations as fed in the feed lot.

Animals used. Three ewe lambs averaging about 73 pounds used on the previous nitrogen study were used on the second study.

Design of experiment. A latin square (3 x 3) was used to study rations of hay alone, hay and raw red kidney beans, and hay and cooked red kidney beans. This experiment may be diagramed as follows:

		Lamb No. 466	Lamb No. 485	Lamb No. 1046
Period	1	A	B	C
"	2	B	C	A
"	3	C	A	B

<u>Daily rations</u>.

A	-	Alfalfa hay (2nd cutting)	1000 grams
		Salt (block)	
B	-	Alfalfa hay (2nd cutting)	650 grams
		Raw red kidney beans	350 grams
		Salt (block)	
C	-	Alfalfa hay (2nd cutting)	650 grams
		Cooked red kidney beans	350 grams
		Salt (block)	

Each series of rations was assigned to a lamb by chance.

This design made it possible to calculate by difference some values for beans alone.

Seven day collection periods and fourteen day adjustment periods between collections were used. Shorter periods were used because Hall and Wolfolk (1952) had found even shorter periods adequate.

The three lambs were fed all hay until the maximum intake was reached. The lambs to be fed beans were then given beans to replace part of the hay. Hay was gradually replaced by beans until the apparent maximum intake of beans was reached. These amounts were then held constant for the entire trial.

The other experimental procedures were the same as for Trial I.

Amino Acid Analysis of Red Kidney Beans

Samples of the raw red kidney beans and the cooked red kidney beans used in the 1951-52 digestion study were analyzed for their amino acid content. The determinations were made by Doctor Harold H. Williams in the laboratory of the Department of Biochemistry and Nutrition at Cornell University. The amino acid composition of these beans was estimated by microbiological assay procedures discussed by Williams (1947). The eleven amino acids estimated were arginine, isoleucine, threonine, tryptophan, tyrosine, valine, histidine, leucine, methionine, phenylalanine, and lysine. Doctor Williams reported his results as the grams of each amino acid in 100 grams of the feed being studied.

RESULTS AND DISCUSSION

Feed Lot Trial 1952-1953

A practical method of measuring the value of various feeds has been to feed test rations to livestock and record their performance. Table 4 is a summary of the 1952-53 feed lot trial set up to test the feeding value of raw and cooked cull red kidney beans, and the value of adding linseed meal or brewers' dried yeast to such cull bean rations.

Daily gains. The average daily gains attained by the five lots of lambs show that the addition of linseed meal (.10 lb. per lamb daily) and the cooking of the cull red kidney beans increased the rate of gain. In order to compare the rations for the same number of days fed, average daily gains for 126 days are given in a footnote to table 4 for those lots finishing at other than 126 days.

The beneficial effects of adding linseed meal and cooking the cull red kidney beans secured in this trial further confirmed the results of previous trials reported by Willman (1953) and summarized in tables 15 through 21 in the appendix.

Brewers' dried yeast was fed in lot XV as a substitute for linseed meal. The slower gains obtained in lot XV compared to lot XI indicated that dried brewers' yeast was not a satisfactory substitute for linseed meal when fed on an equal protein basis.

TABLE 4

CULL BEANS FOR FATTENING LAMBS 1952-53

	Sh. Corn Cull Beans (raw) L.O.M. Silage Hay 0.75# Salt	Sh. Corn Cull Beans (raw) Silage Hay 0.75# Salt	Sh. Corn Cull Beans (cooked) L.O.M. Silage Hay 0.75# Salt	Sh. Corn Cull Beans (cooked) Silage Hay 0.75# Salt	Sh. Corn Cull Beans (raw) Brewers' Yeast Silage Hay 0.75# Salt
Lot No.	XI	XII	XIII	XIV	XV
Lambs per lot.	20.7	19.7	21	21	21
Days lambs were fed. .	126	154[(a)]	119[(a)]	126	140[(a)]
Av. initial weight . .lbs	54.24[(b)]	54.29[(b)]	54.24[(b)]	54.14[(b)]	54.24[(b)]
Av. final weight . . .lbs.	92.95	91.89	93.67	93.86	91.76
Av. gain per lamb. . .lbs	37.83	36.70	39.43	39.71	37.52
Av. daily gain . . . .lbs	0.301 ±.013[(c)]	0.238 ±.013[(c)]	0.331 ±.013[(c)]	0.315 ±.013[(c)]	0.268 ±.013[(c)]
<u>Av. daily ration:</u>					
Shelled corn. . . . .lbs	0.52	0.50	0.53	0.59	0.48
Cull beans, raw . . .lbs	0.52	0.50	---	---	0.48
Cull beans, cooked. .lbs	---	---	0.52	0.58	---
Linseed oil meal. . .lbs	0.098	---	0.097	---	---
Brewers' dried yeast.lbs	---	---	---	---	0.08
Alfalfa hay . . . . .lbs	0.75	0.75	0.75	0.75	0.75
Corn silage . . . . .lbs	1.96	2.01	2.32	2.16	2.02
Plain salt . . . . .lbs	0.015	0.014	0.014	0.015	0.015
<u>Am't. of feed per cwt. gain:</u>					
Shelled corn . . . .lbs	174.37	211.63	158.93	186.01	179.16
Cull beans, raw . . .lbs	172.90	208.87	---	---	177.70
Cull beans, cooked. .lbs	---	---	157.54	183.61	---
Linseed oil meal. . .lbs	32.46	---	29.38	---	---
Brewers' dried yeast.lbs	---	---	---	---	29.75
Alfalfa hay . . . . .lbs	249.55	315.25	226.15	237.74	279.60
Corn silage . . . . .lbs	651.85	844.54	701.57	685.49	752.54
Plain salt . . . . .lbs	5.11	5.95	4.23	4.80	5.46
Feed cost per cwt. gain $	14.27	15.65	13.38	13.13	18.00
Initial cost per cwt.. $	23.81	23.81	23.81	23.81	23.81
Est. S.P. per cwt. . . $	24.03	23.71	24.62	24.53	23.91
Grade on foot	2.53[(d)]	2.33[(d)]	3.10[(d)]	3.00[(d)]	2.48[(d)]
Initial cost per lamb. $	12.91	12.93	12.91	12.89	12.91
Cost of feed per lamb. $	5.40	5.74	5.28[(e)]	5.21[(e)]	6.75
Total cost per lamb. . $	18.31	18.67	18.19	18.10	19.66
Est. S.P. per lamb . . $	22.33	21.78	23.06	23.02	21.94
Net return per lamb. . $	4.02	3.11	4.87	4.92	2.28

(a) Lot XII at 126 days: av. weight 84.83 lbs; av. daily gain 0.235 lb.
Lot XIII " " " " " 96.19 " " " " 0.333 "
Lot XV " " " " " 85.48 " " " " 0.248 "

(b) Range: 52-58 pounds

(c) Standard error of the mean

(d) Grades (based on fatness): 4-prime; 3-choice; 2-good; 1-utility

(e) Feed cost does not include cost of cooking beans

TABLE 4

CULL BEANS FOR FATTENING LAMBS 1952-53

	Sh. Corn Cull Beans (raw) L.O.M. Silage Hay 0.75# Salt	Sh. Corn Cull Beans (raw) Silage Hay 0.75# Salt	Sh. Corn Cull Beans (cooked) L.O.M. Silage Hay 0.75# Salt	Sh. Corn Cull Beans (cooked) Silage Hay 0.75# Salt	Sh. Corn Cull Beans (raw) Brewers' Yeast Silage Hay 0.75# Salt
Lot No.	XI	XII	XIII	XIV	XV
Lambs per lot.	20.7	19.7	21	21	21
Days lambs were fed. .	126	154(a)	119(a)	126	140(a)
Av. initial weight . . .lbs	54.24(b)	54.29(b)	54.24(b)	54.14(b)	54.24(b)
Av. final weight . . .lbs	92.95	91.89	93.67	93.86	91.76
Av. gain per lamb. . .lbs	37.83	36.70	39.43	39.71	37.52
Av. daily gain . . . .lbs	0.301 ±.013(c)	0.238 ±.013(c)	0.331 ±.013(c)	0.315 ±.013(c)	0.268 ±.013(c)
Av. daily ration:					
Shelled corn. . . . .lbs	0.52	0.50	0.53	0.59	0.48
Cull beans, raw . . .lbs	0.52	0.50	----	----	0.48
Cull beans, cooked. .lbs	----	----	0.52	0.58	----
Linseed oil meal. . .lbs	0.098	----	0.097	----	----
Brewers' dried yeast.lbs	----	----	----	----	0.08
Alfalfa hay . . . . .lbs	0.75	0.75	0.75	0.75	0.75
Corn silage . . . . .lbs	1.96	2.01	2.32	2.16	2.02
Plain salt . . . . .lbs	0.015	0.014	0.014	0.015	0.015
Am't. of feed per cwt. gain:					
Shelled corn . . . .lbs	174.37	211.63	158.93	186.01	179.16
Cull beans, raw . . .lbs	172.90	208.87	----	----	177.70
Cull beans, cooked. .lbs	----	----	157.54	183.61	----
Linseed oil meal. . .lbs	32.46	----	29.38	----	----
Brewers' dried yeast.lbs	----	----	----	----	29.75
Alfalfa hay . . . . .lbs	249.55	315.25	226.15	237.74	279.60
Corn silage . . . . .lbs	651.85	844.54	701.57	685.49	752.54
Plain salt . . . . .lbs	5.11	5.95	4.23	4.80	5.46
Feed cost per cwt. gain $	14.27	15.65	13.38	13.13	18.00
Initial cost per cwt.. $	23.81	23.81	23.81	23.81	23.81
Est. S.P. per cwt. . . $	24.03	23.71	24.62	24.53	23.91
Grade on foot	2.53(d)	2.33(d)	3.10(d)	3.00(d)	2.48(d)
Initial cost per lamb. $	12.91	12.93	12.91	12.89	12.91
Cost of feed per lamb. $	5.40	5.74	5.28(e)	5.21(e)	6.75
Total cost per lamb. . $	18.31	18.67	18.19	18.10	19.66
Est. S.P. per lamb . . $	22.33	21.78	23.06	23.02	21.94
Net return per lamb. . $	4.02	3.11	4.87	4.92	2.28

(a) Lot XII at 126 days: av. weight 84.83 lbs; av. daily gain 0.235 lb.
Lot XIII " " " " " 96.19 " " " " 0.333 "
Lot XV " " " " " 85.48 " " " " 0.248 "

(b) Range: 52-58 pounds

(c) Standard error of the mean

(d) Grades (based on fatness): 4-prime; 3-choice; 2-good; 1-utility

(e) Feed cost does not include cost of cooking beans

An analysis of variance summarized in table 5, of the average daily gains shows a highly significant difference due to rations in this trial.

TABLE 5

ANALYSIS OF VARIANCE FOR DAILY GAINS

Feed Lot Trial

1952-53

Source of Variance	Degrees of Freedom	Sum of Squares	Mean Square	F
Total	104	.472074		
Outcome Groups	20	.082078	.0041039	1.19
Ration	4	.113491	.0283727	8.21**
Error	80	.276505		

** Highly significant (1% level)

Feed intake. A major objective of this entire series of studies was to try and explain some of the differences obtained in previous feed lot trials conducted at the Cornell Agricultural Experiment Station. Low feed intake has been considered one of the main reasons for slow gains. It is difficult to study feed intake where group feeding is practiced but average data for each group may indicate major differences.

The average daily intake of the various feeds on an air dry basis was compared to the National Research Council recommended allowance (1949) for similar weight lambs. This comparison was

expressed as per cent of NRC allowance. A summary of the average calculations made for each lot and for each weigh period is reported in table 6. The calculation for each weigh period for the various lots may be found in tables 22, 23, and 24 in the appendix.

