THE USE OF HIGH ROUGHAGE PELLETS IN CATTLE AND SHEEP FEEDING

by

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TABLE OF CONTENTS

LIST OF TABLES

THE USE OF HIGH ROUGHAGE PELLETS IN CATTLE AND SHEEP FEEDING

INTRODUCTION

Cattle feeders in the Klamath Basin in Oregon have become interested in pelleted feeds containing large proportions of alfalfa hay and other roughages. This was due partly to the increased rate of gains and lower feed requirements secured in high roughage pellet feeding experiments with fattening lambs conducted by Neale (26, p. 2-10) and with wintering steer calves at the Illinois Experiment Station (20, p. 1-3) on a pelleted ration of alfalfa and timothy hay. Interest was intensified when roughage pellets became available with the establishment of a pellet mill by a local lamb feeder.

Pelleting feeds for livestock offers other advantages. The feed is much easier to handle. It can be hauled in bulk and placed in self feeders quickly and easily with mechanical equipment. The storage space for the feed is greatly reduced. Pellets used here weigh 40 pounds per cubic foot as compared with baled hay 10 pounds, chopped hay 13.3 pounds, and rolled barley 40 pounds. Pellets, however, must be stored where no water can enter because moisture will break them up and cause them to mold readily. Chopped or baled hay storage requires a roof but side walls are not so important. The greater density of pelleted roughage is a great advantage in shipping because the bulk of baled hay or chopped hay limits the tonnage that can be hauled by truck or railroad car.

Labor requirements for feeding pelleted rations are lowered. With the use of self feeders and automatic feeding wagons, one large sheep feeding operation reduced the number of men required to feed a given number of lambs from 10 to 3. Coupled with this is the fact that less attention to feeding operations by the owner or other skilled labor is necessary. The entire ration is in the pelleted feed and it is safe to self feed the mixture. The owner does not need to keep as close a watch for digestive disturbances or stock "going off feed" which might require changes in amounts or kinds of unpelleted feeds.

When alfalfa hay is fed long and grain fed twice each day as has been practiced in the past, someone experienced in feeding stock must constantly observe the reaction of cattle and sheep to their feed. Bloat or scours from alfalfa and barley are common. Pelleting these ingredients in this area has been found to materially reduce these problems. This is true when the fineness of the grind is at an optimum and when feed is always available to the animals. Experience in this area has shown that it is safe to place lambs or cattle to be fattened directly on a free choice feeding program of pelleted high roughage feed mixtures. Lindahl, et al. (23, p. 3) found that lambs could be started on full feed more quickly and easily on pelleted than unpelleted feed.

Another advantage to pelleted feeds is the possibility of including more roughage and lower quality feed in the ration. Botkin and co-workers at Wyoming (4, p. 1) showed that lambs fed pellets containing 70 per cent roughage gained as well as those receiving pelleted feed containing 50 or 60 per cent hay and the feed costs were lower. In a trial at Illinois by Cate, et al. (7, p. 2) lambs fed pelleted timothy hay as the roughage outgained lambs receiving alfalfa as the roughage. This indicates that the pelleting process makes lower quality feeds more useful in lamb fattening rations.

The Klamath Basin produces an abundance of alfalfa of good quality but also produces some alfalfa of low quality. A large acreage of alsike clover provides sizable quantities of clover straw of little value in its natural state. Also, a large acreage of barley and oats provides large quantities of straw that are only used to a minor extent for feed. A large part of this material is either burned, used for bedding or plowed into the soil. In many instances the straw must be removed from a field if it is to be seeded to legumes or grasses or for other reasons. This involves extra expense which cannot at present be recovered through feeding or other uses.

In this area the roughage feeds furnish the lowest cost nutrients for ruminants; so any method that makes possible the greatest use of these feeds should lower the cost of producing livestock and provide a market for these crops.

Waste and sorting in unpelleted feed formulas is a common problem. Wind often blows material out of feeders, and livestock pull long hay out of bunks or lift chopped feeds out of mangers in an effort to select the most palatable ingredients. Thus, livestock may not consume a balanced ration. Use of pellets can insure that livestock consume the feed the owner wishes utilized. The pelleted feed is heavy enough so that wind will not lift it from feeders or bunks. The ingredients are so well mixed and blended and are held together so firmly that there is no opportunity for stock to sort the most palatable ingredients. It has long been recognized that the dustiness and fluffiness of chopped or ground feeds are not palatable to livestock. Pelleting removes these objectionable features. Yet when pellets reach the stomach, moisture soon disintegrates them so the benefits from grinding, which reduces the work of digestion of the feed, is secured by the animal.

Considerable information was available on pelleted feeds containing large quantities of roughage for fattening lambs, but only limited information was available on fattening steers on such feeds. Accordingly, an on-farm trial was established in cooperation with Bryant Williams, a stock feeder, the Pacific Supply Cooperative and the author. Results of the trial will be given later in this thesis.

USE OF PELLETED FEEDS: REVIEW OF THE LITERATURE

Description of the Pelleting Process

Pelleting or cubing feed for domesticated animals has been carried on since 1929. Providing a complete or partial pelleted ration for poultry, swine, calves and dogs has been a practice for some time. Range cubes, which furnish high protein concentrated nutrients for sheep and cattle grazing on bleached grass and other forages low in protein in late summer and fall, have also been fed for a number of years.

In the past most pelleted or cubed feeds have been concentrate feeds. More recently the pelleting of feed mixtures containing large proportions of roughage have become important in some areas, and have shown many advantages over natural or ground ingredients. A great variety of pellets or cubes is now being made and preliminary experiments with still different forms are being conducted. Some pellets are made in sizes of 1/4 to 1 inch in diameter. These must be made from finely ground materials. Other types of pellets are made from chopped or long hay and may range in size from 2 to 5½ inches in diameter.

The pelleting process used by the John D. O'Connor & Sons Mill, the one most familiar to the writer, consists of bringing the baled hay to a bale breaker by conveyor and then through the hammer mill with two 3/16" screens and one 1/8" screen set side by side. At this point, grain or other concentrates are added and ground in the second hammer mill with the hay. The percentage of grain is determined by an automatic metering device. The hay and grain mixture is blown to a hopper where it is fed into a mixer and an antibiotic is added by a machine. From here the mixture is augered into the pellet mill where molasses is added, and steam under 90 degrees pressure is introduced and the ingredients mixed.

Following this the feed is forced through dies 3/8" in diameter by heavy corrugated rollers. Die sizes can be changed. The dies are at an angle to a diameter line of the die casting. The rollers move in the direction that the dies are angled. The pellets come from the machine with considerable heat from the steam and the pressure necessary to force the feed through the dies. For this reason the finished pellets are elevated to a cooler to reduce the temperature and dry the material. The pellets move down through the open air cooler onto a conveyor that carries them to a hopper above a sacker, or to bulk bins.

The pellet mill described is run by a 100 horsepower electric motor. The capacity of the mill varies with the type of feed put through it. The mill capacity for pellets made of 70 per cent alfalfa, 25 per cent grain and 5 per cent molasses is around 6 tons per hour. Grass hay, grain hay or straw will reduce the capacity considerably.

In the early operation of this mill the hay was put through the 1/8" hammer mill only. Putting the material through a second mill with a 1/16" screen increased the capacity of the pellet mill and produced stronger pellets.

A Comparison: Rate of Gain and Feed Requirements

In a trial conducted at the Illinois Experiment Station (39, p. 1-3) in which a timothy-alfalfa mixture was offered to steer calves in four different forms: chopped, baled, pelleted and as silage, the calves gained 1.73 pounds per day on the pellets, 0.62 pounds per day on the chopped hay, 0.63 pounds per day on the baled hay and 0.05 pounds per day on the silage. The feed required for 100 pounds of gain for the pellets was 906 pounds; chopped, 1,772 pounds; baled, 1,732 pounds; and as silage, 30,926 pounds with 7,870 pounds of dry hay.

In another trial conducted by Webb and Cmarik at the Illinois Station using a mixture containing less roughage, (38, p. 1 & 2) yearling steers self-fed a fattening ration consisting of ground ear corn, 65 per cent; molasses, 5 per cent; soybean meal, 10 per cent; ground hay, 20 per cent in pelleted form, plus twelve pounds of silage per day, made daily gains of 2.75 pounds compared to a lot receiving the same ration self-fed as a meal that gained 2.58 pounds per day. The feed required for a gain of 100 pounds in the pellet-fed lot was 792 pounds of the pelleted mixture and 442 pounds of silage. The meal fed cattle required 845 pounds of the meal mixture and 463 pounds of silage for the same gains.

Pelleted dehydrated cereal grass fed free choice, plus ten pounds of ground mixed grain fed to fattening yearling steers in a trial at Washington State College (14, p. 1-7) produced gains of 2.73 pounds per day compared to 2.09 pounds for a lot fed the same concentrates, but receiving the grass hay coarsely ground. The feed required per 100 pounds gained for the lot that received the roughage as pellets was 353.6 pounds of grain and 613.5 pounds of hay, as compared to 613.5 pounds hay and 460.18 pounds grain in the lot receiving coarse roughage.

Some of the earliest research work with pelleting rations for fattening lambs was carried out by P. E. Neale, New Mexico Agricultural Experiment Station, from 1950 to 1952 (26, p. 1-17). Neale was interested in utilizing poor quality alfalfa hay and pelleting was tried for this purpose. His first trials (26, p. 2-6) compared a pelleted ration containing 50-60 per cent of low quality alfalfa hay, 30-40 per cent sorghum grain and 10 per cent molasses, with a ration of high quality alfalfa hay and sorghum fed loose. In these trials the pellet-fed lambs made 47 per cent faster gains and required 28 per cent less feed. In later trials (27, p. 2), Neale found that pelleted rations containing 70 per cent alfalfa produced faster gains with heavy lambs and required less feed for 100 pounds of gain than pellets containing 50 or 60 per cent of hay. Ligher lambs made faster and more efficient gains on pellets made of 60 per cent hay than either 50 or 70 per cent pellets. In trials conducted in 1955 and 1956 Neale (28, p. 1-2) found that lambs fed a ration made up of 80 per cent alfalfa, 10 per cent grain, and 10 per cent molasses made nearly as good gains as those fed 70 per cent alfalfa in the ration, and the gains were cheaper for the higher roughage ration.

