THE EFFECT OF FINE GRINDING AND PELLETING LAMB RATIONS ON GROWTH AND DIGESTIBILITY

By

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THE EFFECT OF FINE GRINDING AND PELLETING LAMB RATIONS ON GROWTH AND DIGESTIBILITY

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INTRODUCTION

Several livestock producers in the Southwest, particularly in Oklahoma, Texas, and New Mexico, are self-feeding pelleted fattening rations to cattle and sheep. Among the possible advantages of such a practice are greater ease of handling the feed, increased consumption of the feed, increased digestibility of the ration, and less waste of feed than when the ration is fed in a coarse or finely ground state. It seems that the first two are the most logical possibilities. However, whether or not pelleting affects the nutritive value of a feed is not fully known.

Considerable research has been reported on the effect of fine grinding on feed consumption and the digestibility of a ration. However, the effect of pelleting a ration on its digestibility has not been studied extensively.

The digestion trials described herein were designed to determine (1) the effect of fine-grinding on the digestibility of a ration, (2) the effect of pelleting the fine-ground ration on its digestibility, and (3) the digestibility of the ration fed in the coarse form. The objectives of the growth studies were to determine the effect on rate and efficiency of gain of (1) ad libitum feeding of the fine-ground ration, (2) ad libitum feeding of the same ration pelleted, (3) free-choice feeding of a coarse ration, and (4) ad libitum feeding of coarse hay but with the intake of concentrates limited to the quantity of concentrates consumed by the animals fed the pelleted ration.

REVIEW OF LITERATURE

Sheep

Murdock and Miller (1951) studied the effect of method of curing and physical state upon the composition and nutritive value of alfalfa hay. The three methods used in curing the hay were regular-dehydrated, wilted-dehydrated, and sun-cured. Each of the three curings of hay was prepared in three physical states: (1) coarse cut, (2) finely ground, and (3) finely ground and pelleted. The coarse-cut hay was passed through the dehydrator without subsequent grinding, and the length of cut varied between one-fourth and two inches. The finely ground hay was prepared by grinding in a hammer mill. The pelleted form of hay was prepared by pelleting part of the finely ground meal in a commercial pelleting plant. The pellets were more or less square and were five-eighths by one-half inch in dimension. In the digestion study, six yearling wether lambs were fed each ration at a level near maintenance. The coarse-cut and pelleted hays had significantly ($P < .01$) higher digestible nutrient values than the fine ground hay. The authors state that the adverse effect of fine grinding on the total digestible nutrient content was due to lowered digestibility of the crude fiber. The coefficients of digestibility of the crude fiber were 44.4, 35.1, and 40.7 percent in the coarse-cut, finely ground, and pelleted rations, respectively. There was a significant difference ($P < .01$) in the crude fiber digestibility of coarse-cut compared to finely ground hay, but no significant difference was shown when the coarse-cut was compared to pelleted hay.

Neale (1953) compared self-feeding pellets made of low-grade hay, sorghum grain, and molasses with a hand-fed ration containing finely ground alfalfa hay and whole sorghum grain for fattening light-, medium-, and heavy-weight lambs. Two pelleted mixtures of the coarse hay and sorghum grain were compared with two hand-fed rations of hay and grain for fattening wethers. One pelleted mixture contained 60 percent alfalfa hay, 30 percent ground sorghum grain and 10 percent molasses (60-40). The other pelleted feed was 50 percent alfalfa hay, 40 percent sorghum grain, and 10 percent molasses (50-50). The hand-fed hay was bright green, fairly fine-stemmed, and of medium grade. The hand-fed sorghum grain was whole and came from eastern New Mexico. The pellets were made of coarse, stemmy, poor colored alfalfa hay. The sorghum grain used in the pelleted ration came from the same area as that used in the hand-fed ration. Each weight group of lambs was divided into two equal lots, one for hand-feeding and one for self-feeding. After feeding the 60-40 pellets for 25 days, the self-fed lambs were changed gradually to the 50-50 pellets and were fed these until the end of the trials. The heavy lambs, with only a 34-day feeding period, were not fed as much of the 50-50 pellets as the light lambs, which had an 82-day feeding period. The final ratios were 1 lb. of concentrate to 1.2 lbs. of hay for light lambs, 1 lb. of concentrate to 1.4 lbs. of hay for the medium lambs, and 1 pound of concentrate to 1.6 lbs. of hay for the heavy weight lambs. The author states it took 25 to 35 percent less total digestible nutrients to fatten wethers on the 60-40 pellets self-fed than on the hand-fed alfalfa hay and whole sorghum grain ration. The 50-50 pelleted ration was between 6 and 7 percent less efficient, as measured by lbs. of

feed required per 100 lbs. of gain, than the 60 percent alfalfa pellets, but was 18 to 25 percent more efficient than the hand-fed ration.

The same workers reported a three-year study of two self-fed rations and two hand-fed rations for fattening yearling wethers. The rations were the 60-40 and 50-50 feeds as described in the previous test. The lambs fed the 60-40 pellets were the most efficient each year. These lambs also had the highest rate of gain in all years and in two years required fewer days to fatten. The lambs fed pellets containing a ration of 50-50 roughage and concentrate did not gain as fast as the lot fed the 60-40 pellets and required more nutrients per unit of gain. The amount of feed required per lb. of gain varied between years, but the differences in requirements between lots were similar each year. The hand-fed lots required 18 to 39 percent more total digestible nutrients than the self-fed lots. The author states that this greater efficiency of gain for the lambs fed the pelleted ration may be due to self-feeding, to the molasses in the mixture, to the preparation of the feed for pelleting, or to the fact each wether had to eat a complete ration at all times. There was little or no waste feed in either lot fed the pelleted ration. The lambs in the hand-fed lots wasted a small amount of hay but no grain.

Bell and associates (1954) conducted an experiment to determine if a ration of corn and alfalfa hay would produce larger and more economical gains when fed as pellets than when the hay was fed long and the corn unground. The feeding of pelleted rations resulted in larger average daily gains (0.06 of a lb. more per lamb in each pelleted lot) than the same ration fed as long hay and whole grain. Also 150 to 160 lbs. less feed was required to produce 100 lbs of gain

with the pelleted rations than with the same rations unpelleted. The authors state that the cost per unit of gain was considerably higher when the pellets were fed because of the high cost of pelleting.

Schneider and associates (1953) reported the results of fattening thirty-two groups of six lambs each in a replicated factorial experiment designed to investigate the effect of Austrian peas added to a low-protein ration; pelleted vs. unpelleted; alfalfa hay vs. pea vine silage; and self-feeding vs. hand feeding. The pelleted or unpelleted feed mixture, other than the alfalfa hay or pea vine silage, consisted of 25 percent alfalfa meal, 20 percent dried molasses beet pulp, 52 percent barley, and 3 percent molasses. The lambs self-fed pelleted feed and those hand-fed unpelleted feeds gained 0.44 and 0.45 lb. per head daily, while those hand-fed pelleted feed and self-fed unpelleted feed gained 0.41 and 0.40 lb. per head daily respectively. This interaction indicated significantly greater gains when the pelleted feed was self-fed and just the opposite, i.e., greater gains with the unpelleted feed, when the lambs were hand-fed. None of the other comparisons was significant.

Noble and associates (1953) self-fed a mixture of 45 percent ground Redland kafir, 50 percent ground alfalfa hay and 5 percent blackstrap molasses in a finely ground and pelleted state. Thirty wethers and 44 ewes were divided into two lots on the basis of sex, weight, and grade. The lambs fed the pelleted ration made average daily gains of 0.46 lb. as compared to daily gains of 0.45 lb. for the lambs on the ground ration. More efficient gains were made by the lambs fed the pelleted ration than by those fed the unpelleted ration, requiring 23 lbs. less milo and 25 lbs. less alfalfa per 100 lbs. of gain. The

cost per 100 lbs. of gain was $ 0.18 less for the pelleted ration compared to the ground ration. The carcass grades were also higher for the lambs fed the pelleted ration, 28 lambs were graded U. S. Choice and 9 were graded U. S. Good as compared to 20 U. S. Choice and 17 U. S. Good lambs in the group fed the unpelleted ration. There was a difference of $ 0.27 per lamb profit in favor of the lambs fed the pelleted ration.

