

THE COMPARATIVE VALUE OF COTTONSEED MEAL,
LINSEED OIL MEAL, AND CORN GLUTEN MEAL AS A PROTEIN
SUPPLEMENT FOR FATTENING STEERS

by

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INTRODUCTION

The greatest amount of experimental work with protein supplements for cattle rations has been conducted in those states having the largest feeding industry and nearest the center of production of both feed and cattle. Cottonseed meal has received by far the greatest attention in an experimental way, about three-fourths of the experiment stations feeding it either in a direct experiment as to its own merit, or as an incidental part of the ration in some other experiment. For the most part, this use has been concentrated to a large degree in the cottonbelt where it is produced though other sections, particularly the corn belt, have used it extensively in experimentation. The great size and scope of the cottonseed industry and the relative economy of the use of cottonseed meal together with a realization of the very little actually known of its nutritive and physiological character, has aided much in advancing research work on the subject. It is used almost exclusively as a protein supplement in the cottonbelt and much work has been done there in determining the economy of its use in rations with different kinds, classes, and grades of livestock and as a supplement to different feeds. In the corn belt and further north, it is a more common

experiment to feed cottonseed meal against other supplementary feeds, particularly linseed oil meal.

Compared to the work done with cottonseed meal, experimentation with linseed oil meal has been rather limited. Only about one-half of the experiment stations use linseed oil meal in their cattle rations for either incidental or specific consideration. For the most part, linseed oil meal experiments have been limited to the regions producing the meal where it can be obtained at a more reasonable rate than elsewhere. Only a small percentage of these stations conduct experiments wherein linseed oil meal is given the only consideration and is being observed under different conditions with different classes of livestock and as supplements to different feeds. Practically all direct experimentation with linseed oil meal is limited to a comparison with cottonseed meal.

Corn gluten meal has received almost no consideration in the past 20 years in an experimental way with cattle, though corn gluten feed has been under investigation to some extent. Early in the present and in the latter part of the last century, some experimental work was done with gluten meal in steer fattening rations, but since that time nothing apparently has been recorded until this year's investigation at the Kansas Agricultural Experiment Station.

This early work was done mostly by stations near the production centers of corn and of gluten meal manufacturing, especially Iowa and Ohio.

Most of the work of comparison between these feeds has been conducted in an area centering in the corn belt and extending into the range country. Approximately 12 per cent of all the stations in the country do no work whatever with these feeds as supplements in rations for fattening steers. This includes particularly the northwest and northeast sections of the United States. In the northwest feeders depend almost entirely on alfalfa hay for their protein in feeding steers and leave the high priced supplementary feeds alone. The experiment stations in that region therefore, do not feel it necessary to include such feeds in their investigations though of late some are contemplating doing so. The northeast or New England region of the country is not a beef feeding section and therefore any such investigations there would be superfluous.

RESUME OF RESULTS OF THE EXPERIMENTAL WORK
INVOLVING THE USE OF COTTONSEED MEAL, LINSEED OIL MEAL, AND
CORN GLUTEN MEAL

Cottonseed Meal

Texas has probably done more in an experimental way with cottonseed meal than any other station. The cottonseed industry is of the greatest importance in that state and even before the by-products were seriously considered for feeding, experiments were run and bulletins written on the feeding of whole cottonseed roasted or treated in other ways. Cottonseed meal is practically the only protein supplement used in their rations and no comparison is made with any other protein feed. One of the first tests conducted was a comparison of silage (1) and hulls fed with both cottonseed meal and whole cottonseed. The meal was much superior to the seed as the latter scoured the animals rather badly. Changing the ration in the latter period from the seed to meal increased the gains per day from 2.09 pounds per head to 3.03 pounds and decreased the cost of feed per 100 pounds gain from \$5.14 to \$4.31. It was stated that cottonseed meal at \$27.00 per ton was more profitable than cottonseed at \$17.00 per ton for fattening cattle.

Following these early experiments, the Texas station has conducted a series of investigations in which cottonseed meal has played an important part. In all cases, silage or soybean fodder supplemented with cottonseed meal, was found to increase the efficiency of gains over that from hulls and meal. Cottonseed feeds proved more satisfactory in a steer ration than peanut feeds (2). In an experiment in which fattening steers were fed cottonseed meal and hulls with and without corn (3), it was found that those receiving the corn gained about one-third more than the others and were better finished. Some indications of poisoning in the steers receiving meal and hulls alone were noticed at the end of the experiment. Their experiments tend to show that silage added to the ration lessens the danger from poisoning. Previous experiments regarding the economy of adding corn or full feeding cottonseed meal show increased rates of gain with the former, better appetites, and more finish but somewhat higher cost.

The Oklahoma station has secured results similar to those of the Texas station in comparing silage with dry roughage when cottonseed meal is fed as a supplement. Corn proved to be the most efficient grain when fed with meal. In an experiment (4) in which two lots of steers were fed hulls and slightly over four pounds of cottonseed meal per

day, several were affected by poisoning, while in a lot receiving silage this was not noticed.