A comparison of the value of pelleted and unpelleted rations for lambs was conducted by Cate _et al_ at the Illinois Station (7, p. 1-4). Three different rations were fed in pelleted and unpelleted forms.

Each ration contained 60 per cent concentrates and 40 per cent roughage. When good quality alfalfa hay was used in both forms the gains and feed requirements were quite similar. The pelleted ration produced 0.43 pounds in daily gains and the unpelleted 0.40 pounds. Requirements of 668 pounds feed per 100 pounds gain for the pellets and 731 pounds for the unpelleted ration were recorded. Pelleting proved of little value in this comparison. With poor quality roughages, however, pelleting showed more advantage. In the same trial comparing pelleted and unpelleted rations containing timothy meal as the roughage, the pellet fed lot gained 0.50 pounds per day and required 754 pounds of feed per 100 pounds of gain. The lot fed the same ration unpelleted gained 0.38 pounds per day and required 895 pounds of feed per 100 pounds gain. In still another comparison the ration was the same as the preceding trial except that the protein supplement was omitted. In this latter trial the pellet fed lot averaged 0.45 pounds daily gain and required 781 pounds of feed per 100 pounds of gain compared to a daily gain of 0.29 pounds and 1049 pounds of feed for 100 pounds of gain for the lambs fed the same ration unpelleted.

In trials in Kansas by Bell, et al (1, p. 1-3) lambs fed a ration of 65 per cent alfalfa and 35 per cent corn, or 55 per cent alfalfa and 45 per cent corn fed as pelleted gained 0.06 pounds per day more than lambs fed the same ration unpelleted. Moreover, the pellet-fed lambs required from 150 to 160 pounds less feed to put on 100 pounds of gain.

Two-year trials conducted by Botkin and Stratton with lambs (4, p. 1) at the University of Wyoming comparing unpelleted and pelleted feeds resulted in increased gains of 35 per cent to 40 per cent and an increase in feed efficiency of 15 to 20 per cent. The feeding period was reduced thirty days through use of pellets. These trials also show that rations containing 60 or 70 per cent roughages and 30 or 40 per cent concentrates were just as satisfactory as those containing 50 per cent concentrates.

Lindahl and Davis, United States Department of Agriculture, conducted two experiments to determine the effect of pelleting on feed utilization by fattening lambs (23, p. 2-3). In one trial an unprocessed mixture of 45 per cent corn, 5 per cent molasses and 50 per cent hay was hand-fed one lot. Another lot received the mixture ground and self-fed, and a third lot was self-fed the mixture as pellets. The average daily gains by the different lots were 0.31 pounds, 0.34 pounds, and 0.42 pounds, and the feed required per 100 pounds gain was 972, 907 and 772 pounds, respectively.

In a second trial the ration consisted of a concentrate mixture of 90 per cent barley and 10 per cent molasses fed with alfalfa hay as the roughage. Three groups of lambs were fed the ration in three different forms as in the first trial and in each lot the total feed consisted of 45 per cent alfalfa hay and 55 per cent concentrates.

The daily gains and feed required per 100 pounds of gain for the hand-fed, unprocessed feed lot was 0.29 pounds and 1210.4 pounds respectively. The lot self-fed the ground ration gained 0.42 pounds per day and consumed 846.7 pounds for each 100 pounds gained, and the lot receiving the pelleted ration gained 0.43 pounds daily and required 831.8 pounds for each 100 pounds of gain.

Reasons for Improved Efficiency by Pelleting

As noted in the experimental results previously listed, pelleting feeds for cattle and sheep generally increased the rate of gain and decreased the feed requirement for each 100 pounds of gain. Some of the reasons for this increased efficiency in feed utilization might be: 1. An increase in the digestibility of the feeds through the pelleting process. 2. Increased palatability, inducing greater feed consumption. 3. Fewer energy losses in digestion.

Digestibility

The question as to whether the fine grinding, pressure and steam heat involved in the pelleting process might increase the digestibility of the feed has been investigated. The effect of grinding and pelleting upon the digestibility of a ration for lambs was studied at the Oklahoma Experiment Station (24, p. 947-950). Digestion trials were conducted with twelve lambs on a ration of 30 per cent prairie hay, 20 per cent alfalfa, 34 per cent yellow corn, 8 per cent cottonseed meal and 8 per cent cane molasses. The feed was given in natural form, ground and pelleted. The lambs were divided into three lots of four each and each lot was fed the three kinds of feeds at different times. Each feed was given so that ten-day collections were made. Table 1 gives the results of the digestion trials.

Table 1 Results of Digestion Trials of Feed for Lambs, Prepared in Different Ways - Given as Per Cent

Preparation	Dry matter	Organic matter	Crude protein	Ether extract	Crude fiber	Nitrogen free extract
Natural	71.2	72.4	66.1	63.1	52.7	80.0
Ground	68.5	69.1	62.8	63.2	46.5	80.0
Pelleted	70.2	72.7	67.9	69.6	49.7	79.0

These experiments revealed: 1. Grinding lowered the over-all digestibility of the feed. 2. Pelleting the ground ration restored its digestibility to about the same level as the ration in its natural state. 3. Average apparent digestion coefficients for organic matter, crude protein, and crude fiber were significantly higher for the pelleted ration than for the ground ration. 4. Values for the apparent digestibility of organic matter, crude fiber and nitrogen-free extract were significantly higher in the natural state than the values obtained with ground and pelleted rations.

Lindahl and Davis conducted a number of tests at the United States Department of Agriculture, Beltsville Station, to determine what happens to feed during the pelleting process (23, p. 4-5). Chemical analyses were made of several rations before and after pelleting and digestion trials were run on similar feeds before and after pelleting. The results of the chemical analysis made by these workers for some of the feeds are shown in table 2.

Table 2 Chemical Analysis, Pelleted and Unpelleted Feeds

Feed and Method of Processing	Crude Protein	Ether Extract	Crude Fiber	Nitrogen Free Extract
70% Alfalfa (Unpelleted	15.00	1.14	27.89	49.08
25% Barley (Pelleted	15.11	1.40	27.72	49.38
5% Molasses				
Alfalfa (Unpelleted	23.43	2.51	17.44	42.88
Meal (Pelleted	23.42	3.34	16.60	42.76
40% Alfalfa (Unpelleted	13.24	1.66	18.80	61.19
55% Barley (Pelleted	12.56	1.84	17.02	63.80
5% Molasses				

Those same workers (23, p. 4,5) found that chemical analysis of feeds before and after pelleting showed that the most common change in chemical composition from pelleting was a slight decrease in crude fiber and an increase in ether extract when the mixture contained alfalfa. Digestion trials conducted to determine whether pelleting altered the digestibility of the ration showed that there was a slight decrease in the digestibility of crude fiber and an increase in digestibility of the ether extract.

Table 3 lists the results of the digestibility trials of a few feeds.

Table 3 Digestibility of Pelleted and Unpelleted Feeds

Feed and Method of Processing	Dry Matter %	Crude Protein %	Ether Extract %	Crude Fiber %	Nitrogen Free Extract %	Total Digestible Nutrients %
Alfalfa Meal						
Unpelleted	67.35	72.58	50.29	49.97	81.52	58.26
Pelleted	68.75	74.42	61.92	49.53	82.42	60.40
55% Alfalfa Hay 40% Barley 5% Molasses						
Unpelleted	67.58	70.61	35.94	41.28	81.06	59.08
Pelleted	66.84	70.25	32.86	38.51	79.99	59.14
75% Alfalfa 20% Corn 5% Molasses						
Unpelleted	65.51	71.68	48.20	39.89	78.98	57.21
Pelleted	64.46	69.58	50.58	36.79	78.30	57.64

The workers concluded that the small changes in the chemical analysis and digestibility of pelleted rations were not sufficient to account for the increased efficiency of feeder lambs fed pelleted rations and that the improved feed lot results and increased feed efficiency must be due either to increased palatability or reduced waste, or both.

Studies to compare the digestibility of pelleted and unpelleted rations having different ratios of roughage to concentrates for lambs were made by Richardson, et al at Kansas State College (23, p. 14-17). The results of these trials show apparent digestibility:

1. To be slightly higher for protein, ether extract, nitrogen free extract and total digestible nutrients for pelleted rations than unpelleted rations containing over 60 per cent roughage.

2. To be higher for crude fiber for unpelleted than pelleted rations containing over 60 per cent roughage.
3. To be higher for all nutrients when enough chopped alfalfa hay was added to a 60-40 pelleted ration to make it a 65-35 ration.
4. To be higher for pelleted rations containing sun-cured than dehydrated alfalfa.

The effect of pelleting on the digestibility of alfalfa hay and alfalfa hay with 30 per cent barley when fed to lambs was studied by Weir, et al (42, p. 805-814). Their report shows that there was no significant difference in the digestibility of crude protein.

The digestion coefficient of the crude fiber of both the alfalfa and alfalfa barley rations were significantly lower for the pelleted feeds. The pelleted hay crude fiber digestion coefficient was 47, the chopped hay 51. The pelleted alfalfa and barley 42, the same ration chopped 53. There was no significant difference in the total digestible nutrients of the two rations.

Energy Changes from Pelleting

Blaxter, et al (3, p. 4), compared the net energy values of chopped grass hay with finely ground grass hay and medium ground grass hay in cubes for lambs. They found that chopped hay gave lower energy losses in the feces but higher methane gas and heat losses than either fine or medium ground hay in pelleted form. The net energy losses were nearly the same for all three forms.

Economics of Pelleted Feeds

In all experiments reviewed comparing pelleted and nonpelleted rations, the rate of gain was greater and the feed required for 100 pounds gain was less for the pelleted feed. In most feeding enterprises, however, the most valuable measure of the financial success of the operation is the cost of the gains, and the value of the finished animals.

In the trials with the steer calves at the Illinois Station (39, p. 2-3) the cost of gain for the timothy-alfalfa feed in pellets was $13.59 per 100 pounds gain, for baled hay $17.32 and chopped hay, $17.22. With hay at $20.00 and pellets at $30.00 per ton, the pelleted feed was worth $39.73 per ton, the baled hay $20.79 and chopped hay, $20.92, when the steers were valued at 18 cents per pound.