Noble and associates (1954) self-fed a mixture containing 45 percent ground Redland kafir, 50 percent ground alfalfa hay and 5 percent blackstrap molasses in the finely ground state, and finely ground and pelleted. Sixty-two lambs were divided into lots of 31 each, drenched with phenothiazine, tagged, and vaccinated against Enterotoxemia. The lambs fed the pelleted ration made average daily gains of 0.44 lb. as compared to daily gains of 0.40 lb. for the lambs fed the ground ration. The lambs fed the pelleted ration also made slightly more efficient gains than lambs fed the ground ration, requiring 9 lbs. less kafir and 10 lbs. less alfalfa hay per cwt. gain, but returned less profit per lamb since the cost per cwt. gain was $0.81 higher due to the cost of pelleting. The carcass grades and dressing percentage were almost identical for the two lots, indicating very little difference in finish. The authors state that pelleting was worth only $1.00 per ton in this test, while the actual cost was $3.00 per ton.

U.S.D.A. workers (1952) at the Beltsville Station conducted a trial during the 1951-52 feeding season with a limited number of fattening lambs in which a ration of alfalfa hay, yellow corn, and blackstrap molasses was (1) hand-fed; (2) ground, mixed, and self-fed; and (3) ground, pelleted and self-fed. Although there were individual

differences between animals, the results indicated that pelleting of the ration increased the rate of gain, shortened the feeding period, and resulted in more efficient feed utilization.

Kuhn and associates (1950) conducted an experiment to determine the effect of grinding and pelleting of feed upon rumination and composition of the milk of ewes. Four lactating ewes were maintained for nine weeks on a ration of corn, wheat bran and alfalfa hay. The rations of two ewes contained alfalfa hay which was ground and pelleted. These two ewes ruminated very little after they were fed the ration a few days. Milk samples were taken at weekly intervals. The average final fat content of the milk from ewes fed the long hay was 8.7 percent, and that from the ewes fed the pelleted hay was 8.0 percent. The authors state that lack of rumination showed no marked effect on the composition of ewe's milk.

Swine

U.S.D.A. workers (1953) at the Beltsville Station observed that the use of pelleted diets was not as advantageous for fattening swine as for lambs. In an experiment at the Agricultural Research Center with pigs kept on pasture and fed a mixture of corn and protein concentrates, growth rates were practically identical for the pelleted and the meal forms of this supplemental feed. The feed efficiency of the ration containing pellets was slightly better than that of the meal form of concentrates, but this was attributed to the fact that there was less wastage, since the pigs were observed to pick up spilled pellets around the feeders, whereas spilled meal mixed into the dirt and was not recovered. An all-pelleted concentrate mixture appeared to have some advantage over one in which the pelleted protein concentrate

was mixed with shelled corn. An earlier test showed that the pigs wasted considerable amounts of the pelleted concentrate because of their preference for corn.

Schneider and Brugman (1950) conducted a study on the value of pelleting feed for swine. It required 379.1 lbs. of feed per 100 lbs. of gain for those fed the pellets, while 409.7 lbs. of unpelleted feed were required per 100 lbs. of gain.

In a second experiment two lots of six Landrace-Chester White pigs each were self-fed the pelleted feed and two comparable lots received the same mixture unpelleted. The pigs fed the pelleted mixture gained an average of 1.68 lbs. per head per day, while those fed the unpelleted mixture gained an average of 1.56 lbs. per head per day. There was also a considerable difference in lbs. of feed required per lb. of gain. It required 4.66 lbs. of pelleted feed and 6.26 lbs. of the same feed unpelleted per lb. of gain to go from a body weight of about 100 lbs. to market weight. There was some difference in feed wastage, but the authors state that they believed the pelleted feed was different nutritionally from the same feed unpelleted. This was due to the selection of the most palatable feeds in the unpelleted ration by the pigs during eating. They conclude that the results of the experiment indicate that pelleting may be worth from 10 percent to 40 percent of the value of the feed when fed to swine, depending on the conditions of feeding.

Dinusson and Light (1951) studied the effect of pelleting as a means of improving the feeding value of barley. Two trials involving 80 pigs are included in the report. The pigs fed pelleted barley gained 12 to 14 percent faster and required from 3 to 17 percent less feed per lb. of gain than pigs on comparable ground barley rations.

When the pelleted barley ration was compared to a corn ration, either ground or pelleted, the pigs fed pelleted barley gained 10 to 14 percent faster, and the feed efficiency was as good or superior to the corn ration. The authors state that the saving in feed more than pays for the cost of pelleting barley rations.

Thomas and Flower (1953) conducted two experiments to study the value of pelleting rations for fattening swine. The pigs used in both experiments were crossbred. In the 1951 trial 180 pigs were divided into two lots; one lot was self-fed the ration in a pelleted form, whereas the other lot was self-fed the ration in a meal form. The pigs fed the pelleted ration required an average of 52 lbs. less feed per 100 lbs. of gain, gained 0.11 lb. more per day, and reached market weight 12 days sooner than pigs fed the same ration in meal form. In the 1952 trial, 48 pigs were divided into six lots on the basis of weight and sex. The initial average weight of pigs in the two heaviest lots was 50 lbs.; medium-weight lots, 39 lbs.; and light-weight lots, 31 lbs. The ration contained barley, oats, wheat, dehydrated alfalfa meal, soybean meal, meat meal, complete mineral mixture, irradiated yeast, a B-vitamin supplement and a B_{12} and antibiotic supplement. There was a significantly greater ($P < .01$) average daily gain among the pellet-fed pigs than among the meal-fed pigs. The average amount of feed required per cwt. of gain was 345 lbs. for the pellet-fed lots and 413 lbs. for the meal-fed lots. Pigs fed the pelleted ration reached marked weight 14 days sooner than did pigs on the meal ration.

Dinussion and associates (1951), in initial trials of a project designed to study methods of increasing the value of barley and oats for swine feeds, allotted thirty Duroc pigs averaging 47 to 48 lbs. in weight at random into three lots. These pigs were self-fed three

rations in a comparison of the value of pulverized barley, ground corn, and pelleted pulverized barley. It was thought that pulverizing the barley to minimize the effect of fiber and then pelleting to increase the palatability would increase its feeding value. The control ration consisted of 73 percent coarsely ground yellow corn, 5 percent dehydrated alfalfa, 5 percent meat scraps, 16 percent soybean oil meal, 1 percent salt-mineral supplement, plus vitamin A and D supplement. The barley rations consisted of 81 percent pulverized barley, 8 percent soybean oil meal, salt and mineral and vitamin A and D supplement. The pigs fed the control ration gained 1.62 lbs. per head daily and required 4.09 lbs. of feed per lb. of gain. Those fed pulverized barley gained 1.57 lbs. per head daily and required 4.09 lbs. of feed per lb. of gain. The pigs receiving the pelleted pulverized barley ration gained 1.79 lbs. per day and required 3.39 lbs. of ration per lb. of gain. The cost of pelleting was more than offset by increased gains and feed efficiency.

Lehrer and Keith (1952) conducted an experiment to determine whether or not pelleting rations was of any economical and/or nutritional value. In this study purebred Poland China and Duroc weaner pigs were equally divided into eight lots. Each lot was comparable in respect to breed, sex, weight and thriftiness. The pigs were housed in concrete lots and had access to shelter with straw bedding. The amount of feed required per lb. of gain was 5.28 lbs. for the pigs fed the non-pelleted feed and 4.4 lbs. for those fed pellets. The pigs in the pelleted lots also made superior daily gains, 0.98 as compared to 0.74 lb. per day for the lots fed the non-pelleted ration. In the second part of the experiment, using eight lots of Poland China and

Duroc weaner pigs treated in the same manner as the animals in trial one, the authors observed that pigs in the pellet-fed lots made slightly greater gains on less feed than those in the lots fed the same ration non-pelleted. One lb. of gain was produced by 3.75 lbs. of the pelleted ration and by 5.09 lbs. of the non-pelleted ration. The average daily gains for the pelleted and non-pelleted feeds were 1.81 and 1.76 lbs. per day, respectively.