That station in 1928 started work on the question of the advisability of adding ground limestone to a ration including cottonseed meal (5). The addition of limestone appeared to increase the gains and finish of the steers, those not receiving this showing the least profit. It was also indicated that nearly three pounds of cottonseed meal may be fed to calves without harm and with large gains, though the gains cost slightly more.

The Kansas Agricultural Experiment Station has been conducting a long series of silage feeding investigations in which an effort was made to determine the amount of cottonseed cake necessary to supplement a full silage ration most economically in fattening baby beef (6). The results indicated that more than one pound per head per day of cottonseed cake under normal feed values when fed with corn, silage, and alfalfa was not economical. Results of experiments with stocker calves have indicated that silage and alfalfa hay or other roughage fed with cottonseed meal make an economical winter ration. The addition of corn increases the cost of gains and lowers the gains made the following summer from grass due to their higher degree of finish when going on pasture.

A long series of experiments at the Hays Branch Station tend to uphold the findings at other stations that cottonseed meal is better utilized with silage than with dry roughage. These experiments also indicated that one pound of 43% cottonseed cake was equivalent to approximately four pounds of alfalfa hay as a protein supplement for wintering stock cattle.

For the past three years (7), the question of supplementing a ration containing cottonseed meal with ground limestone, particularly when prairie hay or a similar roughage is used in place of alfalfa, has been given considerable attention. The results of these tests indicate that satisfactory fat yearlings can be produced on a ration of corn, cottonseed meal, silage, and prairie hay or similar non-leguminous hay, by the addition of approximately one-tenth pound of ground limestone per head per day.

An experiment at the Nebraska station (8) in which calves were wintered on silage, cottonseed cake, alfalfa, and a light ration of corn, showed a gain of 1.57 pounds per day at a feed cost of \$8.27 per hundred and returned an estimated profit of \$3.17 per head during the 145-day winter period. These calves when placed on full feed on a ration of shelled corn, alfalfa hay, and silage gained 2.38 pounds per head per day at a feed cost of \$12.58 per hundred. The addition of 1.91 pounds cottonseed cake per head per day to

this ration resulted in an increased gain of 2.52 pounds per head daily and a lower cost of \$12.34. These calves showed more finish and dressed higher than any other lot in the test.

In these tests, heifer calves gained 22 pounds more than steers and increased their selling price over those on a straight corn and alfalfa ration by 30 cents per hundred or a greater profit, \$92.08, per head. The addition of cottonseed cake to the steer ration also increased the steer gains as well as cost of gains, though the market value was higher than for heifers. Cottonseed cake fed to heifers had a value of \$18.00 per ton while that fed to steers was worth \$9.65 per ton in comparison.

An investigation at Iowa (9) in which one and one-half and three pound amounts of cottonseed meal were added to a standard corn belt ration of shelled corn, corn silage, clover hay, and block salt showed less gains than the check group receiving no meal and an increase in cost per hundred pounds gain. The cottonseed meal lots however, showed less shrink when shipped to market and the three pound groups sold for the same price in Chicago as the check group, while the one and one-half pound group brought 15 cents more per hundred. The margin per steer over feed costs was a minus \$1.00 in the one and one-half pound group; a minus \$3.56 in

the three pound group; and a minus \$1.58 in the check group. The cost of the supplement is the determining factor. This indicated that an amount of cottonseed meal in excess of protein requirements was uneconomical.

The Illinois station has carried on experiments the past few years in which the use of cottonseed meal has been rather extensively investigated (10). It was found that in a ration with a wide nutritive ratio in which no protein supplement was fed, the gains were much lower and the cost higher than where either a medium ration in which 1.64 pounds cottonseed meal, or a narrow ration in which 4.17 pounds of cottonseed meal was used. The narrow ration made a daily gain of 2.57 pounds per steer and returned \$28.15 per head above the cost of cattle and feed. The medium ration gained 2.44 pounds with a return of \$29.52 while the wide ration gained 1.51 pounds and returned only \$13.30. Light and medium calves utilized their feed to make larger gains than heavy calves. It was also found that calves on a normal fattening ration containing about 1.50 pounds of cottonseed meal gained faster for a period of 182 days than a similar lot fed 214 days and did so at a lower feed cost per hundred pounds gain. The longer fed steers however, were more highly finished and brought more on the market, giving a higher net return.

Cottonseed meal was fed with soft ear corn silage with very good results. No bad effects from this feeding were noticed. Several experiments comparing cottonseed meal with soybeans and soybean oil meal seem to indicate that slightly better results can be obtained from the former, the steers fed cottonseed meal appearing to have a better appetite and making slightly larger gains than those fed soybeans.

The Wyoming station has found that native hay alone will winter weanling calves satisfactorily (11), but when cottonseed meal is substituted for some of the hay the rate of gain is increased and cost per hundred pounds gain is lowered. The use of sunflower silage with cottonseed meal in varying amounts did not prove economical.