TABLE 6

AVERAGE AIR DRY FEED INTAKE AND DAILY GAIN

Feed Lot Trial

1952-53

Lot No.	Av. Total Daily Feed	Per Cent NRC Allowance	Av. Daily Gain
	lbs.	%	
Lot XI	2.34	88.4	.30
Lot XII	2.18	83.4	.238
Lot XIII	2.40	91.0	.32
Lot XIV	2.39	89.9	.315
Lot XV	2.23	86.2	.268

The average consumption for all lots failed to reach the air dry intake recommended by the National Research Council for fattening lambs of similar weights. It was interesting to note that the per cent of the NRC allowance attained and the corresponding average daily gain show a close relationship. By using the values for lot XIII, the fastest gaining lot and lot XII, the slowest gaining lot, the average daily gain may be predicted quite

accurately by simple interpolation. The highly significant differences among rations found in average daily gain appear to be caused by differences in feed intake. The lambs receiving the raw beans without linseed would not eat enough to gain as well as the other lambs. The lambs in lot XII showed their dislike for raw beans by taking much longer to consume their concentrate feed than other lots. The lambs being fed raw beans appeared to eat a greater percentage of their alfalfa hay. This might be explained by the preference of the lambs for even the coarser parts of the alfalfa hay compared to the raw beans.

The amount of refused feed or "weigh back" was another indication of how the lambs ate the various rations. It was planned to keep the "weigh back" at ten per cent or less by regulating the amount of feed offered. The average percentage of the total feed offered recorded as refused feed or "weigh back" was 10.39 per cent for lot XI, 10.72 for lot XII, 9.2 for lot XIII, 9.75 for lot XIV and 12.02 for lot XV. These percentages indicate that the slowest gaining lots were the most difficult to keep on feed.

The use of brewers' dried yeast failed to increase the feed intake and daily gain as suggested by Ruf, Hale and Burroughs (1953). They fed semi-purified rations and used yeast as a source of unidentified factors to increase cellulose digestion. The 1952-53 feed lot results gave further support to the 1951-52 trial when brewers' dried yeast also failed to increase intake or daily gains.

Feed efficiency. The amounts of the various feeds required for each one hundred weight of gain are shown in table 4. The variations in these feed efficiency figures are probably due to differences in feed intakes. The slower gaining lambs with the lower feed intakes needed more days to reach the end weight and a much greater proportion of the feed consumed was used for maintenance. The faster gaining lambs with greater feed intakes used a greater proportion of their intake for growth and fattening. This would result in a greater feed efficiency.

Feed cost for each one hundred pounds of gain. This measure of feed lot trials is often considered one of the most practical measures available. Such a measure is actually a rather weak one because after the trial is completed the same price relationships seldom re-occur. Feed prices (per ton) used for this trial were: corn $65.36, linseed meal $101.00, brewers' yeast $300.00, raw and cooked red kidney beans $21.00, corn silage $7.50, alfalfa hay $21.00 and salt $22.00. The cost of cooking the beans was not included. Due to the relatively low cost of beans and the higher cost of linseed meal, lot XIV receiving cooked beans and corn without linseed made the most economical gains. Lot XII receiving the same ration except the beans were raw, had the highest cost of gain because a much larger part of the feed intake was used for maintenance. Lot XII took 28 days longer to reach the finishing weight.

<u>Health of animals</u>. Two lambs in lot XI and three lambs in lot XII died during trial. Postmortem examination at the New York State Veterinary College failed to show that the ration had any influence on the death of the animals. Therefore, the initial cost of the lambs plus the cost of the feed eaten until they died, was charged equally to all lambs living at the completion of the trial as a "mortality charge". The gain of the lambs until death was credited to their respective lots.

A few lambs scoured in all lots and sulfa drugs were used to help control such digestive disorders.

<u>Live market grade</u>. All lambs were graded by Robert E. Rector, Empire Livestock Marketing Cooperative, Incorporated. The average grade of each lot, as shown in table 4, followed very much in line with the rate of daily gain. This difference in grade was reflected in the estimated selling price.

<u>Net return for each lamb</u>. This measure (selling price less initial cost of the lamb, feed costs, services other than labor, and a mortality charge) is often considered a practical measure. It includes the weaknesses of the feed costs discussed previously as well as several other fluctuating price relationships. The main value of this measure is to compare test rations under the specific conditions of an individual trial. The net returns shown in table 4 for this trial are the highest for the cooked bean rations. It must be pointed out, however, that no charge was made for cooking.

All of the data and measures for this feed lot trial shown in table 4 may be compared to similar previous trials summarized in tables 15 through 21 in the appendix.

Digestibility of Rations Containing Raw and Cooked Cull Red Kidney Beans

The average digestion coefficients obtained with eighteen lambs during 1951-1952 are reported in table 7. A summary of the data for individual lambs may be found in table 25 and the composition of feed, feces and orts in table 29 in the appendix. The amounts of hay and concentrate fed to each lamb may be found in table 3 in the section on Experimental Procedure.

TABLE 7

AVERAGE DIGESTION COEFFICIENTS

1951-1952

(Raw and cooked kidney beans vs. shelled corn and linseed meal fed with alfalfa hay)

Ration	No. of Lambs	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	Nitrogen Free Extract	Total Digestible Nutrients
		%	%	%	%	%	%
Raw beans Alfalfa hay	6	71.7 ±1.77 (a)	79.5 ±1.21	42.6 ±2.39	46.8 ±1.68	82.3 ±0.75	60.5 ±0.81
Cooked beans Alfalfa hay	6	71.6 ±1.77	75.0 ±1.21	48.1 ±2.39	51.2 ±1.68	81.9 ±0.75	63.3 ±0.81
Shelled corn Linseed meal Alfalfa hay	6	72.1 ±1.77	77.5 ±1.21	63.1** ±2.39	46.8 ±1.68	83.2 ±0.75	63.2 ±0.81

** Highly significant (1% level)
(a) The error calculated is the standard error of the mean

The average digestion coefficients for the four rations containing raw and cooked cull red kidney beans with and without linseed meal used in trial I in 1953 are reported in table 8. Coefficients secured with individual lambs and details of the rations fed may be found in table 26 and the composition of the feeds used and the feces and orts collected in tables 30 and 31 in the appendix.

TABLE 8

AVERAGE DIGESTION COEFFICIENTS

Trial I - 1953

Ration[1]	No. of Lambs	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	N-free Extract	TDN
		%	%	%	%	%	%
A	4	71.3 ±1.75 (a)	69.3 ±1.77	62.4 ±2.50	47.5 ±3.33	82.3 ±1.39	63.3 ±3.96
B	4	71.3 ±1.75	69.3 ±1.77	60.0 ±2.50	50.7 ±3.33	81.7 ±1.39	63.9 ±3.96
C	4	68.9 ±1.75	67.6 ±1.77	60.8 ±2.50	44.6 ±3.33	80.8 ±1.39	62.5 ±3.96
D	4	70.6 ±1.75	70.9 ±1.77	57.8 ±2.50	48.3 ±3.33	81.7 ±1.39	63.4 ±3.96

(a) Error calculated is the standard error of the mean
(1) Ration: A - Raw red kidney beans. B - Raw beans plus L.O.M. C - Cooked red kidney beans. D - Cooked beans plus L.O.M. Alfalfa hay and corn silage fed to all lambs

Digestion coefficients for raw and cooked cull red kidney beans were determined by difference using data secured in Trial II in 1953. These calculated values are reported in table 9.

TABLE 9

DIGESTION COEFFICIENTS OBTAINED BY DIFFERENCE FOR RAW AND COOKED RED KIDNEY BEANS

Trial II - 1953

Lamb	Type of Beans	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	Nitrogen Free Extract	TDN
		%	%	%	%	%	%
466	Raw	89.7	79.6	25.3	100.0[a]	81.5	78.0
485	Raw	84.0	81.5	39.3	35.9	95.2	74.2
1046	Raw	86.9	87.0	57.1	49.8	94.8	76.4
	Av.	86.9	82.7	40.6	61.9	90.5	76.2
466	Cooked	94.0	81.8	73.8	100.0[a]	83.5	83.7
485	Cooked	94.5	88.7	63.1	98.0	98.5	83.3
1046	Cooked	88.5	78.0	0.0[b]	100.0[a]	95.5	79.4
	Av.	92.3	82.8	45.6	99.3	92.5	82.1
	(c)	±2.63	±4.73			±0.6	±1.77

(a) Values calculated were over 100 per cent
(b) Value calculated was a minus value
(c) The error is the standard error of the difference between means of paired data

Average digestion coefficients for the rations fed in trial II are reported in table 10. Coefficients for individual lambs used in calculating the values for raw and cooked beans may be found in table 27 and the composition of the feeds used and the feces collected in table 32 in the appendix.

Digestion coefficients for raw and cooked cull red kidney beans were determined by difference using data secured in Trial II in 1953. These calculated values are reported in table 9.

TABLE 9

DIGESTION COEFFICIENTS OBTAINED BY DIFFERENCE FOR RAW AND COOKED RED KIDNEY BEANS

Trial II - 1953

Lamb	Type of Beans	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	Nitrogen Free Extract	TDN
		%	%	%	%	%	%
466	Raw	89.7	79.6	25.3	100.0[a]	81.5	78.0
485	Raw	84.0	81.5	39.3	35.9	95.2	74.2
1046	Raw	86.9	87.0	57.1	49.8	94.8	76.4
	Av.	86.9	82.7	40.6	61.9	90.5	76.2
466	Cooked	94.0	81.8	73.8	100.0[a]	83.5	83.7
485	Cooked	94.5	88.7	63.1	98.0	98.5	83.3
1046	Cooked	88.5	78.0	0.0[b]	100.0[a]	95.5	79.4
	Av.	92.3	82.8	45.6	99.3	92.5	82.1
	(c)	±2.63	±4.73			±0.6	±1.77

(a) Values calculated were over 100 per cent
(b) Value calculated was a minus value
(c) The error is the standard error of the difference between means of paired data

Average digestion coefficients for the rations fed in trial II are reported in table 10. Coefficients for individual lambs used in calculating the values for raw and cooked beans may be found in table 27 and the composition of the feeds used and the feces collected in table 32 in the appendix.

TABLE 10

AVERAGE DIGESTION COEFFICIENTS

Trial II - 1953

Ration	No. of Lambs	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	N-free Ex-tract	TDN
		%	%	%	%	%	%
Alfalfa hay	3	61.5* ±0.83(a)	71.9 ±0.93	0.0(b)	46.8* ±0.68	72.9** ±0.38	53.3** ±0.45
Alfalfa hay Raw beans	3	70.2 ±0.83	76.8 ±0.93	13.5	48.8* ±0.68	82.4 ±0.38	61.3 ±0.45
Alfalfa hay Cooked beans	3	72.3 ±0.83	77.0 ±0.93	14.9	53.7 ±0.68	83.3 ±0.38	63.4 ±0.45

* Significant (5% level)
** Highly significant (1% level)
(a) The error calculated is standard error of the mean
(b) All ether extract values for alfalfa hay were minus values

A statistical analysis of the data failed to reveal any striking differences in the various digestion coefficients. A summary of this analysis of variance may be found in table 28 in the appendix.

The apparent digestibility of crude protein, although not significantly different, was the highest for the raw red kidney bean ration in the 1951-52 trial. The cooked beans fed in this trial were cooked by open steam and then dried. They were much lower in moisture when fed than the autoclaved beans fed in the later trials. The differences in crude protein digestibility obtained in trial I in 1953 due to ration were very small but significant differences among lambs were obtained. The two bean rations in trial II in

1953 produced similar crude protein digestion coefficients. The average coefficients calculated by difference for raw red kidney beans and cooked red kidney beans from trial II data were nearly identical; raw beans 82.7 per cent and cooked beans 82.8 per cent.

The results of these studies would not indicate that protein digestibility was a factor for the improved growth obtained in the feed lot when the beans were cooked or when small amounts of linseed meal were fed.

The digestibility of the dry matter in all rations containing red kidney beans, raw or cooked, and with or without linseed meal was similar. The dry matter digestion coefficient for the alfalfa hay ration in trial II in 1953 was significantly lower than the rations containing beans. This should be expected, however, with an all roughage ration. The 61.5 ± 0.83 per cent digestion coefficient obtained for alfalfa was approximately identical with the 61 per cent reported by Schneider (1947) which was an average of 337 trials. The average dry matter digestion coefficient calculated by difference for the raw kidney beans was slightly lower than the one for the cooked beans; 86.9 per cent compared to 92.3 per cent. The differences calculated by data obtained with the same three lambs fed raw and cooked beans during different periods were all in one direction favoring the cooked beans. The higher values for the cooked beans, however, were not significant when analyzed as paired data.