Terrill and associates (1951) conducted three experiments in the fall of 1950. Fifty sows and litters were used to study the value of various creep rations for suckling pigs and to compare the palatability of a variety of feeds and rations when offered free-choice to suckling pigs. The pigs had access to rations in an outdoor creep located near the sow's self-feeder. A ration consisting of hulled oats and pig supplement fed free-choice was compared with dry synthetic milk creep-ration in the first experiment. Part of the dry synthetic milk ration was pelleted and offered free-choice with the unpelleted form of this ration at the start of the test. The pigs showed a decided preference for the pelleted form of feed, consuming all of the pelleted feed early in the experiment. During the rest of the test, only the un-pelleted ration was fed in the creep. In experiment II a high efficiency broiler ration was compared with a mixed pig starter. Both rations were fed free-choice in the meal and pelleted form. The meal and pelleted form of the mixed pig starter ration proved to be about equally palatable to the pigs, but the pigs fed the high-efficiency broiler ration ate over four times as much of the pelleted ration as of the unpelleted. The same workers conducted a third trial designed to compare the palatability of a variety of feeds and rations when

offered free-choice to suckling pigs. Six sows and their litters were used in this phase of the study. From October 5 to November 13, 1950, the 36 pigs had access to 16 different feeds or combinations of feeds. The authors state that the pigs used in this experiment also seemed to prefer pelleted rations to rations in the form of meal.

Lehrer and Keith (1953) of the Idaho station compared pelleted rations with non-pelleted rations for swine. In trial I the animals in each lot were fed rations containing approximately 21 percent protein until they reached an average weight of 125 lbs., at which time they were fed rations containing approximately 16 percent protein. Animals were fed until they reached the weight of approximately 180 lbs. The authors state that the pigs fed the pelleted rations gained an average of 1.85 lbs., while those fed the non-pelleted rations gained an average of 1.73 lbs. The lbs. of feed required per lb. of gain also showed considerable difference between feed preparations. The pigs required an average of 375 lbs. of pelleted feed for every 100 lbs. of gain as compared to 510 lbs. of the same feed non-pelleted, a difference of 135 lbs.

In a second trial the relative value of pelleted vs. non-pelleted rations which were high in dehydrated alfalfa meal was studied. Desirable average daily gains were made by pigs fed the pelleted ration and they required less feed to produce 100 lbs. of pork than pigs fed the same ration non-pelleted. In this trial the pigs fed non-pelleted rations also wasted more feed than those pigs fed similar rations pelleted.

Dimusson *et al.* (1953) conducted two experiments designed to compare the intake and palatability of a ration of high fiber content, when fed to pigs as a finely ground ration, and finely ground and

pelleted. In the two experiments more than eighty pigs were involved. The author states that statistical analysis showed that the differences in rate of gain between lots (Experiment I) was significant at the five percent level, and the difference in experiment II approached significance. In these two experiments the pelleted rations showed a definite advantage in rate of gain in that pigs gained from 12 to 14 percent faster than the pigs on ground barley rations and required from eight to 17 percent less lbs. of feed per hundred lb. of gain. The author states that pelleted ration made from good quality barley and properly supplemented can compete with corn ration in terms of rate of gain and feed efficiency. The lots fed pelleted barley ration gained from 10 to 14 percent faster and the feed efficiency was as good as, and in some cases superior to,the corn rations.

Steffen (1953) compared a pelleted ration fed to pigs with the same ration fed in the meal form. Sixty-four pigs were allotted at random into eight groups of eight pigs per group. All were self-fed and water was available at all times. The principal ingredient of the ration was wheat. In this experiment 100 lbs. of the pellets proved as valuable as 108.4 lbs. of the meal. Based on the value of the meal each 100 lbs. of the pellets was worth $4.65 or 26 cents more than they actually cost. The pigs fed pellets gained 0.1 lb. per day faster and required 32 lbs. less feed per 100 lbs. of gain than those fed the ration in the form of meal. The advantage of pelleting was small as measured by rate of gain; however, the feed required per 100 lbs. of gain by the group fed pellets represented a considerable saving. The author states that the greatest feed savings from pelleting may be expected where relatively unpalatable rations are used.

Cattle

Schneider (1951) compared sun-cured alfalfa hay with dehydrated alfalfa hay in different physical forms. Forty steers were divided into four lots and fed for 128 days. The author states that pelleted dehydrated forages were superior to other types of feeds. The pelleted feed appeared to be more palatable and produced greater gains, 2.59 lbs. per head daily as compared to 1.81 and 1.97 lbs. per head daily for the ground sun-cured alfalfa and ground dehydrated forage respectively. This comparison indicated that 62.8 lbs. of pelleted dehydrated forage was equal to 80.7 to 88.2 lbs. of ground dehydrated forage and 100 lbs. of ground sun-cured alfalfa. Required for 100 lbs. of gain was 619 lbs. of the sun-cured alfalfa, as compared to 559 lbs. of pellets.

Foster et al. (1953) conducted a feeding trial designed to compare pelleted and non-pelleted rations for beef cattle. Thirteen heifers, averaging 290 days of age and representing each of the three major beef breeds, were placed on test December 30, 1952; six on the ground non-pelleted and seven on the pelleted ration. The rations were fed in individual self-feeders by allowing each animal access to its respective feeder for a 1-hour period twice daily. Hay was included in the pellets. The non-pelleted rations consisted of the ground concentrate mixed with chopped hay. The non-pelleted group required an average of 905.2 lbs. of feed per 100 lbs. of gain, whereas the pelleted group required only 710 lbs. of feed per 100 lbs. of gain. The authors state that this difference was statistically highly significant ($P < .01$).

Eaton and associates (1952) conducted an experiment in which eighteen 7-day-old Holstein and Guernsey calves were used in the comparison of the relative value of field-cured and field-baled alfalfa hay, artificially dried and chopped alfalfa hay, and artificially dried and pelleted alfalfa hay as the source of roughage. The Holstein calves in 105 days consumed 235 lbs. of the artificially dried and pelleted alfalfa hay, 220 lbs. of the artificially dried and chopped alfalfa hay and only 168 lbs. of the field-cured and field-baled alfalfa hay. The consumption of alfalfa hay in the three different physical conditions followed the same trend with the Guernsey calves. The calves gained an average of 220 lbs. when fed the artificially dried and pelleted alfalfa hay, 219 lbs. when fed the artificially dried and chopped hay, and 205 lbs. when fed the field-cured and field-baled alfalfa hay. The authors concluded that Holstein and Guernsey calves consume larger quantities of alfalfa as dehydrated pellets or as dehydrated chopped than as long field-cured hay.

Newman and Savage (1938) reported the results of an experiment designed to obtain information as to the value of pelleting calf starters. They observed that pelleting of the rations decreased the consumption of the calf starter by young calves and resulted in slightly slower gains. The average daily gain from 2 to 16 weeks, as the percent of normal, was 118 for the calves fed pellets and 127 percent for the calves fed meal.

Norton and Eaton (1946) observed that pelleting of calf starters failed to increase growth. In fact the calves fed the pelleted

formulas gained less than did those that received the same formula in meal form.

Savage et al. (1938) studied the desirability of pelleting two different calf starters. The growth of the calves fed the pellets was slightly less than that of the calves fed the starters in meal form. The authors state that this was probably due to lower consumption of the pellets as compared with meal while the calves were very young.

Eaton et al. (1952) fed Holstein calves alfalfa hay using three different methods of preparation. Both the total amount of hay and dry matter as hay were consumed in greater amounts by the calves fed the pelleted hay than by calves fed either field-baled or ground hay. The ground hay used in this experiment was clearly not as palatable to the calves as the pelleted hay.