Also at the Illinois Station (38, p. 1-2) an experiment conducted by Webb and Cmarik on the comparative value of pelleted and unpelleted rations for yearling steers, the cost per 100 pounds gain for the pelleted ration was $16.86 and the ration fed as a meal $19.29. The investigators calculated that the lower cost of the gains by the pellets would allow $6.39 per ton for pelleting. Feed prices used in the study were: ear corn, $1.40 per bushel; soybean meal, $75.00 per ton; molasses, $34.00 per ton; hay, $24.00 per ton; and silage, $10.00 per ton.

Ensminger and coworkers at Washington State College (14, p. 6) compared dehydrated cereal grass-legume mixtures in three forms:

finely ground, coarse ground, and pelleted with ground alfalfa. The cost of gain was the lowest in the lot of steers fed the grass-legume mixture as pellets at $30.15 per hundred pounds; coarse ground, $35.10; fine ground $35.18; and ground alfalfa $41.97. Feed costs used in the experiment were: pellets, $74.00; coarse and finely ground, $70.00; and ground alfalfa, $57.00.

In studies with lambs at the Kansas Experiment Station, Bell and Erhart (1, p. 3) found that although lambs gained faster on a pelleted ration of milo stover, alfalfa and milo grain than lambs fed a similar ration unpelleted, the cost of gains for the pellet-fed lambs was $18.03 per hundred pounds as compared to $16.72 for the lambs receiving the ration unpelleted. The cost of pelleting was $12.00 per ton; alfalfa $30.00 per ton; milo $40.00 per ton; stover $15.00 per ton. In later trials at Kansas State College (33, p. 18) feed cost of 100 pounds gain for a pelleted ration was $16.44 and for a nonpelleted ration $16.25.

Cate, et al at the Illinois Station (7, p. 4) found that pelleting a good alfalfa and corn ration for lambs did not increase the economy of gains, but pelleting rations containing timothy hay did lower the costs of gains. At the U.S.D.A. Beltsville Station, Lindahl and Davis reached similar conclusions.

From these studies it appears that pelleting feeds lowers the cost of gains when feed prices are relatively high; when young animals are fed and when roughages of low quality are used. When good quality roughages were used and prices of feeds relatively low, the added cost of pelleting offset the greater efficiency in feeding pelleted rations. The saving in labor from feeding pelleted feeds is not considered in the above comparisons.

Effect of Pelleting on Grade and Dressing Percentage of Lambs and Cattle

Of interest and importance in considering the relative value of different feeds or methods of feed preparation is the influence each might have on the finished carcass grade and yields of the animals fattened. Only limited information is available on grade and yield of pellet-fed animals, especially for cattle. Usually the most rapid gains result in a higher finish grade and higher yield.

Cate, et al (7, p. 3), marketed all lambs from an experiment with pelleted feeds that were choice or better at 56 days. They found little difference in the number marketed at this age whether fed alfalfa meal and corn as pellets or unpelleted. On the other hand, when timothy replaced alfalfa a much greater percentage of the lambs graded choice or better. Carcass yield in these trials was slightly higher for lambs receiving alfalfa and corn as pellets than the same ration unpelleted. The carcass yield was slightly higher for the timothy rations fed as meal than as pellets. In a later trial in Illinois (20, p. 3) it was found that a pelleted ration of alfalfa and corn produced lambs of higher finish and dressing percentage than the same ration fed as meal.

Neale (12, p. 1) reported on the live grades of lambs fed various ratios of roughage to concentrate. In these studies, lambs fed rations containing 70 per cent roughage gave the highest finish. Those receiving rations with 80 per cent roughage followed closely, while those receiving 60 per cent roughage were lowest in live grade.

There is less data available on the effect of pellet feeds on carcass grade and yield in fattening cattle. Ittner and coworkers (21, p. 2) show that the carcass grade for yearling steers fed a high roughage ration was slightly higher for pellet-fed cattle than for those receiving the unpelleted roughage. The carcass yield was also higher for those fed pelleted roughages.

Webb and Cmarik (38, p. 2) in trials with yearling steers fed a high concentrate ration both as pellets and meal found that the carcass grade and yield was practically the same for both groups.

Roughage to Concentrate Ratio

The greatest improvement in the performance of feed through pelleting seems to be in rations with a high percentage of roughage and with rations containing poor quality roughage. Furthermore, research indicates that young animals such as lambs and calves respond with proportionately greater gains and feed efficiency from pelleted rations than older animals.

Neale (28, p. 3-7) found that lamb rations containing a ratio of roughage to concentrate of 60:40 gave faster gains, required less feed for 100 pounds gain and cost less per pound of gain than rations with a ratio of 50:50 roughage to concentrate. Further improvement in performance was secured when the ratio was widened to 70:30 and even at 80:20 the performance was nearly equal to the 70:30 ratio. Cost of gains was still less for the 80:20 ratio.

Lamb feeding trials conducted by Cate, et al (7, p. 5) showed that pelleted rations of good alfalfa and grain in proportions of 60:40, 50:50 and 40:60, respectively, gave improved performance compared to the same rations unpelleted, although not enough to pay for extra cost of pelleting. In the same trials, pelleted rations containing timothy hay instead of alfalfa actually gave faster gains and greater efficiency at less cost per pound of gain than either unpelleted rations or those containing alfalfa in pelleted form. Botkin (4, p. 1) found that "Rations made up of 60 per cent or 70 per cent alfalfa hay and 40 per cent or 30 per cent concentrate have been just as satisfactory as rations made up of 50 per cent alfalfa and 50 per cent concentrate. Also the feed costs have been relatively low for these rations high in roughage, even considering the cost of pelleting."

Neale (28, p. 4) concluded from his work that the maximum performance of pelleted feeds for lambs was secured when the ratio of roughage to concentrate was 73 to 27, nitrogen free extract range 48 to 50 per cent, crude fiber content 15 to 20 per cent and calculated total digestible nutrients was below 60 per cent. Esplin and Hazle (15, p. 2-7) concluded in trials involving different ratio of roughage to concentrate that lambs can be fattened on pelleted, dehydrated or suncured alfalfa hay and that the addition of small amounts of grain apparently does not increase gains. They also concluded that the best roughage to concentrate ratio was between 60-40 and 70-30 parts roughage to concentrate, respectively, and that the pelleted ration should contain at least 50 per cent roughage.

In order to make the most complete comparison of the performance of pelleted and unpelleted rations for lambs, the results of a number of experiments that made direct comparisons between the two forms of feed have been summarized in table 4. The trials were divided to show lambs getting rations containing over 50 per cent roughage and those getting rations with less than 50 per cent roughage. These figures show that superior performance is secured from pelleted rations containing over 50 per cent roughage.

Response to pelleted feed by cattle is quite similar to that in lambs. In table 5 has been listed the increase or decrease in rate of gain, feed per 100 pounds gain, pounds of feed consumed per day, and cost per pound of gain due to pelleting, as shown by a number of experiments. These trials have been listed for calves and yearlings and each of these age groups has been divided for rations consisting of roughage to concentrate wider than 50:50 and those with ratios of less than 50:50.

The average of all trials cited in table 5 shows a decided advantage from pelleting high roughage rations for calves. In the nine comparisons listed, the average rate of gain was increased by 106 per cent by pelleting. Feed per 100 pounds gain was reduced 30 per cent. Feed consumption was increased 39 per cent and cost of gains reduced 12 per cent by pelleting. Trials to compare the relative value of pelleted and unpelleted rations with smaller percentages of roughage have not been conducted for calves.

A number of cases where calves were placed on free choice pelleted rations containing 70 per cent or more hay have been observed in Klamath County. In all cases, such calves actually fattened. Much of the increased gain is in fat. Several lots observed were continued on feed and finished for market, and reached market finish in much shorter time than conventional rations. Pellet feeds are apparently excellent for calves to be finished for market in the feed lot.

It is questionable whether weaner calves, self-fed pelleted feed during the winter, and placed on grass in the spring, would make economical gains on grass. It might be more efficient to restrict winter gains somewhat by limiting the quantity of pellets consumed by such cattle by hand feeding.

Table 5 shows that yearling steers fed rations high in roughage made superior performance in rate of gain, feed per pound gain, feed consumption, and cost of gains when the ration was pelleted, than when fed as a meal. Trials with yearling steers at Purdue by Perry, et al (32, p. 1-4) indicate that pelleted rations containing less than 50 per cent roughage in the form of corn cobs gave faster gains and a higher carcass grade than those fed on rations containing 70 per cent corn cobs.

Webb and Cmarik (40, p. 1-3) compared the effects of three levels of roughage in fattening rations for yearling steers. One lot received a pelleted ration containing 25 per cent timothy-alfalfa mixture, a second 35 per cent and a third 45 per cent. The balance of each ration was ground shelled corn and soybean oil meal. In this trial the steers fed the lower roughage ration made slightly higher gains than those with higher roughage levels. The daily gains were 2.89 pounds per day for the steers receiving a ration of 25 per cent roughage; the lot receiving the 35 per cent roughage gained 2.85 pounds; and the one getting 45 per cent roughage was 2.71. It is doubtful that these differences are statistically significant, and perhaps one may interpret these findings to mean that a wide range of roughage to concentrate ratios may be successfully fed in pelleted rations. Pelleting rations of 40 per cent roughage depressed gains compared to meal. Gains on pellets were 2.40 pounds per day on meal, 2.46 pounds.

Animal Reaction to Pelleted Feeds

Palatability of high level roughage rations seems to be improved by pelleting as shown by the greater consumption of the pelleted feed. Table 5 shows that the average feed consumption for pelleted rations by calves was 39 per cent greater than that of the unpelleted feed. The table also shows that the difference in daily intake on pelleted and loose feeds became less when the percentage of roughage in the pelleted feed was decreased and when the animals were older.

Increased intake of pelleted feed may be due to the reduced bulk of the roughage from pelleting, and the reduced chewing required for pelleted feeds. Several research workers pointed to the apparent craving for coarse unprocessed roughage by animals eating complete pelleted feed. Bell (1, p. 3) showed that lambs ate 0.24 pounds of straw per day with their pelleted rations. At the Montana experiment station, Thomas and Jordan, (37, p. 3) found that the addition of straw to a pelleted ration containing 70 per cent roughage increased gains in yearling steers by 0.27 pounds per day. As further evidence of the animal's need for bulk, Ensminger, Ham and Algeo (14, p. 3) found that all cattle fed rations that were finely ground, whether pelleted or unpelleted, showed a great desire for more roughage in their ration. The cattle took on a fill of straw used for bedding each time it was brought into the shed. Bush and Jordan (5, p. 2) also found that pellet-fed lambs would eat straw each time bedding was placed fresh in their pens. Cate, et al (7, p. 2) observed further that when roughage was reduced to 40 per cent of the ration lambs seemed to crave more roughage and ate some of their bedding.