The ether extract digestion coefficients are of interest but probably do not provide much worthwhile information on the problem. Red kidney beans used in these studies contained less than 2.0 per cent ether extract. The ether extract digestion coefficient for the control ration of shelled corn, linseed meal and alfalfa hay used in the 1951-52 trial was enough greater than the ration containing raw kidney beans to be highly significant. The higher ether extract digestion coefficient for corn and linseed meal compared to red kidney beans reported by Schneider (1947) and the low and variable values calculated by difference from trial II - 1953 data would indicate such results should be expected. There were no significant differences between rations containing beans. The average digestion coefficients for ether extract in red kidney beans calculated by difference are similar to those of Schneider (1947). They may not be very reliable due to the great variation of individual values, the low ether extract content of red kidney beans and the limitations of the method.

The average digestion coefficients obtained for crude fiber exhibit some interesting differences. The cooked bean ration produced a slightly higher average crude fiber digestion coefficient during the 1951-52 trial. The difference, however, was not significant. Table 28 in the appendix gives a summary of the analysis of variance for the digestibility data. The average crude fiber digestion coefficients for the two rations containing linseed meal were slightly higher than those rations without linseed. It was

found, however, by an analysis of variance of these data that most of the differences were due to lamb and period differences and very little of the difference was due to the ration. None of the differences were significant but lamb and period differences approached significance.

The average crude fiber digestibility obtained in trial II - 1953 for cooked red kidney beans and alfalfa was significantly higher than a similar ration containing raw red kidney beans. Each of the three lambs digested a greater percentage of the crude fiber in the alfalfa and cooked bean ration than they did in the alfalfa raw bean ration. The non-significant differences obtained in the 1951-52 trial were also in favor of the cooked bean alfalfa hay ration. The 1951-52 trial was conducted with each lamb receiving only one ration while trial II - 1953 was conducted by a 3 x 3 latin square design with each lamb receiving each of the three rations. It should be noted, however, that the crude fiber digestion coefficient for cooked bean ration in trial I - 1953 was slightly but not significantly lower than the coefficient for the raw bean ration.

Ruf, Hule and Burroughs (1953) reported that an unidentified factor in feedstuffs including linseed meal may stimulate cellulose digestion and improve live weight gains in lambs. The small non-significant increased crude fiber digestion noted in trial I - 1953 might have been due to this unidentified factor in the linseed meal.

The crude fiber digestion coefficients calculated by difference for raw and cooked red kidney beans are reported but are not con-

found, however, by an analysis of variance of these data that most of the differences were due to lamb and period differences and very little of the difference was due to the ration. None of the differences were significant but lamb and period differences approached significance.

The average crude fiber digestibility obtained in trial II - 1953 for cooked red kidney beans and alfalfa was significantly higher than a similar ration containing raw red kidney beans. Each of the three lambs digested a greater percentage of the crude fiber in the alfalfa and cooked bean ration than they did in the alfalfa raw bean ration. The non-significant differences obtained in the 1951-52 trial were also in favor of the cooked bean alfalfa hay ration. The 1951-52 trial was conducted with each lamb receiving only one ration while trial II - 1953 was conducted by a 3 x 3 latin square design with each lamb receiving each of the three rations. It should be noted, however, that the crude fiber digestion coefficient for cooked bean ration in trial I - 1953 was slightly but not significantly lower than the coefficient for the raw bean ration.

Ruf, Hule and Burroughs (1953) reported that an unidentified factor in feedstuffs including linseed meal may stimulate cellulose digestion and improve live weight gains in lambs. The small non-significant increased crude fiber digestion noted in trial I - 1953 might have been due to this unidentified factor in the linseed meal.

The crude fiber digestion coefficients calculated by difference for raw and cooked red kidney beans are reported but are not con-

sidered to be valuable. The low fiber content of the beans and the expected differences in crude fiber digestibility on the two levels of alfalfa hay intake probably make these calculations inaccurate.

The nitrogen free extract digestion coefficients for the ration containing red kidney beans used in the 1951-52 trial and trial I and II in 1953 were very similar. The nitrogen free extract digestion coefficient for the alfalfa hay fed in trial II - 1953 was lower than the coefficients for the bean rations in the same trial. This difference was highly significant but the alfalfa hay coefficient of 72.9 ± 0.38 was very similar to those reported by Schneider (1947). The uniformity of all the individual nitrogen free extract digestion coefficients shown by the small standard errors of the means would indicate that the digestion of the nitrogen free extract has little or no influence on the value of the various rations studied.

The nitrogen free extract digestion coefficients of 90.5 per cent and 92.5 per cent calculated for raw and cooked red kidney beans are very similar to the 88 per cent reported by Schneider (1947).

The average total digestible nutrient values expressed as percentages of the air dry intake of the ration containing beans were quite similar. There were no significant differences. The average total digestible nutrient values calculated by difference

in trial II - 1953 were 76.2 per cent for raw red kidney beans and 82.1 per cent for cooked red kidney beans. This difference in favor of the cooked beans was not significant when analyzed as paired data. The t value of 3.33, however, approached the t value of 4.30 needed for significance at the 5 per cent level. The total digestible nutrient values calculated in this study were somewhat higher than the 68 per cent reported by Schneider (1947).

Nitrogen Utilization

Ruminants are less dependent upon the quality of the protein in their ration than non-ruminants. Nitrogen utilization data, however, obtained in conjunction with digestion coefficients has been considered an important aid in measuring the nutritive value of a ration for ruminants. The averages for the grams of nitrogen retained, the per cent of absorbed nitrogen retained, the per cent of dietary nitrogen retained, the estimated true digestibility of the nitrogen and the calculated biological values are reported in table 11 for trial I - 1953. The individual lamb values for these same items as well as for the grams of nitrogen consumed and the grams of nitrogen absorbed may be found in table 33 in the appendix.

TABLE 11

AVERAGE NITROGEN UTILIZATION

Trial I - 1953

Ration[1]	No. of Lambs	Nitrogen Retained	Absorbed Nitrogen Retained	Dietary Nitrogen Retained	True Dig. (Estimated)	Biological Value
		gm.	%	%	%	
A	4	38.0	31.4 ±2.87[a]	22.2 ±2.62	92.6 ±1.39	56 ±1.35
B	4	45.6	32.6 ±2.87	23.9 ±2.62	93.2 ±1.39	54 ±1.35
C	4	35.2	28.9 ±2.87	20.2 ±2.62	90.0 ±1.39	55 ±1.35
D	4	47.9	35.2 ±2.87	24.9 ±2.62	91.1 ±1.39	56 ±1.35

(a) The error calculated is the standard error of the mean
(1) Ration: A - Raw red kidney beans
B - Raw red kidney beans plus L.O.M.
C - Cooked red kidney beans
D - Cooked red kidney beans plus L.O.M.
Alfalfa hay and corn silage fed to all lambs

Average nitrogen utilization data for trial II - 1953 may be found in table 12. Data for individual lambs will be found in table 34 in the appendix.

In order to obtain one figure to express the value of the protein as found in the raw and cooked beans, biological values were calculated by difference from data secured in trial II - 1953. All biological values were calculated by using the Thomas-Mitchell method.

TABLE 12

AVERAGE NITROGEN UTILIZATION

Trial II - 1953

Ration[1]	No. of Lambs	Nitrogen Retained	Absorbed Nitrogen Retained	Dietary Nitrogen Retained	True Dig. (Estimated)	Biological Value
		gm.	%	%	%	
A	3	38.4	31.3 ±1.46[a]	22.5 ±1.18	92.1 ±0.89	53 ±0.47
B	3	43.4	27.8 ±1.46	21.3 ±1.18	93.7 ±0.89	46 ±0.47
C	3	49.7	31.0 ±1.46	24.0 ±1.18	93.8 ±0.89	49 ±0.47

(a) The error calculated is the standard error of the mean
(1) Ration: A - Alfalfa hay only
B - Alfalfa and raw kidney beans
C - Alfalfa and cooked kidney beans.

The values used for metabolic fecal nitrogen and endogenous urinary nitrogen are shown in the section on experimental procedure. These calculated biological values for raw and cooked beans are reported in table 13.

TABLE 13

BIOLOGICAL VALUES OBTAINED BY DIFFERENCE FOR RAW AND COOKED RED KIDNEY BEANS

Trial II - 1953

Lamb	Type of Beans	Biological Value	Lamb	Type of Beans	Biological Value
466	Raw	37	466	Cooked	52
485		36	485		49
1046		41	1046		28
		38 av.			43 av.

Further information on nitrogen utilization may be indicated by the weight changes of the lambs while being fed the various bean rations. These weight changes expressed in kilograms may be found in table 36 for trial I - 1953 and table 37 for trial II in the appendix. Most lambs made slight gains on the test rations but three of the four lambs used in trial I - 1953 when fed raw beans, and corn without linseed meal failed to gain or lost weight. It was always harder to keep the lambs receiving raw beans eating well.

The per cent of the absorbed nitrogen retained was similar for all the rations fed in both trial I and trial II in 1953. By analyzing the data statistically, a summary of which may be found in table 35, it was shown that the various rations caused very little difference. Significant differences were found among lambs, however, in their ability to retain the nitrogen absorbed in both trial I and trial II.

An example of these lamb differences may be shown by examining the data for lamb 1046 in appendix tables 33 and 34. At times, this lamb failed to absorb nitrogen or retain nitrogen as well as the other lambs in the trials. The biological value for cooked beans calculated by difference with the data secured with lamb 1046 was very low because its best utilization of nitrogen was for the alfalfa hay ration and the poorest for the alfalfa and cooked bean ration in trial II - 1953.

The nitrogen in the rations as fed was retained about equally well for all rations. There were no significant differences for the per cent of dietary nitrogen retained by the lambs on the various test rations.

The true digestibility of the nitrogen in the various rations was calculated by using the estimated metabolic fecal nitrogen of 0.55 grams for each 100 grams of dry matter intake as described in the experimental procedure. These average estimated true digestibility coefficients for nitrogen were uniform and not significantly different.

The four average biological values (Thomas-Mitchell method) calculated with the data from trial I - 1953 were around 55 and not significantly different. The average biological values calculated with data from trial II - 1953 varied somewhat but were not significantly different. They were somewhat lower, however, than those for trial I. The test rations in trial I, which were similar to the feed lot rations, contained corn and corn silage and less alfalfa hay and beans. In trial II the biological values for the alfalfa hay ration were higher for all lambs than the rations containing either raw or cooked red kidney beans. This condition caused the biological values calculated by difference for raw and cooked red kidney beans to be relatively low. The average biological value of 38 obtained for raw red kidney beans and the 43 for cooked red kidney beans were not significantly different. The

extremely low value of 28 for cooked red kidney beans calculated for lamb 1046 was entirely out of line with the values for other lambs.

The analysis of variance summarized in table 35 in the appendix shows the differences in biological values calculated in both trial I and trial II - 1953. The differences among lambs and periods were greater than those among rations. Significant differences were obtained among lambs in trial I.

The data secured in these two trials shows little difference in the utilization of the nitrogen among rations containing raw and cooked red kidney beans with or without added linseed meal. The biological values obtained in these studies were somewhat lower than the 60 predicted by Johnson, Hamilton, Mitchell, and Robinson (1942) for ruminants regardless of the ration fed.

Amino Acid Content of Red Kidney Beans

The estimated amino acid content of the raw and cooked cull red kidney beans used in the 1951-52 digestion trial are reported in grams per 100 grams of feed in table 14. In order to compare these values with published values for other feeds, they were also converted to grams of each amino acid for one hundred grams of dry matter and for sixteen grams of nitrogen (per cent protein).

The differences in the individual amino acid values for raw and cooked red kidney beans are very small. When compared to values for soya beans reported by Block and Mitchell (1947), the

red kidney beans are lower in all the amino acids reported except leucine, lysine and valine. This comparison was on a basis of grams of the amino acid for each sixteen grams of nitrogen. Methionine appears to be very low in red kidney beans. Williams (1947), however, stated that his methionine values for soybean oil meal were about one-half those reported by other workers and he was unable to offer an explanation.

A comparison of the amino acid values for linseed oil meal and red kidney beans obtained in the same laboratory by the same procedures showed that linseed meal was higher for all the amino acids estimated, except lysine. Linseed meal, however, was higher in protein content.