Whether pelleting improves palatability above that for long hay such as field-baled was not determined in this experiment because there were differences in hay quality. The author states that besides possibly influencing palatability, pelleting may increase the quantity of roughage the young calves can consume. An analysis of live weight data, which included adjustment for differences between individual calves in weight at 7 days of age, showed that those calves fed the pelleted hay made greater total gains and more rapid gains than those calves fed the other two types of hay. No significant differences were found between the gains of the calves fed the field-cured and field-baled hay and artificially dried and ground hay. With the exception of occurrence of bloat in one calf fed the ground hay, the remaining observations as to the health of the calves were not associated with hay groups.

Blosser et al. (1952) conducted an experiment to compare the value of finely ground, chopped and pelleted alfalfa hay when fed at a 30 percent grain-replacement level to lactating cows. Twenty one high producing cows were divided into three lots of seven each and were paired as evenly as possible as regards level of production, body weight and stage of lactation and gestation. Cows on this experiment were fed medium-quality chopped alfalfa hay, grass silage, grain and dehydrated alfalfa. All of the dehydrated forage used was harvested in the same field on the same day. Two-thirds of the material which had been put aside for use in the feeding trial was finely ground in a hammer mill. One-half of this was pelleted into small pellets 0.25 inch in diameter by 0.25 inch in length. After the necessary grain was calculated, 30 percent was replaced with one of the three physical forms of first-cutting dehydrated alfalfa. The difference in favor of the pelleted material was 1.7 lbs. of 4 percent fat corrected milk per cow per day. The decline in lactation was also less rapid on the pelleted material. There were no marked differences between cows on finely ground forage and those on chopped forage in number of times off-feed. However, there were fewer cases of off-feed on pelleted alfalfa than on either of the other physical forms. The authors state that the advantage shown for pelleted alfalfa hay in this experiment is difficult to explain. They state it may be due to some of the finely ground material passing directly into the abomasum, thereby escaping action of rumen microorganisms.

The pelleting of rations to be fed to sheep, cattle or swine apparently increases rate of gain, causes a shortened feeding period and more efficient feed utilization. The data reviewed indicates

that pelleted rations have significantly higher digestible nutrient values than the same rations fed finely ground. However, the cost per unit of gain is frequently higher when a ration is fed in the pelleted form because of the high cost of pelleting.

EXPERIMENT I

Objective

In the spring of 1953, an experiment was initiated with the following objectives:

1. To determine the effect of fine grinding on the digestibility of a ration fed to lambs.
2. To determine the effect of pelleting a fine-ground ration on its digestibility by lambs.
3. To determine the digestibility by lambs of the same ration fed in the natural form.

Procedure

Twelve western wether lambs were used in this experiment. They were divided by randomization into 3 lots, 4 head per lot, on May 9, 1953. The same ration was fed in the natural, finely ground, and finely ground and pelleted state. These rations are presented in Table 1. The hay used was average quality prairie (mainly bluestem) and alfalfa hay obtained in the vicinity of Stillwater, Oklahoma. Corn yellow dent, number 2, and 41 percent protein cottonseed meal were used. The hay was ground in a hammer mill using a $\frac{1}{2}$ inch roughage screen. The corn was ground in the same mill using a 1/16 inch screen. The concentrates were premixed in a Hobart mixer prior to mixing with the hay. It was necessary to mix the coarse concentrate feed each ten days to prevent molding. The lambs were individually fed twice daily and water was

kept before them at all times except during the two feeding periods of approximately one hour each. The feces were collected daily, dried for 24 hours in an electric oven, and placed in a container which held the total 10-day collection. At the close of each collection period the feces were weighed, mixed and a sample taken for chemical analysis. Rations were sampled at each feeding to make a composite sample for each trial in the experiment. (See Table 2.)

This experiment was divided into three trials, each having a ten-day preliminary period and a ten-day collection period. The procedure of feeding, collecting samples of feces and feeds and chemical analysis was the same in each period. The lambs were randomly divided in each trial with the restriction that no lamb be fed the same ration as in the preceding trial.

Results and Discussion

A summary of the coeffficients of apparent digestibility is presented in Table 3. Data for individual lambs are given in Appendix Tables I to VI. A summary of the analysis of variance as calculated by the method described by Snedecor (1946) is presented in Table 4.

The average apparent digestion coefficients for organic matter were 72.73 percent for the pelleted ration, 69.13 percent for the finely ground ration, and 72.73 percent for the ration fed in the natural state; this difference was highly significant ($P < .01$). The ration fed in the natural state was compared to the combined values of the pelleted and finely ground rations and was found to be significantly superior ($P < .01$). There is a definite trend for the digestion coefficients for the finely ground ration to be lower than either of the other treatments.

Table 1. Rations Fed in Digestion Studies with Lambs.

Feed	Daily Allowance, Grams		
	Ration 1 Pelleted	Ration 2 Finely ground	Ration 3 Natural
Pelleted	908	—	—
Finely Ground	—	908	—
Concentrate Mix	—	—	454
Prairie Hay	—	—	272
Alfalfa Hay	—	—	182

Table 2. Chemical Composition of Feeds.

Trial and Feed	Percent Dry Matter	Percentage Composition of Dry Matter				
		Organic Matter	Crude Protein	Ether Extract	Crude Fiber	N-Free Extract
Trial I						
Pelleted	92.06	92.63	13.41	2.74	14.78	61.70
Finely Ground	91.25	92.27	12.28	3.00	16.31	60.68
Prairie Hay	93.61	92.11	5.05	3.22	31.66	52.18
Alfalfa Hay	90.69	88.45	18.29	3.08	27.07	40.01
Concentrate Mix	94.08	94.71	14.73	4.62	3.06	72.30
Trial II						
Pelleted	93.44	92.31	14.24	3.77	13.79	60.51
Finely Ground	92.50	93.79	12.56	3.08	14.56	63.59
Prairie Hay	92.82	91.94	6.68	3.95	28.90	52.41
Alfalfa Hay	93.08	89.24	16.89	3.10	27.61	41.64
Concentrate Mix	92.66	94.95	15.29	3.68	3.38	72.60
Trial III						
Pelleted	92.59	91.95	13.45	2.93	14.57	61.00
Finely Ground	91.46	93.77	12.09	2.75	20.61	58.32
Prairie Hay	92.07	92.50	6.24	2.91	32.19	51.16
Alfalfa Hay	90.48	84.95	19.34	2.81	22.92	39.88
Concentrate Mix	94.05	94.22	15.35	2.40	3.57	72.90

1. The pelleted feed was ration 1 and the finely ground mixture was ration 2. The prairie hay, alfalfa hay, and concentrate mix were fed in ration 3.

Table 3. Average Apparent Coefficients of Digestibility With Standard Error for Rations in Three Physical States, Percent.

Trial and Ration	Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	N-Free Extract
Trial I						
Pelleted	68.07± .07	70.17± .22	65.29± .90	65.86± 1.11	45.08± 1.78	77.15± .90
Fine-Ground	68.42± .16	66.78± .64	60.80± .14	55.94± .82	48.17± 1.02	77.60± .61
Coarse	70.21± .19	71.45± .23	64.49± .16	60.43± .61	51.49± .54	78.84± .93
Trial II						
Pelleted	73.83± .62	76.61± .53	72.27± .57	81.76± .64	59.49± 1.71	81.91± .14
Fine-Ground	68.33± .78	70.49± .73	64.46± .98	70.71± 1.95	44.55± .63	77.61± .99
Coarse	69.84± .16	70.63± 1.02	65.07± .83	72.21± .13	48.99± .65	79.26± .52
Trial III						
Pelleted	68.77± .69	70.42± .82	66.24± .99	61.23± 4.75	44.56± 1.56	77.97± .99
Fine-Ground	68.62± .13	70.11± .09	63.12± .07	62.89± .66	44.83± 1.29	78.14± .16
Coarse	73.53± .10	75.04± .63	68.68± .57	56.53± 1.89	56.53± 1.38	81.86± .63
Average of 3 Trials						
Pelleted	70.22± .91	72.73± .52	67.93± 1.09	69.62± 3.10	49.71± 2.44	79.01± .73
Fine-Ground	68.46± .04	69.13± .59	62.79± .53	63.18± .58	46.52± .58	77.78± .08
Coarse	71.19± .58	72.37± .68	66.08± .65	63.06± 1.11	52.69± 1.11	79.99± .48

Table 4. Analysis of Variance of Apparent Digestion Coefficients For Organic Matter.