Esplin and Story (16, p. 17) observed that lambs fed pelleted rations chewed on boards and fences and suggested that this resulted from a depraved appetite. Trace minerals, limestone and phosphate were added to pellets containing 50 per cent alfalfa and 50 per cent corn to determine whether these minerals might stop the lambs from eating boards. Although the minerals improved the efficiency of gains and tended to reduce fence chewing, they did not eliminate it.

Size of Pellets and Fineness of Grind

Feeds can be pelleted in a great variety of sizes and shapes. Most machines can manufacture pellets of different diameters and lengths by changing the dies and by changing the length the pellets are cut.

Naturally, the question of the effect of the size of pellet on performance on pelleted feeds has been considered and some studies made. Esplin and Hazle (16, p. 11) found in trials with lambs that there was little difference between pellets one-quarter inch in diameter and one-quarter inch long, pellets (wafers) one inch by one-half inch, or pellets (wafers) one and one-quarter inches by three-quarters of an inch by one and one-quarter inches. The smallest pellet gave slightly smaller daily gains than the intermediate or large pellets. The actual daily gains were .502, .564, and .531 pounds, respectively. The data were not tested statistically. There is some question whether the differences are significant.

Trials conducted by Esplin and Storey (16, p. 18-19) with lambs to study the influence of fineness of grind of feed materials used in pellets revealed faster (.502 to .43 pounds daily) and cheaper gains (22.61 to 22.88 pounds per one hundred pounds of gain) by lambs fed pellets made with ingredients ground through a one-quarter inch screen than lambs fed the same kind of ration made from feed ground through a one-sixteenth inch screen.

Church and Fox (11, p. 2) found that although statistical analysis revealed that there was no significant difference in pellets of sizes of one-quarter, three-eighths, or one-half inch and of fineness of grinds from three-thirty seconds, three-sixteenths or one-quarter inch screens when such pellets were fed to lambs, the data indicated that the finest grind tended toward a slight advantage in gain, feed conversion and cost of gain compared to the other grinds. The data also indicated that the larger (one-half inch) pellet gave slightly faster gains than the other two sizes (one-quarter and three-eighths inches). Both the one-half and three-eighths inch pellets were superior to the one quarter inch pellet in all categories studied. In another trial designed to compare fine and coarse ground feed for lambs these same research workers (10, p. 1-3) secured a slight (non-significant) increase in daily gains with finer ground feeds.

The effect of fineness of grind of pelleted feed for steers was investigated by Webb and Cmarik (40, p. 1-2). Two lots of steers were fed a ration containing 35 per cent alfalfa-timothy hay, 55 per cent corn, and 10 per cent soybean oil meal. The pellets fed one lot were made from materials ground much finer than the other. Grinding the ration components very finely reduced daily gains somewhat (2.85 and 2.63 pounds), but not significantly so.

Summary: Review of Literature

During the last five years, stockmen and feed manufacturers have become intensely interested in pelleted feeds containing a large proportion of roughage. The earliest trials using this form of feeding were carried out with lambs. As late as 1956 only a few experiments had been conducted with high roughage pellets for cattle. Since 1957, many research projects using pelleted feeds have been completed.

The results of a number of these experiments making direct comparisons between pelleted and unpelleted rations containing similar ingredients in the same ratios have been tabulated for lambs in table 4, and for cattle in table 5.

Although the data in most trials were not subjected to statistical analysis, the results of the experiments show strong trends in rate of gain, feed conversion, feed consumption, and ease of handling. Following is a summary of the results of the experiments cited:

Rates of gain in fourteen trials with lambs averaged 34 per cent higher for pelleted than unpelleted rations containing over 50 per cent roughage. For rations containing less than 50 per cent roughage the advantage from pellets was 12 per cent in nine trials.

In nine trials with beef calves, the pelleted rations containing over 65 per cent roughage (no trials reviewed with between 50 and 66 per cent roughage) produced an average of 106 per cent faster gains than similar rations unpelleted. The average of the trials with calves fed rations containing only 20 per cent roughage showed the same rate of gain for both pelleted and unpelleted rations.

In six trials with yearling steers fed rations made up of over 60 per cent roughage, pellet fed cattle averaged 16 per cent faster gains than cattle receiving the same feed unpelleted. Yearling cattle fed rations of less than 50 per cent roughage made almost the same gains from unpelleted as pelleted feeds. This would indicate that the greatest advantage in pelleting is secured with high roughage pellets. This conclusion was also reached by research workers who compared pelleted and meal feeds in varying ratios of roughage to concentrates.

Feed required to produce 100 pounds of gain is reduced by pelleting high roughage mixtures for both lambs and cattle. The fourteen trials reviewed for fattening lambs show 24 per cent less feed required for pelleted than unpelleted rations containing over 50 per cent roughage. For rations with less than 50 per cent roughage, the advantage shown for nine trials was 9 per cent. For beef calves fed rations with over 65 per cent roughage the pelleted rations required an average of 50 per cent less feed for 100 pounds gain than unpelleted feeds. Beef calves required an average of 14 per cent less feed when fed pelleted rations in three trials with feeds containing only 20 per cent roughage. Six trials with rations containing over 60 per cent roughage fed to yearling steers required an average of 9 per cent less feed for one hundred pounds gain when fed as pellets than the same feed unpelleted. When the roughage ingredient was dropped to less than 30 per cent the advantage in feed conversion averaged only 2 per cent less for pelleted feeds in three trials.

Feed consumption is increased by feeding rations in pelleted form for both lambs and cattle in high roughage feed formulas. For the fourteen lamb feeding trials reported in table 4, the figures show an average increase of 4 per cent for feeds containing over 50 per cent roughage, and 5 per cent increase in rations with less than 50 per cent roughage when the rations were fed as pellets as compared to unpelleted feed of the same composition.

With cattle, the nine trials summarized in table 5 give an average increase of 35 per cent in feed consumed per day by beef calves receiving a pelleted ration of over 65 per cent roughage over calves receiving the same kind of feed unpelleted. Calves getting a low roughage ration of 20 per cent roughage consumed 10 per cent less feed in pelleted form, where the data from three trials is averaged. Yearling steers averaged 7 per cent more feed per day as pelleted than unpelleted feed when the roughage content was over 60 per cent. When the roughage in rations for yearling steers was dropped to 30 per cent, or less, three trials show that the cattle ate about 5 per cent less when the ration was pelleted.

The costs of feed to produce one hundred pounds of gain from feeding pelleted and unpelleted rations as reported from a number of experiments show a rather wide variation. Some of this is due to varying costs of the pelleting charges in the different areas, and because of the level of the prices of feeds used. Table 4 gives an average of $1.57 lower costs per one hundred pounds of gain for lambs fed pelleted rations with over 50 per cent roughage. For the rations with less than 50 per cent roughage, the advantage of pelleted compared to unpelleted feed dropped to $0.53 per hundred pounds of gain.

In the cattle trials summarized in table 5, the cost of one hundred pounds of gain for calves fed the high roughage pellets was $7.58 per hundred less than those fed the same feed unpelleted. For calves fed pelleted rations low in roughage, the cost of gain was only $0.70 per hundred less than calves fed the same ration as a meal. The cost of gains for yearling steers was only $0.37 less for cattle fed rations with over 60 per cent roughage as pellets than as meal. When rations of 30 per cent or less roughage was fed as pellets the cost of gains for steers fed the rations as pellets was $1.66 per hundred more than for those fed meal.

The influence of feeding pelleted rations on the carcass grade and yield of lambs was included in a number of lamb studies, but only a few cattle feeding experiments. There was an appreciable increase in the dressing percentage and the carcass grade of lambs fed high roughage feeds in pelleted form over those receiving unpelleted feed. The differences in these characteristics for lambs fed rations containing less than 50% roughage were probably not significant.

The data for cattle indicate that the grade might be improved when cattle are fed high roughage rations in pelleted form, but there was very little difference in the carcass yield. For cattle fed high concentrate rations the carcass grade was slightly lower for pellet fed cattle, although the yield was slightly higher than from the meal fed cattle.

Roughage to concentrate ratios of pelleted feed that gave the best performance in fattening lambs is near 70 per cent roughage and 30 per cent concentrates. Results from rations of 60 to 80 per cent roughage, however, have been satisfactory.

The most desirable roughage to concentrate ratio for feeding cattle has not been as definitely established as for lambs. A wide range of roughage to concentrate ratios may be successfully fed. Research does show that the greater advantage of pelleting is secured in rations of high roughage content. When the roughage to concentrate ratio is less than 40:60 there is little advantage to pelleting the feed for cattle weighing over 600 pounds.

Pelleting high roughage feeds permits starting lambs or cattle on full feed without digestive disturbances. Both classes of livestock show a craving for some coarse feed. Labor for feeding pellets is greatly reduced and pellet feeds are more adaptable to mechanical equipment than unpelleted feed. The larger size pellets (1/2 inch for sheep and one inch for cattle) gave higher gains than smaller size. The fineness of the grind of the material used in pelleted feeds that gives the greatest efficiency has not been established. Experiments conducted so far have not agreed on this question.

The digestibility coefficients of crude fiber are lower and the ether extract higher in pelleted than unpelleted feed. Digestibility coefficients of crude protein and total nutrients are nearly the same for the two methods of preparing feed. Net energy losses for pelleted and unpelleted feed are about equal. Energy losses in the feces are greater for pelleted feed, but methane gas and heat losses are lower.