TABLE 14

AMINO ACID CONTENT OF RAW AND COOKED RED KIDNEY BEANS

(Other feeds listed for comparison)

Amino Acid	Raw Red Kidney Beans(1)			Cooked Red Kidney Beans(2)			Soya Bean	LCM
	gm. per 100 gm. of feed	gm. per 100 gm. of D.M.	gm. per 16 gm. of N	gm. per 100 gm. of feed	gm. per 100 gm. of D.M.	gm. per 16 gm. of N	gm. per 16 gm. of N	gm. per 100 gm. of feed
	(3)	(4)	(5)	(3)	(4)	(5)	(6)	(7)
Arginine	1.43	1.62	5.88	1.27	1.39	5.03	7.1	3.60
Histidine	0.58	0.66	2.39	0.60	0.66	2.38	2.3	0.78
Isoleucine	1.20	1.36	4.85	1.18	1.29	4.67	4.7	1.53
Leucine	1.87	2.12	7.69	1.84	2.01	7.29	6.6	2.30
Lysine	2.24	2.54	9.22	2.12	2.32	8.40	5.8	1.77
Methionine	0.25	0.28	1.03	0.23	0.25	0.91	2.0	0.30
Phenylalanine	1.30	1.48	5.35	1.30	1.42	5.15	5.7	1.54
Threonine	0.86	0.98	3.53	0.80	0.96	3.49	4.0	1.40
Valine	1.44	1.63	5.93	1.41	1.54	5.59	4.2	1.94
Tryptophan	0.26	0.29	1.07	0.26	0.28	1.03	1.2	0.60
Tyrosine	0.68	0.77	2.80	0.65	0.71	2.57	4.1	0.84

(1) Raw red kidney beans were 24.30% protein, 11.92 moisture
(2) Cooked red kidney beans were 25.24% protein, 8.86% moisture
(3) Grams per 100 grams of feed is the value reported by Dr. H. H. Williams
(4) Grams per 100 grams of dry matter was calculated
(5) Grams per 16 grams of nitrogen was calculated
(6) Value reported by Block and Mitchell (1947)
(7) Value reported by Williams (1950)

SUMMARY

Several thousand tons of the discolored, split, and broken beans sorted out during the processing of dry beans for human food are available annually for feeding livestock. The states of Michigan and New York have about ten thousand tons of these "cull beans" each year. The nutrient content of "cull beans" may be similar to concentrates frequently fed to livestock, but the feeding value appears to be lower.

A feed lot trial, a digestibility trial, two combined nitrogen utilization and digestibility studies, and an amino acid composition analysis were conducted to determine how cooking and the addition of linseed meal improved the feeding value of cull red kidney beans and if further improvement was possible. Work with lambs at the Cornell Agricultural Experiment Station indicated that cooking the beans, adding linseed meal, or a combination of the two, produced higher feed lot gains than those obtained with raw beans.

A basal concentrate mixture of equal parts of shelled corn and cull red kidney beans was fed to 105 lambs in five lots. The value of cooking the beans, adding 0.10 of a pound of linseed meal to cooked or raw beans and adding dried brewers' yeast to raw beans was studied. Both cooking the beans and adding linseed meal in-

creased the daily gains and shortened the feeding period. Brewers' dried yeast failed to be a satisfactory substitute for linseed meal. Highly significant differences in gains were found among rations. The variation in feed intake among lots appeared to be a major reason for differences in gains.

A comparison of the digestibility of the dry matter, crude protein and the non-nitrogenous nutrients in three studies failed to show any large differences in digestibility among rations containing raw and cooked red kidney beans with or without linseed meal added. The only significant difference was the higher crude fiber digestion coefficient for an alfalfa and cooked red kidney bean ration compared to a ration of alfalfa and raw beans. Results obtained with other rations, though not significant, indicated that cooking the beans or adding linseed meal may slightly influence the crude fiber digestibility of the entire ration.

The digestion coefficients calculated by difference for raw red kidney beans were: dry matter 86.9, crude protein 82.7, ether extract 50.6, crude fiber 61.9, and nitrogen free extract 90.5. The corresponding values for cooked beans were: dry matter 92.3, crude protein 82.8, ether extract 45.6, crude fiber 99.3, and nitrogen free extract 92.5. The values for crude fiber and ether extract are reported, but may not be dependable because red kidney beans contain only small amounts of these nutrients. The total digestible nutrient percentages were 76.2 for raw beans and 82.1 for cooked beans.

Nitrogen utilization in addition to digestibility was studied with the lambs on the two 1953 trials. An analysis of the data on grams of nitrogen retained, the per cent of absorbed nitrogen retained, the per cent of dietary nitrogen retained, and biological values determined by the Thomas-Mitchell method failed to show significant differences among rations. There were, however, a few significant differences among the lambs used and the collection periods.

A microbiological amino acid analysis demonstrated that cooking did not appreciably alter the amino acid content of red kidney beans. They were, however, low in a number of amino acids, especially methionine and tryptophan.

After analyzing all phases of this study, it appeared that the faster gains which resulted from changing a cull red kidney bean ration by adding linseed meal or cooking the beans were due primarily to greater feed intake.

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APPENDIX

TABLE 15

CULL BEANS FOR FATTENING LAMBS 1946-47

November 22 - January 31

	Sh. Corn Corn Silage Hay 0.25# LOM 0.20# Ca., Salt	Sh. Corn Cull Beans Corn Silage Hay 0.25# Ca., Salt	Sh. Corn Cull Beans Corn Silage Hay 0.25# Ca., Salt	Sh. Corn Cull Beans Corn Silage Hay 0.25# Ca., Salt	Cull Beans Corn Silage Hay 0.25# Ca., Salt
Lot No.	VII	VIII	IX	X	XI
Lambs per lot	20	19.8	19.8	19.6	19.4
Days lambs were fed	70	70	70	70	70
Av. init. wt. . . . .lbs	61.9	61.8	61.7	61.6	62.1
Av. final wt. . . . .lbs	83.8	80.6	73.1	70.3	69.6
Av. gain per lamb . .lbs	21.9	17.3	10.7	7.0	7.9
Av. daily gain. . . .lbs	0.31	0.25	0.15	0.10	0.11
Av. daily ration:					
Sh. corn. . . . . .lbs	.85	.73	.34	.16	.04
Cull beans. . . . .lbs	---	.23	.29	.37	.45
Linseed meal. . . .lbs	.16	.01	---	---	---
Whole oats. . . . .lbs	.002	.002	.002	.002	.002
Alfalfa hay . . . .lbs	.25	.25	.25	.25	.25
Corn silage . . . .lbs	4.01	3.33	3.92	3.84	3.89
Gr. limestone . . .lbs	.02	.02	.02	.02	.02
Salt. . . . . . . .lbs	.029	.03	.03	.03	.026
Am't. of feed per cwt. gain:					
Sh. corn. . . . . .lbs	274.1	294.7	221.8	163.3	38.4
Cull beans. . . . .lbs	---	92.1	188.7	367.7	399.8
Linseed meal. . . .lbs	51.1	4.39	---	---	---
Whole oats. . . . .lbs	.69	.88	1.42	2.19	1.96
Alfalfa hay . . . .lbs	79.6	100.4	162.0	248.0	219.8
Corn silage . . . .lbs	1286.7	1349.6	2563.4	3842.8	3454.5
Gr. limestone . . .lbs	5.73	8.11	13.08	19.8	18.11
Salt. . . . . . . .lbs	9.4	11.99	19.34	29.93	23.53

TABLE 16

CULL BEANS FOR FATTENING LAMBS 1946-47

January 31 - April 18

	Sh. Corn Cull Beans Corn Silage Hay 0.25# Ca., Salt	Sh. Corn Cull Beans Corn Silage Hay 0.25# LOM 0.17# Ca., Salt	Sh. Corn Cull Beans Corn Silage Hay 0.25# LOM 0.17# Ca., Salt	Sh. Corn Cull Beans Corn Silage Hay 0.70# LOM 0.60# Ca., Salt
Lot No.	VIII	IX	X	XI
Lambs per lot	19	19	18	18
Days lambs were fed .	77	77	77	77
Av. init. wt. . . . . .lbs	80.6	73.1	70.3	69.6
Av. final wt. . . . . .lbs	92.6	103.6	100.7	101.9
Av. gain per lamb . .lbs	11.9	30.5	30.4	32.4
Av. daily gain. . . .lbs	0.16	0.40	0.39	0.42
Av. daily ration:				
Sh. corn. . . . . . . .lbs	.70	.47	.63	.75
Cull beans. . . . . . .lbs	.23	.47	.21	.25
Linseed meal. . . . .lbs	---	.17	.17	.10
Alfalfa hay . . . . .lbs	.25	.25	.25	.70
Corn silage. . . . .lbs	3.35	4.17	4.09	3.04
Gr. limestone . . .lbs	0.02	0.02	0.02	0.01
Salt. . . . . .lbs	0.03	0.035	0.045	0.019
Am't. of feed per cwt. gain:				
Sh. corn. . . . . . .lbs	452.6	117.5	159.9	177.6
Cull beans. . . . . .lbs	151.0	117.5	53.3	59.2
Linseed meal. . . .lbs	---	42.5	42.8	24.1
Alfalfa hay . . . . .lbs	161.1	63.2	63.3	166.4
Corn silage . . . . .lbs	2157.2	1052.5	1035.5	722.8
Gr. limestone . . .lbs	13.6	5.0	5.03	2.35
Salt. . . . . .lbs	18.1	8.79	11.33	4.51

TABLE 17

CULL BEANS FOR FATTENING LAMBS 1947-48

	Sh. Corn Cull Beans Hay 0.28# Corn Silage Ca., Salt	Sh. Corn Cull Beans LOM 0.17# Hay 0.28# Corn Silage Ca., Salt	Sh. Corn Cull Beans Hay 0.28# Corn Silage Ca., Salt Co-Cu	Sh. Corn Cull Beans LOM Hay 0.70# Corn Silage Ca., Salt	Sh. Corn Cull Beans LOM Hay 0.28# Corn Silage Ca., Salt
Lot No.	VI	VII	VIII	IX	X
Lambs per lot	22.69	23.38	24.00	24.00	22.54
Days lambs were fed .	112.0	112.0	112.0	112.0	112.0
Av. init. wt. . . . .lbs	62.0	62.1	61.9	62.1	62.0
Av. final wt. . . . .lbs	90.5	95.7	91.9	96.1	92.6
Av. gain per lamb . .lbs	28.2	33.3	30.0	34.0	30.3
Av. daily gain. . ..lbs	0.252	0.297	0.267	0.304	0.271
Av. daily rations					
Sh. corn. . . . . .lbs	0.67	0.69	0.69	0.74	0.44
Cull beans. . . . .lbs	0.22	0.23	0.23	0.25	0.42
Whole oats. . . . .lbs	0.005	0.005	0.005	0.005	0.005
Linseed meal. . . .lbs	---	0.17	---	0.09	0.08
Corn silage . . . .lbs	3.25	3.08	3.02	2.22	3.12
Alfalfa hay . . . .lbs	0.28	0.28	0.28	0.72	0.28
Gr. limestone . . .lbs	0.02	0.02	0.02	0.01	0.02
Salt. . . . . . . .lbs	0.026	0.020	0.031	0.021	0.027
Am't. of feed per cwt. gain:					
Sh. corn. . . . . .lbs	266.2	230.8	258.2	244.0	162.9
Cull beans. . . . .lbs	87.8	76.5	85.4	80.9	156.3
Whole oats. . . . .lbs	2.03	1.67	1.81	1.59	1.9
Linseed meal. . . .lbs	---	55.7	---	30.6	27.94
Corn silage . . . .lbs	1289.2	1035.9	1129.6	729.9	1151.2
Alfalfa hay . . . .lbs	111.1	93.8	104.0	238.5	104.5
Gr. limestone . . .lbs	7.97	6.19	7.72	3.06	6.99
Salt. . . . . . . .lbs	10.31	6.81	11.68	6.85	9.94
Feed cost per cwt. gain$	21.24	20.88	20.08	21.25	18.25
Init. cost per cwt. . $	23.84	23.84	23.84	23.84	23.84
Grade on foot	2.73(a)	2.87(a)	3.04(a)	2.62(a)	2.64(a)
Est. S.P. per cwt.. . $	20.95	21.06	21.17	20.88	20.90
Init. cost per lamb . $	14.78	14.80	14.76	14.80	14.78
Cost of feed per lamb $	5.99	6.95	6.02	7.22	5.53
Total cost per lamb . $	21.47	22.45	21.48	22.72	20.01
Est. S.P. per lamb. . $	18.96	20.15	19.16	20.07	19.35
Net return per lamb . $	-2.51	-2.30	-2.62	-2.65	-1.66