Source of Variation	Degrees of Freedom	Mean Square
Total	35	
Treatment	2	43.38**
Lot 3 vs. 1 and 2	(1)	(22.37)**
Lot 1 vs. 2	(1)	(64.39)**
Trial	2	30.28**
Treatment x Trial	4	30.41**
Within Lots	27	1.53

** Significant at the 1% level.

The apparent digestion coefficients for crude protein (N x6.25) were 67.93 percent for the pelleted ration, 62.79 percent for the finely ground ration, and 66.08 percent for the ration fed in the natural state. Statistical analysis of variance using the mean square for variance within lots in the "F" test showed these differences to be highly significant ($P < .01$). The pelleted ration was compared to the finely ground ration and was found to be significantly superior ($P < .01$). In this experiment the grinding of the ration tended to lower the digestibility of crude protein, and the pelleting of the finely ground ration tended to raise the digestibility of crude protein. The average apparent digestion coefficients for crude fiber were 49.71 percent for the pelleted ration, 46.52 percent for the finely ground ration, and 52.69 percent for the ration fed in the natural state; this difference was highly significant ($P < .01$). The crude fiber digestibility of the ration fed in the natural state was significantly higher ($P < .01$) than the combined values of the pelleted and finely ground rations. The pelleted ration was significantly superior to the finely ground ration. The fine-grinding of the ration tended to lower crude fiber digestibility, and the pelleting of the finely ground ration tended to increase the digestibility of crude fiber.

The same trend was shown in the digestibility of organic matter, crude protein, and crude fiber; the fine-grinding of the ration lowered the apparent digestibility and the pelleting of the finely ground ration raised the apparent digestibility to the approximate level of digestibility of the ration fed in the natural state. In all cases the trend was for the finely ground ration to be inferior to the other two treatments.

If the mean square for within lots were used in the "F" test there were significant differences in the apparent digestion coefficients for crude protein, organic matter, and crude fiber. It is possible that this estimate of variance fails to correctly evaluate the variation. If this should be true it is doubtful if it would be possible to repeat the levels of significance shown in this trial.

Treatment, trial and interaction between treatment and trial were highly significant for organic matter, crude protein, and crude fiber, using the within lots variance as the error term in the "F" test (Snedecor 1946). In order to make an unqualified statement as to the reality of these differences, one should use the treatment-trial interaction to test significance in the "F" test. Such a test did not show significance, consequently the real cause of significance is somewhat in doubt. The apparent digestion coefficients for the pelleted ration in trial II were in disagreement with the apparent digestion coefficients for trials I and III. It is the failure of these differences to be alike that produces the discrepancy.

The results of this experiment are in agreement with the study with sheep by Murdock and Miller (1951) in which the digestibility of crude fiber of the coarse cut, finely ground, and pelleted rations was 44.0, 35.1, and 40.7 percent, respectively.

EXPERIMENT II

In the summer of 1953, an experiment was initiated with the following objectives:

1. To compare the feed consumption of lambs fed a ration in the natural state, the same ration finely ground, and the ration finely ground and pelleted.
2. To compare the rate of gain of lambs fed the rations listed above.
3. To compare the efficiency of gain of lambs fed these same rations.
4. To compare the feed wastage of lambs fed these rations.

Procedure

Sixteen western lambs were equally allotted to four treatments on the basis of weight and previous treatment. Twelve lambs had been used in the previous digestion study; the other four lambs were chosen from a group of similar weight, condition, and previous history. The initial weight of the lambs ranged from 83.8 to 107.9 lbs. They were housed in individual pens (3 1/2 x 5 1/2 feet) and provided with individual feeders. The lambs were removed from the pens only for weighing. Fresh water was available to the lambs at all times.

In this experiment four different rations were fed, and four lambs were fed individually on each ration. The rations were as follows:

Lot 1. A finely ground ration fed ad libitum in the pelleted form.

Lot 2. A finely ground ration fed ad libitum.

Lot 3. Both a concentrate mixture and prairie hay fed free-choice.

Lot 4. The intake of concentrates limited to the concentrate intake of the lambs fed the pelleted ration, and prairie hay fed ad libitum.

The pelleted and finely ground ration used in this experiment were 50 percent average quality prairie hay secured in the vicinity of Stillwater, Oklahoma, 8 percent cane molasses, 29 percent yellow corn, and 13 percent cottonseed meal. Salt was added at a rate of 7 grams per lamb per day. The entire finely ground and pelleted ration was mixed in one batch, one-half of the mixture was pelleted and the remainder was fed as the finely ground ration.

The concentrate mixture of 58 percent yellow corn, 26 percent cottonseed meal, and 16 percent cane molasses was mixed in a Hobart mixer. Salt was added to the ration in such an amount that each lamb would receive approximately 7 grams per day. The finely ground hay used in this experiment was ground in a hammer mill using a 1/4 inch screen; the corn used in the pelleted and finely ground ration was ground in a hammer mill using a 1/16 inch screen. The chemical composition of the rations fed is given in table 5.

The initial and final weights were an average of three consecutive daily weights taken during the afternoon. The feeding period started July 28, 1953 and continued until September 11, 1953, a period of 45 days.

Table 5. Chemical Composition of Feeds.

Feed	Percent Dry Matter	Percentage Composition of Dry Matter				
		Organic Matter	Crude Protein	Ether Extract	Crude Fiber	N-Free Extract
Pelleted	93.04	93.03	13.06	2.33	13.89	63.75
Finely Ground	92.32	92.97	12.33	2.59	17.10	60.95
Prairie Hay	94.67	91.99	4.01	2.27	35.15	50.56
Concentrate Mix	96.30	94.85	18.71	3.90	5.13	67.11

Results and Discussion

Most of the lambs in this experiment readily consumed the various rations offered. All lambs were on full-feed in two to three weeks, although it took the lambs on the concentrate mixture and hay free-choice somewhat longer than the other groups.

Table 6 gives a summary of the average weight data and feed intake for lambs fed the different rations. Data for individual lambs are presented in appendix table VII. The greatest total gain in weight was 20.5 lbs. for a lamb fed the finely ground ration (Lot 2), and the least gain was 5.4 lbs. for a lamb fed the pelleted ration (Lot 1). The average gain in Lot 1 was 14.6 lbs., and 17 lbs. was the average gain in Lot 2. The difference was apparently due to one lamb in Lot 1 which consumed the least concentrate of any lamb in this trial and gained very little weight (5.4 lbs.). This lamb was within two standard deviations (13.6 $\pm$ 4.34 lbs.) and could not be excluded from the analysis.

The least significant difference was calculated for daily gain according to the method of Snedecor (1946). There were no significant differences between the various treatments. The greatest average gain of 0.31 lb. was made by the lambs fed the finely ground ration ad libitum (Lot 2). The smallest average daily gain was the 0.21 lb. made by the lambs self-fed prairie hay and fed a controlled amount of concentrates (Lot 4). The lambs fed the pellets (Lot 1) gained 0.28 lb. per head daily and those fed both prairie hay and concentrate free-choice (Lot 3) gained an average of 0.22 lb. per head daily. The average daily ration (Table 6) ranged from 4.52 lbs. for the lambs in

Table 6. A Summary of Weights and Feed Consumption of Lambs (Lbs.)

Ration[1]	Weight		Daily Gain			Daily Ration			Ratio of Concentrate to Hay
	Initial	Final	Average	Low	High	Concentrate	Hay	Total	
1	96.4	108.9	.28	.09	.38	1.99	1.99	3.98	1:1
2	95.7	109.5	.31	.23	.40	2.26	2.26	4.52	1:1
3	97.9	107.9	.22	.17	.29	2.51	.58	3.09	4.2:1
4	97.3	106.2	.20	.15	.23	2.03	.93	2.96	2.2:1

[1]Ration 1 is the finely ground and pelleted ration fed ad libitum.
Ration 2 is the finely ground ration fed ad libitum.
Ration 3 is the concentrate mix and prairie hay free-choice.
Ration 4 is controlled intake of concentrate and prairie hay ad libitum.