Table 4 - A Comparison of Performance of Pelleted with Unpelleted Feeds of the Same Composition for Lambs

Work Cited	Roughage Fed	Ratio Roughage Concentrate 50:50	Rate of Gain Pel.	Rate of Gain Unpel.	Feed/Cwt. Gain Pel.	Feed/Cwt. Gain Unpel.	Pounds Feed Per Day Pel.	Pounds Feed Per Day Unpel.	Cost/Cwt. Gain Pel.	Cost/Cwt. Gain Unpel.	Carcass Yield % Pel.	Carcass Yield % Unpel.	Carcass Grade* Pel.	Carcass Grade* Unpel.
1	Alfalfa	65:35	.30	.27	1039.3	1309.3	3.11	3.58	18.37	17.99	49.2	49.2	5.0	5.0
5	Alfalfa	75.25	.57	.46	719.0	721.0	4.10	3.33	12.64	12.19	52.9	49.2	5.0	5.0
2	Alfalfa	55:45	.45	.36	801.0	1041.0	3.63	3.81	16.68	19.17	49.8	51.3	4.1	4.6
2	Alfalfa	55:45	.49	.34	736.0	1069.0	3.82	3.65	17.49	21.42	53.0	50.0	5.1	5.2
2	Alfalfa	55:45	.47	.36	824.0	1075.0	3.89	3.65	17.23	19.94	51.0	52.4	4.8	4.2
26	Alfalfa	55:45	.39	.28	913.0	1130.0	3.52	3.20						
26	Alfalfa	58:42	.45	.29	771.0	1203.0	3.46	3.52						
26	Alfalfa	60:40	.43	.28	862.0	1252.0	3.68	4.07						
9	Alfalfa	67:33	.44	.25	798.0	1736.0			13.70	16.10			4.0	3.0
36	Alfalfa	70:30	.51	.34	903.0	1152.0			16.69	18.60	49.5	48.4		
41	Alfalfa	100:00	.39	.30	943.0	1031.0	3.7	3.1			53.1	49.8	4.6	2.9
41	Alfalfa	70:30	.36	.31	897.0	916.0	3.2	2.8			55.2	52.4	5.0	4.4
33	Alfalfa	65:35	.40	.32	839.1	1062.7	3.4	3.4	13.68	14.90			4.6	4.5
33	Alfalfa	55:45	.39	.32	825.2	943.9	3.21	3.03	13.95	14.27			4.9	4.6
Average			.43	.32	848.0	1117.0	3.56	3.43	15.60	17.17	51.7	50.3	4.7	4.3
5	Alfalfa	50:50	.54	.51	664.0	556.0	3.5	3.37	13.56	10.78	51.0	48.7	5.0	6.0
7	Alfalfa	45:55	.43	.40	668.0	731.0	2.89	2.96			51.6	52.2	4.5	4.6
7	Timothy	45:55	.38	.50	754.0	895.0	3.70	3.45			51.9	49.9	4.4	4.0
7	Timothy	45:55	.43	.29	781.0	1049.0	3.50	3.08			48.9	50.6	4.0	3.5
23	Alfalfa	50:50	.42	.34	772.0	907.0	3.00	3.0			49.1	48.6		
23	Alfalfa	45:55	.43	.42	831.0	846.0	3.56	3.53			50.7	50.4		
20	Alfalfa	50:50	.56	.44	620.0	690.0	3.47	3.06			52.3	50.0	5.0	4.7
36	Alfalfa	50:50	.47	.43	885.0	882.0			13.47	13.34	48.3	47.7		
36	Alfalfa	30:70	.51	.39	739.0	857.0			14.88	16.19	49.1	48.7		
Average			.46	.41	746.0	824.0	3.37	3.21	13.97	13.44	50.3	49.6	4.6	4.6

*Prime + = 9; Prime = 8; Prime - = 7; Choice + = 6; Choice = 5; Choice - = 4; Good + = 2; Good - = 1.

Table 5 - A Comparison of Several Experiments Showing Response of Beef Calves and Yearlings to the Same Ration in Pelleted or Unpelleted Form

Work Cited	Roughage Fed	Ratio Roughage :Concentrate	Rate of Gain Pel.	Rate of Gain Unpel.	Feed/Cwt. Gain Pel.	Feed/Cwt. Gain Unpel.	Lbs. Feed Per Day Pel.	Lbs. Feed Per Day Unpel.	Cost/Cwt. Gain Pel.	Cost/Cwt. Gain Unpel.	Carcass Grade* Pel.	Carcass Grade* Unpel.	Carcass Yield % Pel.	Carcass Yield % Unpel.
Beef Calves														
39	Alfalfa-Timothy	100:0	1.73	.62	906	1722	15.69	10.70	13.59	17.22				
40	Alfalfa	100:0	1.77	.18	792	5160	14.0	9.4	13.86	61.93				
40	Alfalfa	100:0	1.82	.43	744	2275	13.50	9.90	13.12	27.31				
40	Alfalfa-Timothy	100:0	1.32	.30	971	2502	12.90	7.50	15.88	33.02				
40	Sericea	100:0	.38	.21	3087	4730	11.60	10.10	48.74	42.55				
18	Alfalfa-Grass	66:34	3.30	2.24	650	710	21.50	16.40	10.90	12.60				
29	Alfalfa	100:0	2.22	1.43	785	1073	17.40	15.3	12.76	11.94				
29	Alfalfa	100:0	1.88	1.07	1044	1360	19.60	14.6	16.97	15.13				
29	Alfalfa	100:0	1.54	1.24	1255	1144	19.30	13.9	20.39	12.73				
	Average		1.77	.86	1137	2297	16.16	11.98	18.47	26.05				
31	Corn Cobs	20:80	2.35	2.65	709	904	18.4	24.0	15.80	16.90				
31	Corn Cobs+ Hygromycin	20:80	2.24	2.32	802	829	17.9	19.2	16.80	16.10				
31	Corn Cobs+ Hygromycin	20:80	1.95	1.58	750	892	14.7	13.9	16.20	18.00				
	Average		2.18	2.18	754	895	17.0	19.0	16.30	17.00				
Yearling Steers														
30	Alfalfa	50:50	2.78	2.47	1025	1145	28.5	27.6	19.6	16.7				
43	Alfalfa	100:0	2.22	1.75	1010	1103	22.4	19.3			5.0	3.0	57.3	56.5
39	Corn Cobs	35:65	2.75	2.58	1171	1308	32.0	32.9	16.68	19.29	4.7	4.7	58.5	58.5
43	Alfalfa	70:30	2.29	2.07	918	967	20.6	20.0			5.3	3.9	59.6	59.5
21	Alfalfa	90:10	2.17	1.80	945	980	20.48	17.59			5.0	4.5	59.8	58.7
32	Corn Cobs	70:30	1.98	1.57	1290	1500	25.5	23.4	22.4	23.8				
	Average		2.36	2.04	1060	1167	24.91	23.46	19.56	19.93	5.0	4.0	58.8	58.3
32	Corn Cobs	45:55	2.18	2.06	1180	1170	25.7	24.2	23.6	21.7				
43	Alfalfa	40:60	2.14	2.46	768	809	16.3	20.0			3.3	5.0	60.5	59.5
32	Corn Cobs	20:80	2.13	2.17	1020	1040	21.7	22.5	22.9	21.8	3.9	4.0	61.7	60.1
38	Alfalfa	30:70	2.41	2.53	769	787	18.6	20.0	17.40	15.20	2.0	3.0		
38	Alfalfa & Straw	30:70	2.68	2.53	764	787	20.4	20.0	16.73	15.20	3.0	3.0		
	Average		2.31	2.35	900.3	918.6	20.5	21.4	20.16	18.50	3.0	3.8	61.1	59.8

*Prime + = 9; Prime = 8; Prime - = 7; Choice + = 6; Choice = 5; Choice - = 4; Good + = 3; Good = 2; Good - = 1

EXPERIMENTAL

Objective

There is a surplus of alfalfa hay, clover straw, and grain straw produced in the Klamath Basin. These roughages supply the lowest cost nutrients for feeding and fattening livestock, so it is desirable to make maximum use of them in fattening cattle. Although a large acreage of barley is grown in the area, it is mostly malting barley which sells for a premium over feed barley. With this situation prevailing there is often a shortage of feed grains. When high roughage pellets became available in Klamath County, cattle feeders wanted to know whether the pelleting process would allow them to make greater use of local roughages in finishing feedlot cattle. No experimental data or feedlot experience were available to show whether fattening steers could satisfactorily utilize pelleted rations containing a high percentage of alfalfa or lower quality roughage such as alsike clover straw.

In order to determine the value of this type of feed, it is important to know the rate of gain that could be secured; the feed required for each pound of gain; the cost of producing a pound of gain and the degree of finish or the carcass grade that could be expected from cattle fed such rations. To be of value, it was necessary to compare the performance of high roughage rations in pelleted form with the standard ration fed in the area which consists of long or chopped alfalfa hay with or without other roughages and barley, oats and molasses.

Methods and Materials

To achieve this purpose, an on-farm experiment was set up on January 26, 1957 with Bryant Williams, a rancher; the Pacific Supply Cooperative, a feed processor; and the writer, cooperating.

Three lots of yearling and long yearling steers were assembled. They had been wintered on limited alfalfa hay and were in Medium feeder condition. The live grade was mostly Good with a few Medium and Choice. The cattle ranged in weight from 565 lbs. to 845 lbs. with an average of 712 lbs. The individual weight and grade for the steers in each lot will be found in Appendices A, B, and C. The lots were made up by random selection of the cattle secured. The lots of cattle were placed in separate pens and started on their rations on January 26 and January 29, 1957, and the feeding period ended May 22, making a total of 113 days for two lots and 116 for the third.

The feeds given the different lots of steers and the analysis of each are listed in Table 6. The analysis was made by the Agricultural Chemistry Department, Oregon State University.

Table 6 - Chemical Analyses of Feedstuffs Used in Experiment

Lot	Description	% Dry Matter	% Ash	% Crude Protein	% Crude Fat	% Crude Fiber	Nitrogen Free Extract
I	Grain cubes - 5% molasses, 65% barley, 30% oats, Aureomycin, 28 grams per ton	93.56	4.27	10.52	2.81	6.47	69.49
	Hay - 50% alfalfa, 50% oat, chopped	94.15	7.81	9.18	2.46	25.70	49.00
II	Pellets - 70% alfalfa hay, 25% barley, 5% molasses - Aureomycin 14 grams per ton	93.71	7.42	13.28	1.55	22.58	44.88
III	Pellets - 35% clover hay, 35% alfalfa, 25% barley, 5% molasses, Aureomycin 14 grams per ton	93.84	6.33	10.37	1.44	24.37	31.33

Experience had already shown that the pellets could safely be fed free choice, so the pelleted fed cattle were started in this manner. Lot I, those receiving the chopped hay and grain, were given the hay free choice and the grain hand-fed. The amount of grain being fed each day was increased as rapidly as possible. It was planned that the grain would also be self-fed, but the cattle showed signs of digestive disburbances when the daily grain allowance exceeded 14 pounds per day, so the twice daily feeding was continued throughout the feeding period.