(a) Grades (based on fatness): 4-choice; 3-good; 2-medium

TABLE 18

CULL BEANS FOR FATTENING LAMBS 1948-49

	Sh. Corn LOM .10# Hay 1.0# Corn Silage Salt	Sh. Corn Cull Beans Hay 1.0# Corn Silage Salt	Sh. Corn Cull Beans LOM .10# Hay 1.0# Corn Silage Salt	Sh. Corn Cull Beans LOM .10# Hay 1.0# Corn Silage Salt
Lot No.	VII	VIII	IX	X
Lambs per lot	24	24	24	23.1
Days lambs were fed .	112	112	112	112
Av. init. wt. . . . . .lbs	63.2	64.2	63.5	64.3
Av. final wt. . . . . .lbs	97.3	94.4	96.8	93.7
Av. daily gain. . . .lbs	0.305	0.270	0.297	0.260
Av. daily ration:				
Sh. corn. . . . . . .lbs	1.16	0.87	0.85	0.56
Cull beans. . . . .lbs	---	0.29	0.28	0.55
Linseed meal. . . .lbs	0.10	---	0.10	0.10
Clover hay. . . . .lbs	1.00	1.00	1.00	1.01
Corn silage . . . .lbs	1.31	1.28	1.22	1.29
Salt. . . . . .lbs	0.017	0.019	0.019	0.021
Am't. of feed per cwt. gain:				
Sh. corn. . . . . . .lbs	380.4	323.4	287.3	215.9
Cull beans. . . . .lbs	---	107.1	95.3	211.3
Linseed meal. . . .lbs	31.3	---	32.2	36.9
Clover hay. . . . .lbs	327.8	370.8	336.8	386.8
Corn silage . . . .lbs	430.6	474.8	409.1	496.6
Salt. . . . . .lbs	5.46	7.05	6.35	8.12
Feed cost per cwt. gain $	18.01	16.74	16.25	16.38
Init. cost per cwt. . $	23.72	23.72	23.72	23.72
Grade on foot	3.46 (a)	3.21 (a)	3.04 (a)	3.17 (a)
Est. S.P. per cwt... $	24.06	23.76	23.60	23.72
Init. cost per lamb . $	14.99	15.23	15.06	15.25
Cost of feed per lamb $	6.14	5.06	5.41	4.82
Total cost per lamb . $	21.13	20.29	20.47	20.07
Est. S.P. per lamb. . $	23.41	22.43	22.84	22.23
Net return per lamb . $	2.28	2.14	2.37	2.16

(a) Grades (based on fatness): 4-choice; 3-good; 2-medium

TABLE 19

CULL BEANS FOR FATTENING LAMBS 1949-50

	Sh. Corn LOM 0.10# Hay 0.75# Corn Silage Salt	Sh. Corn Cull Beans LOM 0.10# Hay 0.75# Corn Silage Salt	Sh. Corn Cull Beans LOM 0.20# Hay 0.75# Corn Silage Salt	Sh. Corn Cull Beans A.A. Mix.0.10#(a) Hay 0.75# Corn Silage Salt
Lot No.	XI	XIII	XIV	XV
Lambs per lot	24	24	24	24
Days lambs were fed .	110	110	110	110
Av. init. wt. . . . . .lbs	64.8	65.7	66.5	66.0
Av. final wt. . . . . .lbs	101.8	97.2	101.2	98.8
Av. gain per lamb . .lbs	37.0	31.5	34.7	32.8
Av. daily gain. . . .lbs	.336	.287	.315	.297
Av. daily ration:				
Sh. corn. . . . . .lbs	1.03	.49	.47	.49
Cull beans. . . . .lbs	---	.48	.46	.48
Linseed meal. . . .lbs	.095	.094	.180	---
Amino acid mixture.lbs	---	---	---	.077
Alfalfa hay . . . .lbs	.75	.75	.75	.75
Corn silage . . . .lbs	2.17	2.12	2.27	2.16
Salt. . . . . .lbs	.012	.009	.009	.006
Am't. of feed per cwt. gain:				
Sh. corn. . . . . .lbs	307.3	168.9	150.4	166.2
Cull beans. . . . .lbs	---	165.7	147.3	162.4
Linseed meal. . . .lbs	28.4	32.9	57.3	---
Amino acid mixture.lbs	---	---	---	25.9
Alfalfa hay . . . .lbs	224.3	262.1	238.8	253.1
Corn silage . . . .lbs	647.9	739.7	720.2	725.2
Salt. . . . . .lbs	3.48	3.09	2.70	2.17
Feed cost per cwt. gain$	16.09	14.72	14.55	14.12
Init. cost per cwt. . $	24.86	24.86	24.86	24.86
Grade on foot	3.29(b)	3.08(b)	2.96(b)	3.12(b)
Est. S.P. per cwt.. . $	27.14	26.92	26.82	26.95
Init. cost per lamb . $	16.11	16.33	16.53	16.41
Cost of feed per lamb $	5.97	4.64	5.05	4.63
Total cost per lamb . $	22.08	20.97	21.58	21.04
Est. S.P. per lamb. . $	27.63	26.17	27.14	26.63
Net return per lamb . $	5.55	5.20	5.56	5.59

(a) The amino acid mixture (A.A.) is a by-product in the manufacturing of mono sodium glutamate and contained about 56% protein. It was supplied through the courtesy of Internation Minerals and Chemical Corporation, Chicago, Ill.

(b) Grades (based on fatness): 4-choice; 3-good; 2-medium

TABLE 20

CULL BEANS FOR FATTENING LAMBS 1950-51

	Sh. Corn Corn Silage LOM 0.10# Hay 0.75# (2)Co-Cu Salt	Sh. Corn(1) Cull Beans (raw) Corn Silage LOM 0.20# Hay 0.75# Co-Cu Salt	Sh. Corn(1) Cull Beans (raw) Corn Silage LOM 0.20# Hay 0.75# Co-Cu Salt	Sh. Corn(1) Cull Beans (cooked) Corn Silage LOM 0.20# Hay 0.75# Co-Cu Salt	Sh. Corn(1) Cull Beans (cooked) Corn Silage Hay 0.75# Co-Cu Salt
Lot No.	XI	XII	XIII	XIV	XV
Lambs per lot	21	21	21	21	21
Days lambs were fed .	76	76	76	76	76
Av. init. wt. . . . . .lbs	72.1	71.8	71.9	71.8	72.2
Av. final wt. . . . . .lbs	100.1	96.9	96.3	99.0	96.5
Av. gain per lamb . .lbs	28.0	25.0	24.4	27.3	24.3
Av. daily gain. . . .lbs	0.37	0.33	0.32	0.36	0.32
Av. daily ration:					
Sh. corn. . . . . . .lbs	1.17	0.53	0.48	0.59	0.69
Cull beans. . . . .lbs	---	0.43	0.38	0.47	0.55
Linseed oil meal. .lbs	0.098	0.186	---	0.186	---
S.O.M. . . . . . . .lbs	---	---	0.182	---	---
Alfalfa hay . . . .lbs	0.75	0.75	0.75	0.75	0.75
Corn silage . . . .lbs	1.93	2.24	2.38	2.12	1.67
CoCu Salt . . . . . .lbs	0.015	0.02	0.015	0.02	0.014
Am't. of feed per cwt. gain:					
Sh. corn. . . . . . .lbs	316.0	160.6	149.8	163.4	214.4
Cull beans. . . . .lbs	---	128.8	119.6	129.2	171.3
Linseed oil meal. .lbs	26.5	56.1	---	51.7	---
S.O.M. . . . . . . .lbs	---	---	56.7	---	---
Alfalfa hay . . . .lbs	203.3	227.6	233.8	208.9	234.3
Corn silage . . . .lbs	520.2	667.2	738.7	588.5	518.6
Co-Cu Salt . . . .lbs	4.0	5.97	4.73	5.58	4.29
Feed cost per cwt. gain$	15.66	14.00	13.80	13.36	13.33
Init. cost per cwt. . $	33.36	33.36	33.36	33.36	33.36
Grade on foot	3.05(a)	2.90(a)	2.76(a)	2.95(a)	3.10(a)
Est. S.P. per cwt. . $	35.50	35.30	35.13	35.42	35.56
Init. cost per lamb . $	24.05	23.96	23.99	23.94	24.08
Cost of feed per lamb $	4.39	3.51	3.37	3.65(b)	3.04(b)
Total cost per lamb . $	28.44	27.47	27.36	27.59	27.32
Est. S.P. per lamb. . $	34.13	32.68	32.17	33.28	32.67
Net return per lamb . $	5.69	5.21	4.81	5.69	5.35

(1) Corn and cull beans fed in equal parts by weight the first 42 days and 6 parts corn to 4 parts cull beans by weight thereafter.

(2) Co supplied at the rate of 3/4 oz. per 100# salt (21 g. of $Co\ cl_2\ 6^{H}20$)
Cu supplied at the rate of 2¼ oz. per 100# salt (63 g. of $Cu\ s^{O}4\ 5^{H}20$)

(a) Graded (based upon fatness): 4-choice; 3-good; 2-medium

(b) The cost of feed does not include a charge for cooking the beans.

TABLE 21

CULL BEANS FOR FATTENING LAMBS 1951-52

	Sh. Corn LOM 0.10# Hay 0.75# Silage Salt	Sh. Corn Cull Beans LOM 0.10# Hay 0.75# Silage Salt	Sh. Corn Cull Beans Brewers' Yeast 0.08# Hay 0.75# Silage Salt	Sh. Corn Cull Beans LOM 0.10#* Hay 0.75# Silage Salt	Sh. Corn LOM 0.10#* Hay 0.75# Silage Salt
Lot No.	XI	XII	XIII	XIV	XV
Lambs per lot	21	21	21	21	21
Days lambs were fed .	83	83	83	83	83
Av. init. wt. . . . . .lbs	75.4	74.6	74.2	74.3	74.3
Av. final wt. . . . . .lbs	103.5	104.8	101.8	99.1	103.2
Av. gain per lamb . .lbs	28.1	30.2	27.5	24.9	28.9
Av. daily gain . . .lbs	0.338	0.364	0.332	0.299	0.348
Av. daily ration:					
Sh. corn. . . . . . .lbs	1.13	0.57	0.58	0.56	1.13
Cull beans. . . . . .lbs	---	0.56	0.57	0.55	---
Linseed meal. . . .lbs	0.097	0.097	---	---	---
LOM & aureomycin. .lbs	---	---	---	0.096	0.097
Brewers' yeast. . .lbs	---	---	0.08	---	---
Alfalfa hay . . . .lbs	0.79	0.79	0.79	0.79	0.79
Corn silage . . . .lbs	2.88	3.19	2.82	2.69	2.67
Salt. . . . . .lbs	0.015	0.015	0.013	0.015	0.018
Am't. of feed per cwt. gain:					
Sh. corn. . . . . . .lbs	333.62	156.82	174.03	187.51	324.28
Cull beans. . . . . .lbs	---	154.30	171.26	184.44	---
Linseed meal. . . .lbs	28.78	26.78	---	---	---
LOM & aureomycin. .lbs	---	---	---	32.14	27.97
Brewers' yeast. . .lbs	---	---	24.27	---	---
Alfalfa hay . . . .lbs	232.41	216.28	237.24	262.69	225.91
Corn silage . . . .lbs	850.00	877.76	850.52	898.28	767.87
Salt. . . . . .lbs	4.58	4.26	3.81	5.17	5.27
Feed cost per cwt. gain $	21.07	16.04	19.52	18.58	20.21
Init. cost per cwt. . $	33.79	33.79	33.79	33.79	33.79
Grade on foot	2.71(a)	2.76(a)	2.86(a)	2.52(a)	2.86(a)
Est. S.P. per cwt. . $	29.00	29.03	29.11	28.78	29.15
Init. cost per lamb . $	25.47	25.20	25.09	25.10	25.10
Feed cost per lamb . $	5.29	4.84	5.37	4.62(b)	5.84(b)
Total cost per lamb . $	31.39	30.04	30.46	29.72	30.94
Est. S.P. per lamb. . $	30.01	30.41	29.62	28.54	30.08
Net return per lamb . $	-1.38	0.37	-0.84	-1.18	-0.86

* Linseed meal contained Aurofac A which contained 1.8 grams of aureomycin per pound. Aurofac was added at the rate of 884 grams per 100 pounds of linseed meal. Lot XIV was fed this amount for two weeks and then the amount was reduced to 442 grams per 100 pounds of LOM.