Lot 2 to 2.96 lbs. for the lambs in Lot 4. The feed consumption of the lambs in Lot 1 was 3.99 lbs. per day and those in Lot 3 consumed 3.09 lbs. per head daily.

The weighted average feed per 100 lbs. of gain (Table 7) was obtained by averaging the feed required per 100 lbs. of gain of the individual lambs. Data for individual lambs are presented in appendix Table VIII. The pooled average feed per 100 lbs. of gain (Table 7) was obtained by dividing the total feed consumed by the lambs on each ration by the total gain on each ration and multiplying by 100.

The concentrate required per 100 lbs. of gain (pooled average) ranged from 346 lbs. for the lambs in Lot 2 to 527 lbs. for the lambs in Lot 4. The lambs in Lots 1 and 2 (self-fed the pelleted or finely ground ration) were more efficient than the lambs in Lots 3 and 4. They made the same amount of gain on an average of 285 lbs. less concentrate and 293 lbs. more hay. The total feed required per 100 lbs. of gain ranged from 1077 lbs. for the lambs in Lot 3, to 1323 lbs. for the lambs in Lot 4. The fact that the pooled average is slightly less than the weighted average is an indication that the more efficient lambs gained slightly more than the lot average as would be expected. In the case of the pelleted lot three of the four lambs gained more than the lot average and as would be expected the weighted average was considerable more than the pooled average.

Using the feed required per 100 lbs. of gain for the individual gains of the lambs there were no significant differences in the amount of feed required per 100 lbs. of gain in the different lots.

The cost of 100 lbs. of gain at the feed prices given (Table 8) was the least for the lambs fed the finely ground ration ($28.58), and was the highest for the lambs fed the pelleted ration ($34.97). The

Table 7. Efficiency of Feed Utilization by Lambs (Lbs.)

Feed	Feed per 100 lbs. Gain			
	Pelleted	Finely Ground	Conc. and Hay Free-Choice	Controlled Conc. Hay Ad libitum
			Weighted Average	
Corn	412	351	528	535
Cottonseed Meal	185	157	237	240
Cane Molasses	114	97	145	148
Total Concentrate	711	605	910	923
Hay	711	605	218	415
Total Feed	1422	1210	1128	1338
			Pooled Average	
Corn	354	346	505	527
Cottonseed Meal	159	155	226	236
Cane Molasses	98	96	139	145
Total Concentrate	611	597	870	908
Hay	611	597	206	415
Total Feed	1222	1194	1077	1323

Table 8. Prices of Feed and Milling

Corn	$ 1.80 per bu.
Cane Molasses	$ 2.00 per cwt.
Cottonseed Meal	$ 80.00 per ton
Prairie Hay	$ 20.00 per ton
Grinding Corn	$ 0.07 per cwt.
Grinding Hay	$ 0.30 per cwt.
Mixing	$ 0.07 per cwt.
Pelleting	$ 0.10 per cwt.

high cost of 100 lbs. of gain of the lambs fed the pelleted ration can be attributed to one lamb, the cost of 100 lbs. of gain for this lamb was $56.76. The average cost per 100 lbs. of gain for the other three lambs fed the pelleted ration was $27.70.

The greatest waste from the feeders occurred with the finely ground ration, an average of 6.9 lbs. per lamb in the entire period. The only other observable waste was by one lamb fed the pelleted ration.

The ratio of concentrate to hay (Table 6) was 1:1 for the pelleted and finely ground rations, 4.2:1 for ration 3, and 2.2:1 for ration 4.

In Lot 3 (concentrate and hay free-choice) and Lot 4 (concentrate intake controlled and hay ad libitum) the high ratio of concentrate to hay would be expected to prove uneconomical in lamb feeding. The pelleted ration used in this experiment required less storage space, was easier to handle, and had less wastage than the finely ground ration. The finely ground ration tended to clog in the self-feeders. An appreciable loss by wind blowing could be expected with finely ground ration in many feeding operations.

Summary

In a digestibility experiment 12 wether lambs were divided into three lots of 4 lambs each and were individually fed the same ration in three different physical states, (1) the ration finely ground and pelleted, (2) the ration finely ground, and (3) the ration in the natural state. The rations used were 30 percent prairie hay, 20 percent alfalfa hay, 34 percent yellow corn, 8 percent cane molasses,

plus 7 grams of salt per lamb daily.

The apparent digestion coefficients for crude protein and organic matter in the pelleted ration were higher than those of the same ration in the natural state or finely ground; these differences were highly significant. These apparent digestion coefficients were higher for the ration in the natural state than when finely ground; these differences were highly significant.

In the second experiment 16 wether lambs were divided into lots of 4 lambs each and were fed 4 different rations: (1) pelleted and finely ground, (2) finely ground, (3) concentrate mixture and prairie hay free-choice, and (4) prairie hay ad libitum with the concentrate intake limited to the concentrate intake of the lambs on the pelleted ration.

The lambs self-fed the pelleted or finely ground ration made considerably greater gains than those fed the other two rations. The lambs fed the finely ground ration made the most economical gains, and those fed the pelleted ration the most expensive gain at the feed prices used in this experiment. The number of animals used was not large enough to give a positive answer as to the value of pelleting a ration, and there is need for additional investigations.

LITERATURE CITED

Bell, T.D., Draytford Richardson, J.S. Hughes, and D.B. Parrish. 1954. The Relationship of Physical Balance and Energy Value in Sheep Rations. Kansas Agr. Exp. Sta. Cir. 308:43-44.

Blosser, T.H., F.R. Murdock, R.E. Lintott, R.E. Erb and A.O. Shaw. 1952. The Use of Dehydrated Forages in Dairy Cattle Rations. II Comparative Values of Finely Ground, Chopped and Pelleted Dehydrated Alfalfa as Grain Replacement for Lactating Dairy Cows. Jour. Dairy Sci. 35:515.

Dinusson, W.E. and M.R. Light. 1951. Agricultural Progress Through Research. N. D. Agr. Exp. Sta. Bul. 371:28.

Dinusson, W.E., M.R. Light, D.W. Bolin, and M.L. Buchanan. 1953. Pelleting Makes Pork. N. D. Agr. Exp. Sta. Bi-Mo. Bul. 15:162.

Eaton, H.D., C.A. Carpenter, R.J. Caverno, R.E. Johnson and F.I. Elliott. 1951. A Comparison of U.S. No. 2 Field-Cured Field-Baled Alfalfa Hay with Artificially Dried and Ground and Pelleted Alfalfa Hay as a Source of Carotene and Roughage for Holstein Calves. Jour. Dairy Sci. 34:124-35.

Eaton, H.D., K.L. Dolge, R.D. Mochrie and J.E. Avampato. 1952. Field-Cured and Field-Baled Alfalfa Hay Versus Artificially Dried and Chopped and Pelleted Alfalfa Hay as a Source of Carotene and Roughage for Guernsey and Holstein Calves. Jour. Dairy Sci. 35:98-105.

Foster, D.E., M.W. Galgan and M.E. Ensminger. 1953. Pelleted Vs. Non-Pelleted Rations for Beef Cattle. Wash. Agr. Exp. Sta. Cir. 232.

Kuhn, R.P., J.S. Hughes and R.F. Coy. 1950. Effect of Physical Character of Feed on Composition of Ewes Milk. Jour. Ani. Sci. 9:662.

Lehrer, W.P. and T.B. Keith. 1952. Pelleted Vs. Non-Pelleted Swine Rations and the Role of Herring Fish Meal and Packing Plant Meat Meal in Supplementing Rations Containing Dehydrated Alfalfa Meal. Proc. Annual Meeting Western Section Amer. Soc. of Ani. Pro., Vol. 3.