It was observed that the pellet fed cattle craved some coarse roughage because they consumed portions of their bedding. Straw was also made available in feed bunks, but since it was necessary to add straw to the yards frequently, it was impossible to determine precisely the amount of straw eaten. On another farm where yearling heifers were being fed similar pelleted feed in lots bedded with sawdust, the cattle ate 2 pounds of grass hay per day.

Labor in feeding pelleted rations was much less than that required in providing unpelleted feed. The pellet fed lots were fed free choice right from the start. This required filling the 4 ton feeders once every 3 weeks. The lot receiving the unpelleted feed was fed twice daily.

From this trial and the experience of other feeders in this area, pelleting feeds appears to reduce or nearly eliminate bloating. There is usually a bloat problem associated with normal, loose rations of barley and good quality alfalfa hay. There was no bloat in any of the lots in this trial. The oat hay and oats used in lot I were included to prevent this problem. One steer died in lot III and the veterinarian diagnosed the cause as hemorrhagic septicemia.

Results

The cattle were weighed weekly for 63 days and bi-weekly thereafter. The final weight was secured when the cattle were sold. The condition of sale called for an overnight stand off feed, followed by hauling to market a distance of 10 miles, where the cattle were unloaded and weighed. They were sorted and weighed individually so the shrink was heavy.

Table 7 summarizes the average daily gain, feed consumed, and the cost of gains of the three lots. Since initial and final weights were secured on each animal in each lot, average daily gain for each animal was determined and the data analyzed according to Li (22, p. 151-233). See Appendix D for calculations. Lot II (alfalfa-grain-pellets) made significantly ($P < .01$) higher daily gains (2.46) than Lot I (standard ration) and significantly ($P < .05$) higher gains than Lot III (clover-alfalfa-grain pellets). Lot III made a non-significantly higher daily gain (2.14) than Lot I (standard ration) (1.95).

Individual feed consumption could not be secured, so the feed required to produce 100 pounds of gain could not be tested statistically. The feed consumed by each lot was determined. These figures show that Lot II (alfalfa-grain pellets) consumed 1117 pounds of feed per 100 pounds of gain, Lot III (clover-alfalfa-grain pellets) 1214, and Lot I (standard ration) 1269 pounds.

Table 7 - Summary Gains, Feed Requirements, and Feed Costs

Feed Period - Lot I and II, January 29 - May 22, 1957
Lot III, January 26 - May 22, 1957

	Lot I Chopped Hay, Grain & Molasses	Lot II Pellets Alfalfa, Barley & Molasses	Lot III Pellets Clover Straw Alfalfa, Barley & Molasses
No. Head	13	13	13
Days on Feed	113	113	116
Average Initial Weight - Pounds	707.5	716.1	712.8
Average Final Weight - Pounds	926.0	994.1	961.8
Average Total Gain - Pounds	219.5	278.0	249.0
Average Daily Gain - Pounds	1.94	2.46	2.14
Average Daily Feed - Pounds per head			
I - Chopped Hay(Alfalfa 50%, Oats 50%)	12.51		
Grain Cubed (Barley 65%, Oats 30% Molasses 5%	12.3		
II - Pellets, (Alfalfa 70%, Barley 25% Molasses 5%		27.5	
III - Pellets, (Clover straw 35%, Alfalfa 35%, Barley 25% Molasses 5%			26.1
Total	24.81	27.5	26.1
Feed Requirements per 100 lbs. gain (Feed mixture same as above)			
I - Chopped Hay	645.9		
Grain	622.9		
II - Pellets		1117.3	
III - Pellets			1214.0
Total	1268.8	1117.3	1214.0
Feed Costs per 100 lb. gain (Feed mixture same as above)			
I - Chopped Hay ($22. per ton)	$ 7.10		
Grain & Molasses ($60 per ton)	18.68		
II - Pellets, Alfalfa ($50 per ton)		$27.93	
III - Pellets, Clover, ($45.per ton)			$27.43
Total	$25.78	$27.93	$27.43

These figures indicate that the feed nutrients were more efficiently utilized in the pelleted form. When the total feed consumed per 100 pounds of gain by each of the three lots is converted to total digestible nutrients by using average compositions of digestible nutrients from "Feeds and Feeding" by Morrison (25, p.999) it is found that Lot I (standard ration) required 766.2 pounds total digestible nutrients per 100 pounds gain; Lot II (alfalfa pellets) 625.4 pounds, and Lot III (clover-alfalfa pellets) 743.6 pounds.

In making this comparison, 2 pounds of straw per head per day were added to the pellet fed lots because it was known that these cattle ate some straw. Straw was provided in feeders but an accurate record of the amount consumed could not be determined because the yards were bedded frequently with straw and the cattle ate appreciable quantities of the bedding. The 2 pounds amount was chosen because this was the quantity of loose roughage eaten daily by cattle in another feedlot where wood shavings was the bedding material.

When the straw is added, greater quantities of feed were consumed by the pellet fed cattle but the percentage of total digestible nutrients was lower because a much larger proportion of roughage to concentrates was fed the lots receiving the pellets. Table 8 presents this comparison.

Another approach to studying the efficiency of feed utilization of the pelleted and unpelleted feed is to compare average daily intake of total digestible nutrients by the different lots with the total digestible nutrients required for the average daily weight gains made by each lot, and the maintenance requirements of total digestible nutrients for the average weight of the cattle. The nutrient requirement figures used

Table 8 - A Comparison of Total Feed, Total Digestible Nutrients and Digestible Protein Consumed per 100 Pounds Gain

Feed	TDN	T.D.N. per 100 Lbs. Gain			D.C.P.	Digestible Protein per 100 Pounds Gain		
		Lot I	Lot II	Lot III	%	Lot I	Lot II	Lot III
Alfalfa	50.3	162.5	393.3	213.8	10.9	35.2	85.2	46.3
Oat Hay	47.3	152.8			4.9			
Clover Straw	40.0			170.0	3.8			16.2
Barley Straw	42.2			97.9	.7		1.6	1.6
Barley	75.6	306.2	211.9	229.1	9.2	37.6	25.7	27.9
Oats	68.5	128.1			9.0	16.8		
Molasses	53.3	16.6	20.2	32.8	0	0	0	
Total		766.2	625.4	743.6		95.4	112.5	92.0

Table 9 - Average Digestible Nutrients Consumed Daily Compared with Daily T.D.N. Requirements for Gains Made by Each Lot Cattle at Average Weights for Feeding Period

	Lot I	Lot II	Lot III
Average weight during feeding period	817	855	837
Average daily gain	1.94	2.46	2.14
Digestible protein required for average gain & weight*	1.32	1.52	1.39
Digestible protein furnished by feed consumed**	2.07	2.7	1.96
T.D.N. supplied by feed consumed**	15.0	15.8	14.7
T.D.N. required for average weight & daily gain of lot*	12.4	14.8	13.4
T.D.N. consumed over gain & maintenance req'ts.	1.6	1.0	1.3
T.D.N. required for maintenance at average weight*	4.8	5.0	4.9
T.D.N. consumed above requirements for average gain & weight	10.2	10.8	9.8
T.D.N. requirements for daily gain & weight over maintenance*	7.6	9.8	8.5
T.D.N. consumed over requirements	2.6	1.0	1.3

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* Digestible protein and T.D.N. required for maintenance and gain in beef cattle (poundsper day), Department of Animal Husbandry, University of California.

** Total digestible nutrients and digestible protein calculated from table of average composition of Digestible Nutrients of Feeds Appendix, Table I "Feeds and Feeding", Morrison.

were taken from a table prepared by the University of California (6, p. 1). The comparisons are shown in table 9. These figures show that adequate quantities of digestible protein were available in each ration so that this was not a limiting factor in feed utilization.

They also show that when daily allowances are made for total digestible nutrients required for the daily gains made by different lots that Lot I (standard ration) used 2.6 pounds per day more total digestible nutrients than requirements would indicate are needed, while Lot II (alfalfa pellets) used only 1 pound over these standards and Lot III (clover-alfalfa pellets) consumed 1.3 pounds more total digestible nutrients per day than the standards indicate.

From these figures, it appears that the additional number of pounds of feed consumed each day or total feed consumed for the period alone does not account for the greater daily gains made by pellet fed cattle.

Considering the price of feeds and the cost of processing and pelleting the different feed formulas, the cost of gains was lowest for Lot I (standard ration). The cost per 100 pounds gain for this lot was \$25.78; for Lot III (clover-alfalfa pellets), \$27.43; and Lot II \$27.93. The cost of the processed feeds used in the trial was: chopped hay (alfalfa and oat hay), \$22.00 per ton; cubed grain used for Lot I, \$60.00 per ton; alfalfa pellets used in Lot II \$50.00 per ton and clover-alfalfa pellets used in Lot III \$45.00.

In order for the pelleted rations to compete in cost of gains with the standard ration, the processing costs would have to be reduced \$4.00 per ton for the alfalfa-grain pellets making a processing charge of \$11.10 instead of \$15.10. The processing charge for the clover-alfalfa-grain pellets would have to be reduced $2.40 per ton, resulting in a charge of $12.70 per ton.

Table 10 gives a breakdown of the costs of the ingredients and the processing charges for the pelleted rations.

Table 10 - Ration Costs

Lot II (Alfalfa-Grain Pellets)

Ingredient	Pounds	Price Per Pound	Amount
Alfalfa	1400	.0125	17.50
Barley	500	.0263	13.15
Molasses	100	.025	2.50
Aureo-Pep	5	.35	1.75
Grinding, Mixing & Pelleting			15.10
			50.00
Lot III (Clover-Alfalfa)			
Clover Straw	700	.00535	3.75
Alfalfa hay	700	.0125	8.75
Barley	500	.0263	13.15
Molasses	100	.025	2.50
Aureo-Pep	5	.35	1.75
Grinding, Mixing, Pelleting			15.10
			45.00

The processing charges for the cubed grain used in Lot I was 9.00 per ton; the other ingredients the same as listed in Table 7. The chopped alfalfa-oat hay used in this lot was $22.00 per ton.