(a) Grades (based on fatness): 4-prime; 3-choice; 2-good.

(b) Cost of feed per lamb does not include a charge for Aurofac A.

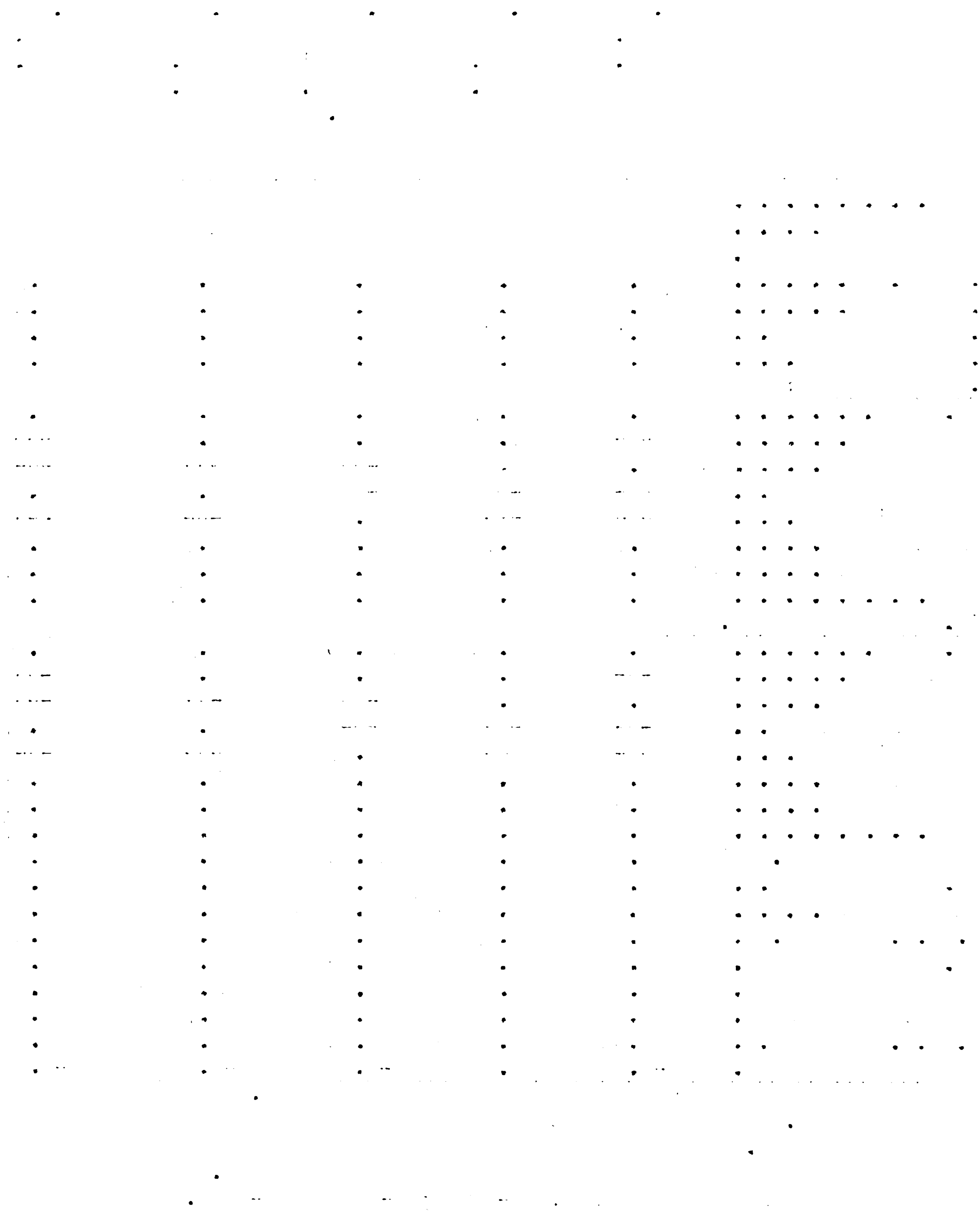

TABLE 22

AVERAGE FEED INTAKE AND DAILY GAIN

Feed Lot Trial 1952-53

	Period (14 Days)	Average Daily Ration: Shelled Corn	Raw Beans	Linseed Meal	Corn Silage(1)	Alfalfa Hay	Total Daily Feed	Per Cent NRC Allowance(2)	Av. Lamb Wt.	Av. Daily Gain
		lb.	lb.	lb.	lb.	lb.	lbs.	%	lbs.	lb.
Lot XI	1	.26	.22	.08	.55	.74	1.85	84.1	56.2	.28
	2	.32	.32	.10	.61	.75	2.10	91.3	59.7	.20
	3	.43	.43	.10	.65	.75	2.36	98.3	62.4	.21
	4	.53	.53	.10	.28	.75	2.19	87.6	65.9	.28
	5	.55	.55	.10	.33	.75	2.28	84.4	70.6	.39
	6	.61	.61	.10	.35	.75	2.42	86.4	75.4	.30
	7	.66	.66	.10	.38	.75	2.55	87.9	80.4	.41
	8	.69	.69	.10	.37	.75	2.60	86.7	85.8	.29
	9	.71	.71	.10	.40	.76	2.68	89.3	90.5	.34
	Av.	.52	.52	.098	.44	.75	2.34	88.4		.30
Lot XII	1	.30	.23		.54	.74	1.81	82.3	55.3	.15
	2	.36	.36		.55	.75	2.02	87.8	57.8	.20
	3	.44	.44		.42	.75	2.05	89.1	59.9	.11
	4	.52	.52		.31	.75	2.10	87.5	62.3	.23
	5	.47	.47		.37	.77	2.08	83.2	65.6	.23
	6	.52	.52		.38	.75	2.17	80.4	69.5	.33
	7	.57	.57		.39	.78	2.31	82.5	74.3	.35
	8	.60	.60		.41	.75	2.36	81.3	78.5	.25
	9	.61	.61		.44	.75	2.41	83.0	82.6	.29
	10	.61	.61		.44	.75	2.41	80.3	87.3	.36
	11	.61	.61		.44	.75	2.42	80.6	90.9	.15
	Av.	.50	.50		.43	.75	2.18	83.4		.238

(1) Corn silage weight is on an air dry basis.
(2) Per cent NRC allowance is the percentage of the National Research Council recommended total feed, air dry basis, given for fattening lambs of corresponding weights (Aug. 1949).

TABLE 23

AVERAGE FEED INTAKE AND DAILY GAIN

Feed Lot Trial 1952-53

	Period (14 Days)	Average Daily Ration: Shelled Corn	Cooked Beans	Linseed Meal	Corn Silage(1)	Alfalfa Hay	Total Daily Feed	Per Cent NRC Allowance(2)	Av. Lamb Wt.	Av. Daily Gain
		lb.	lb.	lb.	lb.	lb.	lbs.	%	lbs.	lb.
Lot XIII	1	.26	.22	.08	.55	.74	1.85	84.0	56.3	.28
	2	.32	.32	.10	.64	.75	2.13	92.6	60.0	.28
	3	.43	.43	.10	.59	.75	2.30	95.8	63.3	.20
	4	.53	.53	.10	.38	.75	2.50	96.1	67.3	.36
	5	.56	.56	.10	.46	.75	2.43	86.8	72.9	.45
	6	.62	.62	.10	.48	.75	2.57	88.6	78.7	.37
	7	.68	.68	.10	.44	.75	2.65	91.3	84.3	.43
	8	.72	.72	.10	.44	.75	2.73	91.0	89.4	.29
	9(a)	.74	.74	.10	.46	.75	2.79	93.0	92.5	.32
	Av.	.53	.52	.097	.49	.75	2.40	91.0		.33
Lot XIV	1	.30	.23		.59	.74	1.86	84.5	56.6	.35
	2	.36	.36		.70	.75	2.17	94.3	60.4	.21
	3	.48	.48		.56	.75	2.27	94.6	63.6	.24
	4	.57	.57		.37	.75	2.26	86.9	67.2	.27
	5	.61	.61		.37	.75	2.48	91.8	71.5	.35
	6	.67	.67		.39	.75	2.48	88.6	76.8	.39
	7	.73	.73		.39	.75	2.60	89.6	82.4	.42
	8	.77	.77		.38	.75	2.67	89.0	87.0	.24
	9	.79	.79		.38	.75	2.71	90.3	91.3	.36
	Av.	.59	.58		.47	.75	2.39	89.9		.315

(a) Only 7 days in this weigh period.
(1) Corn silage weight is on an air dry basis.
(2) Per cent NRC allowance is the percentage of the National Research Council recommended total feed, air dry basis, given for fattening lambs of corresponding weights (Aug. 1949).

TABLE 24

AVERAGE FEED INTAKE AND DAILY GAIN

Feed Lot Trial 1952-53

	Period (14 Days)	Average Daily Ration: Shelled Corn	Raw Beans	Brewers' Yeast	Corn Silage(1)	Alfalfa Hay	Total Daily Feed	Per Cent NRC Allowance(2)	Av. Lamb Wt.	Av. Daily Gain
		lb.	lb.	lb.	lb.	lb.	lbs.	%	lbs.	lb.
Lot XV	1	.26	.22	.069	.54	.74	1.83	83.2	55.2	.14
	2	.32	.32	.081	.58	.75	2.05	93.2	57.4	.17
	3	.44	.44	.081	.38	.75	2.09	90.9	59.8	.23
	4	.52	.52	.081	.42	.75	2.29	95.4	62.2	.17
	5	.44	.44	.081	.37	.75	2.08	83.2	65.4	.29
	6	.49	.49	.081	.36	.75	2.17	80.4	69.5	.29
	7	.54	.54	.081	.43	.75	2.34	83.6	74.6	.44
	8	.58	.58	.081	.45	.75	2.44	84.1	79.0	.21
	9	.60	.60	.081	.45	.75	2.48	85.5	83.0	.35
	10	.60	.60	.081	.45	.75	2.48	82.6	88.6	.45
	Av.	.48	.48	.08	.44	.75	2.23	86.2		.268

(1) Corn silage weight is on an air dry basis.
(2) Per cent NRC allowance is the percentage of the National Research Council recommended total feed, air dry basis, given for fattening lambs of corresponding weights (Aug. 1949).

TABLE 24

AVERAGE FEED INTAKE AND DAILY GAIN

Feed Lot Trial 1952-53

	Period (14 Days)	Average Daily Ration: Shelled Corn	Raw Beans	Brewers' Yeast	Corn Silage(1)	Alfalfa Hay	Total Daily Feed	Per Cent NRC Allowance(2)	Av. Lamb Wt.	Av. Daily Gain
		lb.	lb.	lb.	lb.	lb.	lbs.	%	lbs.	lb .
Lot XV	1	.26	.22	.069	.54	.74	1.83	83.2	55.2	.14
	2	.32	.32	.081	.58	.75	2.05	93.2	57.4	.17
	3	.44	.44	.081	.38	.75	2.09	90.9	59.8	.23
	4	.52	.52	.081	.42	.75	2.29	95.4	62.2	.17
	5	.44	.44	.081	.37	.75	2.08	83.2	65.4	.29
	6	.49	.49	.081	.36	.75	2.17	80.4	69.5	.29
	7	.54	.54	.081	.43	.75	2.34	83.6	74.6	.44
	8	.58	.58	.081	.45	.75	2.44	84.1	79.0	.21
	9	.60	.60	.081	.45	.75	2.48	85.5	83.0	.35
	10	.60	.60	.081	.45	.75	2.48	82.6	88.6	.45
	Av.	.48	.48	.08	.44	.75	2.23	86.2		.268

(1) Corn silage weight is on an air dry basis.
(2) Per cent NRC allowance is the percentage of the National Research Council recommended total feed, air dry basis, given for fattening lambs of corresponding weights (Aug. 1949).