Lehrer, W.P. and T.B. Keith. 1953. Pelleted Vs. Non-Pelleted Rations for Swine. Idaho Ag. Exp. Bul. 295:1-11.

Murdock, F.R. and V.L. Miller. 1951. The Composition and Nutritive Value of Alfalfa Hay Prepared by Three Methods of Curing and in Three Physical States. Proc. Annual Meeting Western Section Amer. Soc. of Ani. Prod., Vol. 2:22.

Neale, P.E. 1953. Alfalfa Cubes for Fattening Lambs and Wethers. N. M. Agr. Exp. Sta. Bul. 375.

Newman, P.E. and E.S. Savage. 1938. The Use of Yeast in Calf Meals and Pellets. Jour. Dairy Sci. 21:161-67.

Noble, R.L., L.S. Pope, Dwight Stephens and R.W. MacVicar. 1953. Fattening Tests with Western Feeder Lambs. Okla. Agr. Exp. Sta. MP-31:51.

Noble, R.L., Dwight Stephens, R.D. Humphrey and R.W. MacVicar. 1954. Fattening Tests with Western Feeder Lambs on Wheat Pasture and in Dry Lots. 28th Annual Livestock Feeders Day Report. Okla. Agr. Exp. Sta.

Norton, C.L. and H.D. Eaton. 1946. Dry Calf Starters for Dairy Calves. Cornell Univ. Agr. Exp. Sta. Bul. 835.

Savage, E.S. and P.E. Newman. 1938. The Use of Yeast in Calf Starters; Pelleting Calf Starter. Cornell Univ. Agr. Exp. Sta. Annual Report. 51:92.

Schneider, B.H. and H.H. Brugman. 1950. Pelleting Feed for Pigs. Wash. Agr. Exp. Sta. Bul. 375.

Schneider, B.H. 1951. Feed Utilization as Affected by Pellets, Mash or Chopped Feed for Swine and Beef Cattle. Abstracts WSC Nutrition Conference 1951:79.

Schneider, B.H., L.C. Luce and E.E. Goodwin. 1953. Pea Supplements, Pelleting, Self-feeding and Pea Vine Silage in Fattening Lambs. Jour. Ani. Sci. 12:930.

Snedecor. G.W. 1946. Statistical Methods. 4th Edition. The Iowa State College Press.

Steffen, H. 1953. Pelleting Swine Rations Saves Feed. Utah Agr. Exp. Farm and Home Sci. 14:78.

Terril, S.W., R.H. Meade, R.O. Nesheim and D.E. Becker. 1951. New Ideas in Creep Feeding. Ill. Swine Growers'Day Report.

Thomas, O.O. and A.E. Flower. 1953. Value of Pelleted Rations for Swine. Jour. Ani. Sci. 12:933.

U.S.D.A. 1952. Pelleted Rations Tested for Lambs, Report of the Chief of The Bureau of Animal Industry, Agricultural Research Administration. 1952:26.

U.S.D.A. 1952. Pelleting Swine Feed Shows Slight Advantage in Feeding Test. Report of The Chief of the Bureau of Animal Industry, Agricultural Research Administration. 1952:34.

APPENDIX

Complete Data for Digestion and Growth Study

Table I. Coefficients of Apparent Digestibility of A Ration Fed in Three Physical States, Trial I.

Ration	Lamb No.	Dry Matter Intake	Fecal Dry Matter	Apparent Percentage of Digestibility					
				Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	N-Free Extract
		Gm.	Gm.						
Pelleted	1	8359	2711	67.56	70.03	63.77	67.33	46.59	77.13
	2	8359	2651	68.28	70.09	65.51	66.31	40.59	77.17
	3	8359	2686	67.87	69.86	64.18	67.17	44.16	77.37
	4	8359	2625	68.59	70.72	67.72	62.63	49.00	76.93
Average		8359	2669	68.07	70.17	65.29	65.86	45.08	77.15
Finely Ground	5	8285	2580	68.86	65.45	59.88	57.91	46.32	65.45
	6	8285	2557	69.14	68.20	61.68	56.59	49.41	79.04
	7	8285	2735	66.99	66.01	61.40	54.23	46.58	66.01
	8	8285	2595	68.68	67.48	60.26	55.00	50.38	78.13
Average		8285	2617	68.42	66.78	60.80	55.94	48.17	77.60
Natural	9	8314	2512	69.78	71.30	63.54	60.42	52.14	78.23
	10	8414	2475	70.23	71.91	63.77	58.85	52.61	79.41
	11	8314	2437	70.68	72.04	65.55	61.27	50.92	79.27
	12	8214	2482	70.14	71.37	65.13	61.20	50.29	78.47
Average		8314	2476	70.21	71.45	64.49	60.43	51.49	78.84

Table II. Coefficients of Apparent Digestibility of A Ration Fed in Three Physical States, Trial II.

Ration	Lamb No.	Dry Matter Intake	Fecal Dry Matter	Apparent Percentage of Digestibility					
				Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	N-Free Extract
		Gm.	Gm.						
Pelleted	5	8484	2181	74.30	77.28	73.41	80.64	59.79	82.57
	7	8484	2109	75.14	77.73	74.03	83.45	57.96	82.75
	8	8484	2324	73.61	75.88	71.41	80.96	56.40	81.06
	11	8484	2352	72.27	75.56	72.64	81.98	51.82	81.26
Average		8484	2242	73.83	76.61	72.87	81.76	56.49	81.91
Finely Ground	3	8399	2542	69.74	71.55	66.39	70.82	45.40	78.59
	9	8399	2676	68.13	70.44	63.52	76.10	42.59	77.92
	10	8399	2835	66.24	68.45	62.19	67.12	45.52	75.00
	12	8399	2586	69.21	71.53	65.75	68.81	44.68	78.95
Average		8399	2660	68.33	70.49	64.46	70.71	44.55	77.61
Natural	1	8425	2487	70.48	72.46	65.87	71.65	50.40	79.75
	2	8425	2533	69.94	71.86	66.42	71.38	49.47	78.96
	4	8425	2660	68.42	67.91	62.67	72.71	47.35	77.96
	6	8425	2482	70.54	70.28	65.31	73.09	48.74	80.36
Average		8425	2540	69.84	70.63	65.07	72.21	48.99	79.26

Table III. Coefficients of Apparent Digestibility of A Ration Fed in Three Physical States, Trial III.

Ration	Lamb No.	Dry Matter Intake	Fecal Dry Matter	Apparent Percentage of Digestibility					
				Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	N-Free Extract
		Gm.	Gm.						
Pelleted	4	8407	2610	68.96	70.58	67.07	57.84	44.78	78.13
	6	8407	2532	69.88	71.58	66.03	58.79	48.08	79.03
	10	8407	2820	66.45	68.07	63.71	53.63	44.88	75.27
	12	8407	2539	69.79	71.49	68.15	74.85	40.50	79.46
Average		8407	2625	68.77	70.44	67.93	61.28	44.56	77.97
Finely Ground	1	8384	2567	69.38	70.71	63.19	64.14	48.27	78.11
	2	8384	2649	68.40	29.96	62.55	61.02	44.91	78.10
	7	8384	2615	68.81	70.34	63.59	63.17	44.13	78.55
	11	8484	2693	67.88	69.44	63.15	63.24	42.03	77.81
Average		8384	2631	68.62	70.11	63.12	62.89	44.83	78.14
Natural	3	8421	2224	73.59	74.76	69.33	55.85	54.48	82.15
	5	8421	2249	73.30	74.95	68.47	53.43	56.30	82.23
	8	8421	2103	75.03	76.73	69.74	61.86	60.59	83.21
	9	8421	2341	72.20	73.71	67.19	55.00	59.09	79.85
Average		8421	2229	73.53	75.04	68.68	56.53	57.61	81.86