The cattle were all slaughtered by the same packer and no difference in the color or firmness of fat could be detected in the different lots. The packer stated that all carcasses were satisfactory in that respect.

The cattle were graded as feeders and as they finished the feeding period. The carcasses were graded by a Federal meat grader. Table 11 gives a summary of these grades. It was not possible to secure data on the slaughter grades or carcass yields for three animals in Lot III. Appendices A, B, and C give these data for each animal in each lot.

Table 11 - Summary - Carcass Grades and Yields - Feeder and Finish Grades

	Lot I Chopped Hay, Grain & Molasses	Lot II Pellets Alfalfa, Barley & Molasses	Lot III Pellets Clover Straw Alfalfa, Barley & Molasses
Number Head	13	13	13
Initial Weight - Average Pounds	707.5	716.1	712.8
*Finished Weight " "	926.0	994.1	961.8
Gain " "	219.5	278.0	249.0
Carcass Weight - Average Pounds	534.8	570.5	540.4
Yield - percent	57.75	57.39	56.17
Carcass Grade:			
Choice	3	7	5
Good	9	6	5
Standard	1		
Feeder Grades:			
Choice		1	1
Good	12	8	8
Medium	1	4	4
Common			1
Finish Live Grade:			
Choice	8	9	7
Good	5	4	6
Standard			1

*Finish weight based on cattle being held off feed overnight and hauled 10 miles and unloaded to weigh.

Statistical analysis of the carcass grades was made according to Li (22, p. 151-233) by assigning arbitrary values of 12 for choice, 10 for good and 8 for standard. The calculations are given in Appendix D.

Although Lot II had seven choice and six good, and Lot I, three choice, nine good and one standard, these differences were not significant at the

5% level (F, 3.3158; critical region, 4.1709), Lot III had five choice and five good, but this was not significantly higher than Lot I (F, 2.3695; critical region, 4.3248).

Carcass yields (dressing per cent) were secured on all cattle slaughtered (Appendices A, B, and C). The average dressing percentage of Lot I was 57.75; Lot II, 57.39, and Lot III, 56.17. Analysis of variance according to Li (22, p. 151-233) indicates that there is no significant difference in the carcass yields at the 5% level when any two of the lots are compared.

SUMMARY AND DISCUSSION

Under conditions of this trial the data and observations indicated the following:

1. Rations containing 70% roughage in pelleted form will fatten yearling steers to satisfactory grade and in normal feeding periods.
2. Pelleted rations containing large percentage of roughages will produce faster gains on less total digestible nutrients per 100 pounds gain than steers on standard hay and grain rations.
3. The high legume roughage in pelleted form produced carcasses that graded higher than the standard ration and the color and firmness of the fat was equal to that of the carcasses produced from the standard ration.
4. The cost of the gains for the pellet fed cattle was higher than that for the standard ration at the price of feeds and

the processing costs prevailing at the time of this feeding trial.

5. Pelleted high roughage rations can safely be fed free choice starting with the first day the animals are placed on feed.
6. Less digestive disturbances were encountered on pelleted high roughage rations than on standard loose hay and grain rations.
7. Cattle on pelleted rations crave some coarse roughage and will eat straw or bedding to satisfy this craving.

CONCLUSIONS

The literature reviewed and the experimental work conducted point to the following advantages and disadvantages of pelleted roughage rations. Advantages claimed and apparently substantiated are:

1. Pelleting high roughage feeds improves the performance of a ration over unpelleted feed by:
    a. Increasing the rate of gain
    b. Decreasing the amount of feed or digestible nutrients required to produce a pound of gain
    c. Improving the palatability of the feed
    d. Increasing the consumption of feed
2. High roughage feeds in pelleted form will fatten lambs and beef cattle to a higher grade or to the same grade in shorter time than the same rations unpelleted.
3. Beef cattle or lambs can be given pelleted rations free choice from the start with less digestive disturbances than the same feeds in unpelleted form.
4. Less skill or attention is needed in feeding pelleted mixtures to sheep or cattle.
5. The greatest advantage from pelleting feed is secured when large quantities of roughage are used and when poor quality roughage feed is utilized.
6. Young animals such as lambs and calves show the greatest response to pelleted rations. This is partly explained by the greater quantity of feed consumed.

7. Labor in feeding is reduced through pelleting because greater mechanization is possible and fewer trips to the feed lot are required.
8. A complete ration can be incorporated in the pellet which prevents animals from sorting out the less palatable ingredients.
9. Less waste from wind or from handling by the feeder and by the animals themselves is experienced when feeds are pelleted.
10. Less space is needed for storage for pelleted feed because of its greater density although the storage must be more moisture proof than storage for hay.
11. Due to its greater density and its adaptability to mechanical handling transportation is less expensive.

Disadvantages have been listed as follows:

1. The feed cost per pound of gain was higher for pelleted feeds in some of the trials cited but credit to the pellets for less labor for handling and increase in carcass value because of higher finish was not accounted for. Present grinding and pelleting charges add $10 to $12 per ton to the feed, which may not be offset by improved performance.
2. Above the extra cost of pelleting feed, there is an additional cost of hauling hay to be processed compared to feeding roughage or long hay when this ingredient is produced where fed. This situation may be improved if field pelleting machinery is developed.
3. Shrinkage of lambs and cattle fed pellets was greater than those fed unpelleted feed. A common practice by packers is to deduct

6% shrink for pellet fed lambs and 4% for lambs fed unpelleted feed. Experience has shown that pellet fed animals carry a greater fill and are slower to lose it.

4. Cattle or lambs fed pelleted rations crave coarse unprocessed roughage such as long hay or straw.

Research and actual feed lot results have shown that pelleting high roughage feed for cattle and sheep improves the performance of the feed. The use of pelleted feeds is increasing and it appears that the principle of the pelleting process will be further utilized. The greatest hurdle to cross before fullest use can be made of this kind of feed is to reduce the cost of processing. Judging from the developments made in other manufacturing processes it seems certain that methods, equipment or other factors will be discovered that will make it possible to fully utilize this method or similar methods of preparing the feed.

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APPENDICES

APPENDIX A

Lot I - Initial and finish weights, grades, and carcass yields

No.	Weights: Initial	Weights: Finish*	Weights: Carcass	Av. Daily Gain	Yield %	Grades: Feeder	Grades: Finish	Grades: Carcass	Grades: Value
282	645	845	487	1.77	57.63	Good	Good	Good	10
278	565	780	452	1.90	57.95	Good	Good	Good	10
486-7	595	750	419	1.37	55.87	Good	Good	Std.	8
277	700	900	538	1.77	59.78	Good-	Good	Good	10
276	695	875	500	1.59	57.14	Good	Choice	Good	10
290	705	940	533	2.08	56.70	Good	Good	Good	10
289	720	980	549	2.30	56.02	Good	Choice	Good	10
499	875	1145	648	2.39	56.59	Good+	Choice	Choice	12
481	890	1180	708	2.57	60.00	Good	Choice	Choice	12
297	770	980	569	1.86	58.06	Medium	Good	Choice	12
294	700	860	498	1.42	57.91	Good	Choice	Good	10
500	730	990	583	2.30	58.89	Good	Choice	Good	10
298	600	820	469	1.95	57.20	Good	Choice	Good	10
	9190	12045	6953	25.27					
Average	706.9	926.5	534.8	1.94	57.75				

*Finish weight based on overnight stand off feed and water and a 10 mile haul to scales

APPENDIX B Lot II - Initial and finished weights, grades, and carcass yields

No.	Weights Initial	Finish*	Carcass	Av. Daily Gain	Yield %	Feeder	Finish	Carcass	Value
280	695	935	505	2.12	54.01	Good-	Good	Good	10
484	610	910	518	2.65	56.92	Good	Good	Good	10
279	600	855	502	2.26	58.71	Good	Choice	Good	10
197	695	960	551	2.35	57.40	Medium	Good	Good	10
284	695	935	546	2.12	58.39	Good+	Choice	Choice	12
489	775	1040	606	2.35	58.27	Choice	Choice	Good	10
295	785	1085	611	2.65	56.31	Good	Choice	Choice	12
292	845	1135	659	2.57	58.06	Medium	Choice	Choice	12
296	755	1105	591	3.10	53.48	Medium	Choice	Choice	12
291	820	1130	666	2.74	58.94	Good	Choice	Choice	12
288	615	870	477	2.26	54.83	Good	Good	Good	10
496	685	965	546	2.48	56.58	Medium	Choice	Choice	12
480	725	995	564	2.39	56.68	Good	Choice	Choice	12
	9300	12920	7342	32.04					
Average	715.3	993.8	564.7	2.46	57.39				

*Finish weight based on overnight stand off feed and water and a 10 mile haul to scales

APPENDIX C

Lot III - Initial and finish weights, grades, and carcass yields

	Weights			Av. Daily	Yield	Grades			
No.	Initial	Finish*	Carcass	Gain	%	Feeder	Finish	Carcass	Value
283	660	915	507	2.20	55.41	Good	Choice	Good	10
194	695	945	530	2.16	56.08	Good	Choice	Choice	12
281	595	740		1.25					
195	550	845		2.54					
196	775	1015		2.07					
488	810	1090	600	2.41	55.05	Good-	Good	Choice	12
490	780	1010	581	1.98	57.62	Good+	Choice	Good	10½
493	805	1080	611	2.37	56.57	Choice	Choice	Choice	12
498	765	995	541	1.98	54.37	Good+	Choice	Choice	12
491	700	985	580	2.46	58.88	Good	Good	Good	10
497	755	1030	567	2.37	55.05	Medium	Good	Good	10
492	700	960	542	2.24	56.46	Medium	Good	Choice	12
293	655	870	489	1.85	56.21	Good+	Choice	Good	10
	9245	12480	5548	27.88					
Average	711.1	960.	554.8	2.14	56.17				

*Finish weight based on overnight stand off feed and water and a 10 mile haul to scales