TABLE 25

INDIVIDUAL DIGESTION COEFFICIENTS

Digestion Trial 1951-52

(Raw and cooked kidney beans vs. shelled corn and linseed meal fed with alfalfa hay)

Lamb No.	Ration(1)	Period(2)	Equip-(3) ment	Dry Matter	Crude Pro- tein	Ether Ex- tract	Crude Fiber	N-free Ex- tract	TDN
				%	%	%	%	%	%
273	Raw	1	S	75.2	81.7	49.2	50.5	85.5	63.5
672		1	C	72.8	79.1	44.3	43.8	83.7	60.8
250		2	C	70.1	77.2	49.9	44.9	80.5	58.5
671		2	S	67.2	77.1	47.4	39.2	78.2	56.0
190		3	C	72.9	80.6	37.0	51.9	83.3	62.5
256		3	S	72.1	81.6	27.9	50.2	82.6	61.5
			Av.	71.7	79.5	42.6	46.8	82.3	60.5
1034	Cooked	1	S	72.9	73.6	45.3	48.5	84.0	64.1
1045		1	C	74.9	76.2	53.0	53.9	85.0	66.6
257		2	C	69.8	73.8	51.9	48.3	80.1	61.2
181		2	S	72.8	78.4	53.9	55.6	80.9	63.1
126		3	C	68.4	71.8	38.6	48.5	80.0	61.2
166		3	S	71.0	76.3	46.1	52.1	81.6	63.6
			Av.	71.6	75.0	48.1	51.2	81.9	63.3
286	Control	1	S	72.4	80.2	56.1	45.8	83.5	63.4
1014		1	C	73.7	79.4	65.9	48.4	84.1	64.1
161		2	C	72.4	76.5	66.9	46.4	83.1	63.0
34		2	S	72.1	78.8	64.9	47.2	82.2	62.0
41		3	C	69.2	73.3	63.2	42.5	82.1	62.0
128		3	S	72.9	76.8	61.4	50.5	84.4	64.8
			Av.	72.1	77.5	63.1	46.8	83.2	63.2

(1) Ration: Raw - Raw red kidney beans and alfalfa hay.
Cooked - Cooked red kidney beans and alfalfa hay.
Control - Shelled corn, linseed meal and alfalfa hay.
(2) Period: Each collection period 7 days.
(3) Collection equipment: S - Stanchion
C - Cage

TABLE 26

INDIVIDUAL DIGESTION COEFFICIENTS

Trial I - 1953

Lamb	Daily(1) Ration	Period	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	N-free Extract	TDN
			%	%	%	%	%	%
323	A	4	73.4	73.7	56.1	50.7	83.0	63.8
466		1	70.4	69.2	63.5	45.5	81.8	62.7
485		3	74.2	73.6	69.8	58.2	83.1	67.9
1046		2	67.2	60.8	59.4	35.6	81.4	58.8
		Av.	71.3	69.3	62.4	47.5	82.3	63.3
323	B	3	73.3	75.3	67.4	53.1	83.4	65.9
466		2	64.4	63.8	48.1	36.2	78.6	58.3
485		1	75.1	75.9	64.4	62.0	82.5	66.5
1046		4	72.5	76.1	60.0	51.7	82.2	64.9
		Av.	71.3	69.3	60.0	50.7	81.7	63.9
323	C	1	70.2	71.2	65.6	41.8	81.4	62.8
466		4	73.9	73.0	59.3	54.7	83.6	66.3
485		2	69.6	68.2	59.2	47.8	81.0	63.1
1046		3	62.1	58.1	59.3	34.1	77.4	57.8
		Av.	68.9	67.6	60.8	44.6	80.8	62.5
323	D	2	65.8	68.1	45.1	36.8	79.5	59.6
466		3	72.6	68.3	64.4	57.9	82.7	65.3
485		4	73.5	75.9	57.5	53.5	83.1	65.7
1046		1	70.6	71.5	64.1	44.9	81.4	62.8
		Av.	70.6	70.9	57.8	48.3	81.7	63.4

(1) Daily ration:

A - Raw red kidney beans 160 gm.
Shelled corn 206
Alfalfa hay (chopped) 340
Corn silage 300
Salt

B - Raw red kidney beans 160 gm.
Shelled corn 160
Linseed meal 46
Alfalfa hay (chopped) 340
Corn silage 300
Salt

C - Cooked red kidney beans 160 gm.
Shelled corn 206
Alfalfa hay (chopped) 340
Corn silage 300
Salt

D - Cooked red kidney beans 160 gm.
Shelled corn 160
Linseed meal 46
Alfalfa hay (chopped) 340
Corn silage 300
Salt

TABLE 27

INDIVIDUAL DIGESTION COEFFICIENTS

Trial II - 1953

Lamb	Ration(1)	Period	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	N-free Extract	TDN
			%	%	%	%	%	%
466	A	1	60.2	71.2	0.0(a)	44.7	71.9	52.2
485		2	62.2	72.9	0.0	47.8	73.3	53.9
1046		3	62.2	71.5	0.0	47.8	73.6	53.8
		Av.	61.5	71.9	0.0	46.8	72.9	53.3
466	B	2	70.3	75.0	8.4	51.5	82.1	61.2
485		3	69.7	76.8	13.1	46.9	82.5	61.0
1046		1	70.7	78.6	19.0	48.0	82.5	61.7
		Av.	70.2	76.8	13.5	48.8	82.4	61.3
466	C	3	72.1	76.3	24.2	53.0	82.9	63.2
485		1	73.5	80.2	20.7	52.2	84.0	64.2
1046		2	71.4	74.5	0.0	56.0	82.9	62.8
		Av.	72.3	77.0	14.9	53.7	83.3	63.4

(1) Ration: A - Alfalfa hay (2nd cutting) 1000 grams

B - Alfalfa hay (2nd cutting) 650 grams
Raw red kidney beans 350 grams

C - Alfalfa hay (2nd cutting) 650 grams
Cooked red kidney beans 350 grams

(a) Ether extract digestion coefficients listed as 0.0 were minus values.

TABLE 28

SUMMARY OF ANALYSIS OF VARIANCE OF APPARENT DIGESTIBILITY DATA

Trial	Source of Variance	Degrees of Freedom	Dry Matter Mean Square	Dry Matter F	Crude Protein Mean Square	Crude Protein F	Ether Extract Mean Square	Ether Extract F	Crude Fiber Mean Square	Crude Fiber F	N-free Extract Mean Square	N-free Extract F	TDN Mean Square	TDN F
1951-52	Period	2	13.3	.71	4.7	.53	158.3	4.62	8.5	.50	18.1	5.32	14.9	3.82
	Ration	2	4.9	.26	30.9	3.51	671.6	19.58**	38.2	2.26	2.7	.79	15.6	4.00
	Error	4	18.7		8.8		34.3		16.9		3.4		3.9	
1953-I	Lambs	3	16.8	1.37	38.9	3.11	15.0	.59	135.4	3.05	2.3	.34	150.5	2.40
	Period	3	27.6	2.24	66.3	5.30*	132.5	5.28*	145.2	3.27	5.4	.81	209.9	3.34
	Ration	3	5.0	.41	19.4	1.55	13.8	.55	25.7	.59	1.4	.21	13.3	.21
	Error	6	12.3		12.5		25.1		44.4		6.7		62.8	
1953-II	Lambs	2	0.6	0.28	4.8	1.85	out		2.0	1.43	.7	1.55	0.5	.04
	Period	2	0.0	0.00	5.1	1.96			9.6	6.86	.1	.22	0.0	0.0
	Ration	2	98.3	46.8*	25.4	9.77			38.5	27.50*	98.3	218.4**	170.4	142.0**
	Error	2	2.1		2.6				1.4		.45		1.2	

* Significant (5% level)
** Highly significant (1% level)

TABLE 29

COMPOSITION OF FEEDS, FECES AND ORTS

Digestion Trial 1951-52

Sample	Period	Total Produced (Dried)	Moisture	Crude Protein	Ether Extract	Crude Fiber	Ash	N-free Extract
		gm.	%	%	%	%	%	%
Raw beans	all		12.54	25.02	1.53	3.93	4.09	52.89
Cooked beans	1		2.92	27.46	1.79	4.58	4.09	59.16
Cooked beans	2 & 3		3.87	28.74	1.59	4.98	3.81	57.01
Shelled corn	all		11.89	9.34	3.96	2.10	1.28	71.43
Linseed meal	all		9.42	34.75	2.43	9.96	5.61	37.83
Alfalfa hay	1		11.63	15.61	2.53	28.18	7.74	34.31
Alfalfa hay	2		13.32	16.37	2.40	29.55	7.75	30.61
Alfalfa hay	3		11.51	15.81	1.52	31.94	5.73	33.49
Feces 273	1	1263	3.29	16.03	4.71	38.59	10.14	27.24
286	1	1387	5.12	14.72	4.68	38.42	9.29	27.77
1034	1	1413	4.58	21.13	4.62	34.12	7.81	27.74
1045	1	1331	2.81	20.82	4.36	34.60	8.90	28.51
1014	1	1360	3.50	15.68	3.91	39.30	9.30	28.31
672	1	1382	2.91	16.74	4.47	38.57	9.28	28.03
161	2	1570	3.00	13.85	4.00	38.25	9.10	31.80
250	2	1709	4.19	17.05	3.72	36.92	9.05	29.07
257	2	1752	5.39	19.51	3.42	34.26	8.69	28.73
671	2	1582	4.01	15.04	3.58	38.93	9.88	28.56
181	2	1306	5.28	17.52	3.73	34.88	8.75	29.84
34	2	1322	3.23	12.89	4.07	40.04	8.18	31.59
128	3	1204	2.47	14.02	3.86	39.69	9.94	30.02
166	3	1287	3.28	18.21	3.04	36.78	9.85	28.84
256	3	1243	3.09	14.32	4.33	39.08	10.57	28.61
41	3	1781	3.71	13.54	3.28	38.88	9.95	30.64
126	3	1690	2.32	20.34	3.21	35.69	9.20	29.24
190	3	1548	3.08	15.71	3.91	38.19	10.50	28.61
Orts 286	1	214	3.63	25.35	1.58	24.22	5.62	39.60
1034	1	199	2.68	16.90	2.15	32.15	6.30	39.82
126	3	330	3.71	20.21	1.62	22.47	7.30	44.69

TABLE 30

COMPOSITION OF FEEDS

Trial I - 1953

Feed	Period	Moisture	Crude Protein	Ether Extract	Crude Fiber	Ash	N-free Extract
		%	%	%	%	%	%
Alfalfa hay	1	10.41	14.70	1.74	31.48	5.46	36.21
Corn silage(1)		8.25	8.13	2.08	25.41	4.51	51.62
Shelled corn		12.33	8.36	4.42	2.44	1.24	71.21
Linseed meal		10.11	35.60	2.22	9.63	5.30	37.14
Cooked beans(2)		9.80	26.02	1.52	4.50	3.46	54.70
Raw beans		12.61	23.98	1.34	4.44	3.81	53.82
Alfalfa hay	2	8.42	12.72	1.75	32.66	5.94	38.51
Corn silage(1)		6.66	8.51	3.80	27.30	4.34	49.39
Shelled corn		10.88	8.49	3.80	2.37	1.24	73.22
Linseed meal		9.32	33.56	1.09	10.25	5.17	40.61
Cooked beans(2)		9.61	24.17	1.52	4.60	3.88	56.22
Raw beans		10.60	23.13	1.34	3.75	3.75	56.39
Alfalfa hay	3	8.45	14.05	1.74	33.65	6.24	35.87
Corn silage(1)		6.46	8.23	1.86	24.71	4.93	53.81
Shelled corn		10.12	8.18	4.15	2.68	1.17	73.70
Linseed meal		8.88	33.70	1.23	11.22	5.59	39.38
Cooked beans(2)		8.41	24.00	1.70	4.72	4.02	57.15
Raw beans		9.34	23.33	1.56	4.53	4.07	57.17
Alfalfa hay	4	9.12	13.32	1.08	33.94	5.91	36.63
Corn silage(1)		7.18	7.21	1.93	23.89	3.65	56.14
Shelled corn		10.95	8.18	2.39	2.08	1.29	75.11
Linseed meal		8.19	33.41	1.10	10.49	5.95	40.86
Cooked beans(2)		8.85	24.14	1.38	4.56	4.48	56.59
Raw beans		9.70	23.83	1.24	3.89	4.51	56.83

(1) Corn silage: Composition listed is for oven dried corn silage. The silage as fed was 74.2 percent moisture on an oven dry basis.