Table IV. Chemical Composition of Rations and Feces, Pelleted Ration

Trial No.	Identification of Sample	Lamb No.	Percent Dry Matter	Percentage Composition of Dry Matter					
				Organic Matter	Ash	Ether Extract	Crude Fiber	Crude Protein	N-Free Extract
I	Ration		92.06	92.63	7.36	2.74	14.78	13.41	61.71
	Feces	1	94.26	85.59	14.41	2.76	24.34	14.98	43.51
	Feces	2	93.13	87.34	12.66	2.91	25.44	14.58	44.41
	Feces	3	92.96	86.90	13.10	2.80	25.69	14.95	43.46
	Feces	4	92.23	86.35	13.65	3.26	24.00	13.78	45.31
II	Ration		93.44	92.31	7.69	3.77	13.79	14.24	60.51
	Feces	5	92.99	81.55	18.45	2.84	22.95	14.73	41.03
	Feces	7	93.15	82.70	17.30	2.51	23.32	14.88	41.99
	Feces	8	93.34	81.27	18.73	2.62	21.95	14.86	41.84
	Feces	11	93.35	81.36	18.64	2.45	23.96	14.05	40.90
III	Ration		92.59	91.95	8.05	2.93	14.57	13.45	61.00
	Feces	4	92.44	87.15	12.85	3.98	25.92	14.27	42.98
	Feces	6	91.93	86.77	13.23	4.01	25.12	15.17	42.47
	Feces	10	92.74	87.51	12.49	4.05	23.94	14.55	44.97
	Feces	12	92.44	86.80	13.20	2.44	28.70	14.18	41.48

Table V. Chemical Composition of Rations and Feces, Fine-Ground Ration

Trial No.	Identification of Sample	Lamb No.	Percent Dry Matter	Percentage Composition of Dry Matter					
				Organic Matter	Ash	Ether Extract	Crude Fiber	Crude Protein	N-Free Extract
I	Ration		91.25	92.27	7.73	3.00	16.31	12.28	60.68
	Feces	5	92.97	87.51	12.50	3.77	26.14	14.71	42.88
	Feces	6	92.63	87.43	12.57	4.22	26.74	15.25	41.22
	Feces	7	91.46	87.38	12.62	4.16	26.40	14.36	42.46
	Feces	8	93.08	88.08	11.91	4.31	25.84	15.58	42.36
II	Ration		92.50	93.79	6.21	3.08	14.56	12.56	63.59
	Feces	3	92.59	88.17	11.83	2.97	26.27	13.95	44.98
	Feces	9	93.48	86.99	13.01	2.31	26.23	14.38	44.07
	Feces	10	93.26	87.66	12.34	3.00	23.50	14.07	47.09
	Feces	12	93.94	86.71	13.29	3.12	26.16	13.97	43.46
III	Ration		91.46	93.77	6.23	2.75	20.61	12.09	58.32
	Feces	1	92.11	88.98	11.02	3.56	26.07	14.93	44.42
	Feces	2	92.80	88.43	11.57	3.75	26.90	14.72	43.06
	Feces	7	91.43	88.47	11.53	3.59	27.64	14.50	42.74
	Feces	11	92.50	88.52	11.48	3.48	27.85	14.25	42.94

Table VI. Chemical Composition of Rations and Feces, Natural Ration

Trial No.	Identification of Sample	Lamb No.	Percent Dry Matter	Percentage Composition of Dry Matter					
				Organic Matter	Ash	Ether Extract	Crude Fiber	Crude Protein	N-Free Extract
I	Conc. Mix		94.08	94.71	5.29	4.62	3.06	14.73	72.30
	Prairie Hay		93.61	92.11	7.89	3.22	31.66	5.05	52.18
	Alfalfa Hay		90.69	88.45	11.55	3.08	27.07	18.29	40.01
	Feces	9	92.16	88.02	11.98	5.09	26.29	15.04	41.60
	Feces	10	92.29	87.43	12.57	5.37	26.96	15.17	39.93
	Feces	11	92.22	88.39	11.61	5.13	27.77	14.65	40.84
	Feces	12	92.62	88.87	11.13	5.05	27.62	14.56	41.64
II	Conc. Mix		92.66	94.95	5.05	3.68	3.38	15.29	72.60
	Prairie Hay		92.82	91.94	8.06	3.95	28.90	6.68	52.41
	Alfalfa Hay		93.08	89.24	10.76	3.10	27.61	16.89	41.64
	Feces	1	93.27	86.65	13.35	3.50	26.71	15.06	41.38
	Feces	2	93.16	86.96	13.04	3.47	26.72	14.55	42.22
	Feces	4	92.96	87.17	12.83	3.25	26.51	15.40	42.11
	Feces	6	92.43	86.56	13.44	3.33	27.67	15.34	40.22
III	Conc. Mix		94.05	94.22	5.78	2.40	3.57	15.35	72.90
	Prairie Hay		92.07	92.50	7.50	2.91	32.19	6.24	51.16
	Alfalfa Hay		90.48	84.95	15.05	2.81	22.92	19.34	39.88
	Feces	3	92.28	87.86	12.14	4.40	27.35	15.58	40.53
	Feces	5	92.65	86.21	13.79	4.59	25.97	15.84	39.81
	Feces	8	92.26	85.67	14.33	4.02	25.05	16.26	40.34
	Feces	9	92.10	86.92	13.08	4.26	23.35	15.83	43.48

Table VII. Weight Gained and Feed Consumed in Growth Study (Lbs.)

Ration Identification	Weight		Total Gain	Average Daily Gain	Feeds Consumed		Feed Waste
	Beginning	Final					
Pelleted	94.7	114.3	19.6	.44	187.6	—	—
	99.5	116.1	16.6	.35	194.1	—	—
	107.8	124.8	17.0	.38	212.1	—	—
	83.8	89.2	5.4	.12	124.6	—	—
Average	96.4	111.1	14.6	.32	179.6	—	—
Finely	94.7	115.2	20.5	.45	210.9	—	12.1
Ground	107.9	126.7	18.8	.42	218.4	—	13.1
	92.0	107.3	15.3	.34	218.0	—	1.1
	88.2	101.7	13.5	.30	166.1	—	1.4
Average	95.7	112.7	17.0	.38	203.4	—	6.9
					Concentrate	Hay	
Concentrate	101.5	113.0	11.5	.25	121.1	29.0	—
and Hay	90.5	106.3	15.8	.35	92.7	23.0	—
Free-Choice	102.8	112.7	9.9	.22	115.1	31.0	—
	96.8	110.3	13.5	.30	111.8	21.7	—
Average	97.9	110.6	12.7	.28	110.2	26.2	—
Concentrate	96.8	106.3	9.5	.21	92.1	46.0	—
Controlled	100.2	112.7	12.5	.27	92.1	46.5	—
Hay Ad	89.2	98.0	8.8	.19	92.1	16.5	—
Libitum	103.0	112.5	9.5	.21	92.0	58.5	—
Average	97.3	107.4	10.1	.22	92.1	41.9	—

Table VIII. Feed Efficiency and Cost Per 100 Pounds of Gain, Weighted Average

Ration Identification	Lamb No.	Hay Per Cwt. Gain (Lbs.)	Concentrate Per Cwt. Gain (Lbs.)	Total Feed Per Cwt. of Gain (Lbs.)	Cost Per Cwt. of Gain (Dollars)
Pelleted	1	479	479	958	$23.55
	2	585	585	1170	$28.78
	3	626	626	1252	$30.79
	4	1154	1154	2308	$56.76
Average		711	711	1422	$34.97
Fine-Ground	5	514	514	1028	$24.24
	6	581	581	1162	$27.42
	7	712	712	1424	$33.63
	8	615	615	1230	$29.04
Average		605	605	1210	$28.58
Concentrate and Hay Free-Choice	9	252	1058	1312	$36.60
	10	146	585	731	$20.29
	11	313	1170	1483	$40.79
	12	161	826	987	$28.20
Average		218	912	1128	$31.47
Controlled Concentrate Hay Ad libitum	13	484	975	1459	$36.23
	14	372	741	1113	$27.57
	15	188	1023	1211	$34.80
	16	616	954	1570	$36.87
Average		415	923	1338	$33.87

VITA

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