APPENDIX D ANALYSIS OF VARIANCE

Average Daily Gain

No.	Lot I	Lot II	Lot III
1	1.77	2.12	2.20
2	1.90	2.65	2.16
3	1.37	2.26	1.25
4	1.77	2.38	2.54
5	1.59	2.12	2.07
6	2.08	2.35	2.41
7	2.30	2.65	1.98
8	2.39	2.57	2.37
9	2.57	3.10	1.98
10	1.86	2.74	2.46
11	1.42	2.26	2.37
12	2.30	2.48	2.24
13	1.95	2.39	1.85
T	25.27	32.07	27.88
$\bar{y}$	1.94	2.46	2.14
			G=85.22

Preliminary Calculations

Source of Variation	Total of Squares	No. Items Squared	Observations Per Sq. Item	Total of Sq. Per Observation
Grand	7262.4484	1	39	186.2166
Treatment	2444.3522	3	13	188.0271
Observation	191.9826	39	1	191.9826

Analysis of Variance

Variation Due to:	Sum of Squares	Degrees of Freedom	Mean Square	F	Critical Region
Treatment	1.8105	2	.9052	8.2366	5% = 3.3158
Error	3.9555	36	.1099		1% = 5.3904
Total	5.7660	38			

APPENDIX D ANALYSIS OF VARIANCE

Average Daily Gains (Continued)

Source of Variation	Sum of Squares	D.F.	Mean Square	F	Critical Region 5%	Critical Region 1%
Feed	1.8105	2	.9052	8.2366	3.3158	5.3904
Std. vs. Subs.	1.1256	1	1.1256	10.2420	4.1709	7.5625
Std. vs. II	1.7785	1	1.7785	16.1820	4.1709	7.5625
Std. vs. III	.2620	1	.2620	2.3840	4.1709	7.5625
II vs. III	.6752	1	.6752	6.1438	4.1709	7.5625
Error	3.9555	36	.1099			
Total	5.7660	38				

Multipliers

	M_1	M_2	M_3
Q_1^2	+2	-1	-1
Q_2^2	+1	-1	0
Q_3^2	+1	0	-1
Q_4^2	0	+1	-1

$$Q_1^2 = \frac{[2(25.27) - 1(32.07) - 1(27.84)]^2}{13[(2)^2 + (-1)^2 + (-1)^2]} = \frac{(-9.37)^2}{78} = \frac{87.80}{78} = 1.1256 \text{ M S}$$

$$Q_2^2 = \frac{1(25.27) - 1(32.07)\ ^2}{12[(+1)^2 + (-1)^2]} = \frac{(-6.80)^2}{26} = \frac{46.24}{26} = 1.7785$$

$$Q_3^2 = \frac{1(25.27) - 1(27.88)\ ^2}{13[(+1)^2 + (-1)^2\ ^2]} = \frac{(-2.61)^2}{26} = \frac{6.8121}{26} = .2620$$

$$Q_4^2 = \frac{1(32.07) - 1(27.88)\ ^2}{13[(+1)^2 + (-1)^2]} = \frac{4.19}{26} = \frac{17.5561}{26} = .6752$$

Conclusions: (1) Average daily gains made by Lot II (Alfalfa and grain pellets) is significantly higher than Lot I (Standard hay and grain) at the 1% level ($F = 16.18 > 7.56$, the critical region with 1 and 36 degrees of freedom). (2) Lot II made significantly higher gains at the 5% level than Lot III (alfalfa, clover, and grain pellets) ($F = 6.1438 < 4.171$, the critical region with 1 and 36 degrees of freedom). (3) The average daily gains made by Lot III were not significantly higher than Lot I at the 5% level ($F = 2.38 < 4.171$, the critical region with 1 and 36 degrees of freedom).

APPENDIX D ANALYSIS OF VARIANCE

Carcass Grade

No.	Lot I	Lot II	Lot III	
1	10	10	10	
2	10	10	12	
3	8	10	12	
4	10	10	10	
5	10	12	12	
6	10	10	12	
7	10	12	10	
8	12	12	10	
9	12	12	12	
10	12	12	10	
11	10	10		
12	10	12		
13	10	12		
T	134	144	110	G=388
$\bar{y}$	10.3077	11.0769	11.0	G^2=150,544
T^2	17956.	20736.	12100.0	
T^2/N	1381.3077	1595.0769	1210.	
y^2	1396.	1608.	1220.	

Preliminary Calculations

Source of Variation	Total of Squares	No. Items Squared	Observations Per Sq. Item	Total of Squares Per Observation
Grand	150,544	1	36	4181.7777
Treatment				4186.3846
Observation				4224.0000

Analysis of Variance

Variation due to:	Sum of Squares	D.F.	Mean Square	F	Critical Region
Treatment	4.6069	2	2.3034	2.0207	5% = 3.3158
Error	37.6165	33	1.1399		
Total	42.2234	35			

Lot I vs. Lot II

$$Q_2^2 = \frac{[1(134) - 1(144)]^2}{13[(+1)2 + (-1)2]} = \frac{(10)^2}{26} = \frac{100}{26} = 3.8461 = \text{M S;}$$

$$\frac{3.8461}{1.1399} = 3.3741 = F\text{; Critical region } 4.1709$$

APPENDIX D ANALYSIS OF VARIANCE

Carcass Grade

The carcass grade of Lot II was not significantly higher than Lot I (F = 3.3741   4.1709, critical region, 1 and 33 D. F.)

Lot I vs. Lot III

Preliminary Calculations

Source of Variation	Total of Squares	No. Items Squared	Observations Per Sq. Item	Total of Squares Per Observation
Grand	59,536	1	23	2588.5217
Treatment				2591.3077
Observation				2616.0000

Analysis of Variance

Variation due to:	Sum of Squares	D.F.	Mean Square	F	Critical Region
Treatment	2.7860	1	2.7860	2.3695	5% = 4.3248
Error	24.6923	21	1.1758		
Total	27.4783				

The carcass grade secured for Lot III is not significantly higher than Lot I at the 5% level (F = 1.3695 4.3248, the critical region for 1 and 21 D.F.)

Lot II vs. Lot III

Preliminary Calculations

Source of Variation	Total of Squares	No. Items Squared	Observations Per Sq. Item	Total of Squares Per Observation
Grand	64,516	1	23	2805.0435
Treatment				2805.0769
Observation				2828.0000

Analysis of Variance

Variation due to:	Sum of Squares	D.F.	Mean Square	F	Critical Region
Treatment	.0334	1	.0334	.0306	5% = 4.3248
Error	22.9231	21	1.0916		
Total	22.9565	22			

APPENDIX D ANALYSIS OF VARIANCE

Carcass Grade (Continued)

The carcass grade secured for Lot II is not significantly higher than Lot III at the 5% level (F = .0306 4.3248, the critical region for 1 and 21 D.F.)

Carcass Yield

No.	Lot I	Lot II	Lot III	
1	57.63	54.01	55.41	
2	57.95	56.92	56.08	
3	55.87	58.71	55.05	
4	59.78	57.40	57.62	
5	57.14	58.39	56.57	
6	56.70	58.27	54.37	
7	56.02	56.31	58.88	
8	56.59	58.06	55.05	
9	60.00	53.48	56.46	
10	58.06	58.94	56.21	
11	57.91	54.83		
12	58.89	56.58		
13	57.20	56.68		
T	749.74	738.58	561.70	G = 2050.02
$\bar{y}$	57.75	57.39	56.17	
T^2	562110.0676	545500.4164	315506.8900	
T^2/N	43239.2360	41961.5705	31550.6890	
Σy^2	43259.4666	41999.4370	31566.7158	Σy^2 = 116825.6194

Preliminary Calculations

Source of Variation	Total of Squares	No. Items Squared	Observations Per Sq. Item	Total of Squares Per Observation
Grand	4202582.0004	1	36	116738.3888
Treatment				116751.4954
Observation				116825.6194

Analysis of Variance

Variation due to:	Sum of Squares	D.F.	Mean Square	F	Critical Region
Treatment	13.1066	2	6.5533	2.91750	5% = 3.3154
Error	74.1240	33	2.2462		
Total	87.2306	35			

APPENDIX D ANALYSIS OF VARIANCE

Carcass Yield (Continued)

Lot I vs. Lot II

$$Q_1^2 = \frac{[749.74 - 738.58]^2}{13\,[(1+1)^2 + (-1)^2]} = \frac{(11.16)^2}{26} = \frac{124.5456}{26} = 4.7902 = M.S;$$

$$\frac{4.7902}{2.2462} = 2.1326 = F; \text{ Critical region } 4.1709$$

The carcass yield for Lot I (57.75) was not significantly higher than Lot II (57.39), ($F = 2.1326 < 4.1709$, critical region with 1 and 33 D.F.)

Lot I vs. Lot III

Preliminary Calculations

Source of Variation	Total of Squares	No. Items Squared	Observations Per Sq. Item	Total of Squares Per Observation
Grand	1719874.8736	1	23	74777.1684
Treatment				74789.9250
Observation				74826.1824

Analysis of Variance

Variation due to:	Sum of Squares	D.F.	Mean Square	F	Critical Region 5%	Critical Region 1%
Treatment	12.7566	1	12.7566	7.3308	4.3248	8.0166
Error	36.2574	21	1.7265			
Total	49.0140	22				

Carcass yield of Lot I is significantly higher at the 5% level than Lot III. ($F = 7.3308$ 4.3248, critical region with 1 and 21 degrees of freedom)

Lot II vs. Lot III

$$G = T_2,\ 738.58 + T_3,\ 561.70 = (1300.28)^2$$

$$G^2 = 1{,}690{,}728.0784$$

APPENDIX D ANALYSIS OF VARIANCE

Carcass Yield (Continued)

Preliminary Calculations

Source of Variation	Total of Squares	No. Items Squared	Observations Per Sq. Item	Total of Squares Per Observation
Grand	1690728.0784	1	23	73509.9164
Treatment				73512.2595
Observation				73566.1528

Analysis of Variance

Variation due to:	Sum of Squares	D.F.	Mean Squares	F	Critical Region
Treatment	2.3431	1	2.3431	.9130	5% = 4.3248
Error	53.8933	21	2.5663		
Total	56.2364	22			

The carcass yield of Lot II is not significantly higher than Lot III at the 5% level ($F = .9130 < 4.3248$, critical region with 1 and 21 degrees of freedom)