(2) Cooked beans: Cull red kidney beans autoclaved 30 minutes at 15 pounds of pressure.

TABLE 31

COMPOSITION OF FECES AND ORTS DRIED AND ALLOWED TO STAND AT ROOM TEMPERATURE AND MOISTURE

Trial I - 1953

Lamb	Period	Total Produced (Dried)	Moisture	Crude Protein	Ether Extract	Crude Fiber	Ash	N-free Extract
		gm.	%	%	%	%	%	%
Feces:								
323	1	2242	6.85	14.72	2.91	35.77	6.94	32.81
485		1859	6.57	16.06	3.38	28.84	9.57	33.58
1046		2201	6.31	15.88	2.93	35.33	7.84	31.71
466		2200	6.23	15.63	3.10	34.12	8.33	32.59
323	2	2609	6.59	14.36	3.77	35.80	8.51	30.97
485		2300	6.94	14.59	3.38	31.95	9.53	33.61
1046		2378	6.53	15.67	3.12	34.02	9.77	30.89
466		2710	6.52	15.49	3.37	34.52	8.83	31.27
323	3	2030	7.25	14.49	2.72	33.99	10.01	31.54
485		1980	7.16	14.45	2.80	30.84	10.05	34.70
1046		2910	7.03	15.76	2.60	33.16	9.88	31.57
466		2080	7.39	17.99	2.92	30.07	9.65	31.98
323	4	2040	6.94	13.48	2.57	34.26	8.57	34.18
485		2040	6.83	13.98	2.46	34.34	9.21	33.18
1046		2120	7.36	13.26	2.18	34.08	9.43	33.69
466		2000	6.70	14.40	2.52	33.25	8.99	34.14
Orts:								
485	2	81	6.80	7.79	0.95	45.72	3.93	34.81
1046	2	352	7.53	10.46	1.70	32.15	35.50	42.66
323	3	95	7.40	11.37	1.05	28.82	8.63	42.76
466	3	113	6.72	27.53	1.54	14.78	7.63	41.79
323	4	153	6.56	11.45	1.44	25.10	7.36	48.09

TABLE 32

COMPOSITION OF FEEDS AND FECES

Trial II - 1953

Sample	Period	Total Feces (Dried)	Moisture	Crude Protein	Ether Extract	Crude Fiber	Ash	N-free Extract
		gm.	%	%	%	%	%	%
Alfalfa hay	all		10.05	15.27	1.35	27.20	5.57	40.56
Cooked beans	all		9.68	24.49	1.23	4.87	3.70	56.03
Raw beans	all		11.80	23.61	1.27	4.32	3.95	55.05
Feces 466	1	2661	5.89	11.57	4.06	39.56	8.97	29.95
485	1	1780	6.34	14.38	4.08	36.40	9.98	28.82
1046	1	1928	6.04	14.16	3.88	36.26	10.82	28.92
466	2	1972	6.07	16.12	4.29	33.03	11.46	29.03
485	2	2522	5.60	11.50	4.40	39.36	9.14	28.78
1046	2	1918	6.04	17.19	5.15	31.15	11.84	29.79
466	3	1869	5.72	16.40	3.72	34.12	10.67	29.37
485	3	2008	5.68	14.71	4.00	35.55	11.28	28.78
1046	3	2511	5.30	5.30	3.90	39.60	9.27	29.79

TABLE 33

INDIVIDUAL NITROGEN UTILIZATION

Data for Ten Day Collection Periods

Trial I - 1953

Lamb No.	Ration[1]	Period		Nitrogen Consumed	Nitrogen Absorbed	Nitrogen Retained	Absorbed Nitrogen Retained	Dietary Nitrogen Retained	True Dig. (Est.)	Bio-logical Value
				gm.	gm.	gm.	%	%	%	
323	A	4		167.2	123.2	43.3	35.1	25.9	97.1	58
466	A	1		178.4	123.5	51.2	41.5	28.7	90.7	63
485	A	3		173.1	127.3	39.8	31.3	23.0	96.2	55
1046	A	2		161.1	101.5	17.9	17.7	11.2	86.2	48
			Av.	169.9	118.9	38.0	31.4	22.2	92.6	56
323	B	3		190.2	143.1	61.9	43.3	32.6	95.6	62
466	B	2		185.4	118.2	31.1	26.3	16.8	84.8	52
485	B	1		198.5	150.7	44.0	29.1	22.1	95.3	50
1046	B	4		188.5	143.5	45.5	31.7	24.2	97.0	53
			Av.	190.6	138.9	45.6	32.6	23.9	93.2	54
323	C	1		183.6	130.8	49.7	38.0	27.1	92.4	59
466	C	4		170.7	124.6	48.8	39.2	28.6	96.0	61
485	C	2		168.6	114.9	27.8	24.2	16.5	91.1	52
1046	C	3		174.9	101.5	14.6	14.4	8.4	80.5	47
			Av.	174.4	117.9	35.2	28.9	20.2	90.0	55
323	D	2		188.0	128.1	43.6	34.0	23.2	89.0	56
466	D	3		188.7	128.8	51.3	39.8	27.2	88.2	61
485	D	4		189.3	143.7	49.0	34.1	25.9	96.7	55
1046	D	1		203.7	145.7	47.8	32.8	23.5	90.5	53
			Av.	192.4	136.6	47.9	35.2	24.9	91.1	56

(1) A - Raw kidney beans; B - Raw kidney beans plus linseed meal; C - Cooked kidney beans; D - Cooked kidney beans plus linseed meal

TABLE 34

INDIVIDUAL NITROGEN UTILIZATION

Data for Seven Day Collection Periods

Trial II - 1953

Lamb No.	Ration(1)	Period	Nitrogen Consumed	Nitrogen Absorbed	Nitrogen Retained	Absorbed Nitrogen Retained	Dietary Nitrogen Retained	True Dig. (Est.)	Biological Value
			gm.	gm.	gm.	%	%	%	
466	A	1	171.0	121.7	51.3	42.2	30.0	91.4	61
485		2	171.0	124.6	27.3	21.9	16.0	93.1	45
1046		3	171.0	122.2	36.6	29.9	21.4	91.7	52
		Av.	171.0	122.8	38.4	31.3	22.5	92.1	53
466	B	2	203.7	152.8	49.2	32.2	24.2	91.9	50
485		3	203.7	156.4	33.8	21.6	16.6	93.7	41
1046		1	203.7	160.0	47.3	29.6	23.2	95.4	47
		Av.	203.7	156.4	43.4	27.8	21.3	93.7	46
466	C	3	207.2	158.2	64.8	40.9	31.3	93.1	57
485		1	207.2	166.2	51.6	31.0	24.9	97.0	48
1046		2	207.2	154.4	32.8	21.2	15.8	91.3	41
		Av.	207.2	159.6	49.7	31.0	24.0	93.8	49

(1) A - Hay only
B - Hay and raw kidney beans
C - Hay and cooked kidney beans

TABLE 34

INDIVIDUAL NITROGEN UTILIZATION

Data for Seven Day Collection Periods

Trial II - 1953

Lamb No.	Ration(1)	Period	Nitrogen Consumed	Nitrogen Absorbed	Nitrogen Retained	Absorbed Nitrogen Retained	Dietary Nitrogen Retained	True Dig. (Est.)	Bio-logical Value
			gm.	gm.	gm.	%	%	%	
466	A	1	171.0	121.7	51.3	42.2	30.0	91.4	61
485		2	171.0	124.6	27.3	21.9	16.0	93.1	45
1046		3	171.0	122.2	36.6	29.9	21.4	91.7	52
		Av.	171.0	122.8	38.4	31.3	22.5	92.1	53
466	B	2	203.7	152.8	49.2	32.2	24.2	91.9	50
485		3	203.7	156.4	33.8	21.6	16.6	93.7	41
1046		1	203.7	160.0	47.3	29.6	23.2	95.4	47
		Av.	203.7	156.4	43.4	27.8	21.3	93.7	46
466	C	3	207.2	158.2	64.8	40.9	31.3	93.1	57
485		1	207.2	166.2	51.6	31.0	24.9	97.0	48
1046		2	207.2	154.4	32.8	21.2	15.8	91.3	41
		Av.	207.2	159.6	49.7	31.0	24.0	93.8	49

(1) A - Hay only
B - Hay and raw kidney beans
C - Hay and cooked kidney beans

TABLE 35

SUMMARY OF ANALYSIS OF VARIANCE OF NITROGEN UTILIZATION DATA

Trial	Source of Variance	Degrees of Freedom	Percent Absorbed N-Retained Mean Square	F	Percent Dietary N-Retained Mean Square	F	Percent True Dig. (Est.) Mean Square	F	Biological Value Mean Square	F
1953-I	Lambs	3	160.5	4.88*	49.7	1.20	36.6	3.15	78.3	7.12*
	Period	3	82.9	2.52	64.0	1.55	59.3	5.11*	20.3	1.85
	Ration	3	24.6	.75	17.7	.43	9.9	.85	4.3	.39
	Error	6	32.9		41.3		11.6		11.0	
1953-II	Lambs	2	161.5	25.23*	79.0	10.97	4.9	2.04	109.8	16.15
	Period	2	64.2	10.03	41.3	5.74	4.9	2.04	31.1	4.57
	Ration	2	11.5	1.80	5.4	.75	2.8	1.17	33.8	4.97
	Error	2	6.4		7.2		2.4		6.8	

* Significant (5% level)

TABLE 36

LIVE WEIGHT RECORD OF LAMBS BEGINNING
AND END OF EACH PERIOD

Trial I - 1953

Date	Period		Ration A Lamb No.	Ration A Wt. Kg.	Ration B Lamb No.	Ration B Wt. Kg.	Ration C Lamb No.	Ration C Wt. Kg.	Ration D Lamb No.	Ration D Wt. Kg.
4-13	1		466	31.29	485	32.20	323	28.12	1046	30.38
4-27				29.93		32.65		29.09		30.84
		Gain or loss		-1.36		+ .45		+ .90		+ .46
5-11	2		1046	32.43	466	32.43	485	34.47	323	31.52
5-21				32.43		32.88		34.47		31.29
		Gain or loss		0.0		+ .45		0.0		- .23
6-1	3		485	35.37	323	32.43	1046	32.88	466	34.01
6-11				35.83		33.33		33.79		34.69
		Gain or loss		+ .46		+ .90		+ .91		+ .58
6-29(a)	4		323	30.84	1046	33.11	466	33.11	485	33.79
7-9				30.61		32.88		33.56		34.24
		Gain or loss		- .23		- .23		+ .45		+ .45
		Av. gain or loss each period		- .28		+ .34		+ .56		+ .32

(a) Lambs shorn 6-12-53

TABLE 37

LIVE WEIGHT RECORD OF LAMBS BEGINNING
AND END OF EACH PERIOD

Trial II - 1953

Date	Period		Ration A Lamb No.	Ration A Wt. Kg.	Ration B Lamb No.	Ration B Wt. Kg.	Ration C Lamb No.	Ration C Wt. Kg.
8-3	1		466	35.1	1046	35.1	485	36.7
8-10				36.3		36.5		37.9
		Gain or loss		+1.2		+1.4		+1.2
8-22	2		485	38.3	466	36.7	1046	38.1
8-29				39.2		37.4		39.0
		Gain or loss		+0.9		+0.7		+0.9
10-14	3		1046	38.5	485	39.2	466	37.9
10-21				38.5		41.5		38.8
		Gain or loss		0.0		+2.3		+0.9
		Av. gain or loss		+0.7		+1.5		+1.0