A series of tests at Arizona (12) show the value of sorghum silage in that section when fed with cottonseed meal. Tests for three years have been made on the grain-saving value of cottonseed meal in a ration. Some of the results were rather conflicting but a few tentative conclusions have been advanced. Cottonseed meal can be substituted for one-third to one-half of the barley allowance when fed with alfalfa hay and hegari silage and has effected a 33% greater net return over a period of three trials. A comparison of barley-cottonseed meal ratios of 5:1 and 4:2 when fed with alfalfa hay has shown a slight saving with the greater allowance of cottonseed meal during

two trials. The addition of a simple mineral mixture to a ration of rolled barley, alfalfa hay, and cottonseed meal did not prove profitable. It must be remembered that these conclusions are based on Arizona conditions and may not apply to the country as a whole.

Four experiments were conducted at the Tennessee station (13) with fattening two-year-old steers, using silage and cottonseed meal as the basis of the ration and feeding varying amounts of meal. The average results of these tests indicated medium cottonseed meal rations in amounts varying from 5 to 7 pounds per head daily to be most efficient in gains and cost. The average daily gain for steers receiving 3 to 5 pounds of cottonseed meal was 1.52 pounds, at a cost of 8.5 cents per pound; for steers receiving 5 to 7 pounds of cottonseed meal was 1.75 pounds at a cost of 8.5 cents per pound; and for those receiving a high ration of 7 to 9 pounds the gain per head daily was 1.72 pounds at a cost of 12.1 cents per pound.

Indiana (14) has conducted a series of tests feeding steers on a corn, clover hay, and corn silage ration with and without cottonseed meal. The addition of cottonseed meal increased the gains from 2.07 pounds to 2.43 pounds and the cost from \$8.39 per hundred to \$9.34. The cottonseed meal seemed to induce a slightly larger consumption of feed. Experiments have also been run comparing cottonseed

meal with soybean meal and whole soybeans. In every case those receiving soybeans made the most gains and the largest profits per steer. These results do not agree with those found at the Illinois station. However, it must be borne in mind that older cattle having different protein requirements than those fed at Illinois were used at this station.

Mississippi (15) has compared rations containing cottonseed meal with those to which light and medium molasses feeds have been added. An average of four year's work indicates the addition of a light molasses feed increases both gains and returns over those receiving the basal ration. The heavier molasses feed gives the greatest gains but the net returns are the lowest of the three lots.

Work at Alabama (16) with wintering feeding steers shows that adding 2.18 pounds of cottonseed meal per steer to a winter ration of Johnson grass hay increased the gains 0.23 pounds daily. The addition of molasses to this ration did not increase the profits but did the rate of gain. Feeding 4.73 pounds of cottonseed meal per day to steers finishing on pasture increased the profits \$5.55 per head.

North Carolina (17) in two experiments in which corn and cottonseed meal has each been fed alone with a basal ration of hulls, alfalfa hay, and wheat straw to mixed lots

of steers and heifers, finds the meal is not harmful during the five months of the experiments. Twice as much corn as cottonseed meal was consumed which increased the cost per hundred pounds gain. The carcasses of cattle fed cottonseed meal were darker in color but were not affected apparently as to quality of meat. As slaughter cattle the corn-fed steers graded 3 to 5 per cent higher than those fed cottonseed meal and as carcass cattle graded approximately 5 per cent higher.

South Carolina (18) has investigated the feeding of cottonseed meal compared with soybean meal. There was but very little difference in the results obtained.

Results at Montana (19) show that one pound of cottonseed cake fed to wintering beef cows has approximately the same feeding value as five pounds of mixed timothy and alfalfa hay. Investigations in winter feeding of steers with medium and heavy grain rations in which oats was fed in daily amounts of 2.47 pounds and 4.93 pounds, and cottonseed meal was fed in daily amounts of 0.62 pounds and 1.23 pounds, both rations were found to fatten the steers too heavily for economical summer pasturing. The medium ration steers were too fat for grass and not fat enough to kill while the heavy ration steers were fat enough to kill but were not prime.

Linseed Oil Meal

Only a comparatively few experiments have been run with linseed oil meal given the major consideration. Nebraska (8) has run a series of experiments testing the advisability of adding linseed cake to a shelled corn and alfalfa hay ration for steer calves. In practically all cases, the addition of the linseed cake increased the gains and the selling price but the extremely high cost of this feed make it most uneconomical.

The results of the experiment in 1927, which is typical of them all, showed an increased gain per head of 24 pounds. The cost per hundred pounds gain was \$1.03 and although the selling price was increased 35 cents per hundred, the profit was 98 cents per head lower. The linseed cake failed to return the cost price by \$7 per ton.

Tests were conducted at Iowa (9) for the purpose of studying the advisability of adding linseed oil meal in varying amounts to a steer ration of shelled corn, corn silage, and clover hay. Results showed that adding linseed oil meal increased the gains, feed consumption, and cost of gain. One and one-half pounds of linseed oil meal added to the ration increased the cost per hundred pounds gain 44 cents, while the addition of three pounds increased it

\$1.63 per hundred. The first group returned a margin over feed costs after allowing for feed saved by hogs, of \$2.90, while the other returned a margin of only 77 cents. Both linseed oil meal groups shrunk less enroute to market and sold for a higher price in Chicago - 25 cents.

Experiments at Missouri (20) with feeding calves to be marketed as yearlings indicates that linseed oil meal is a satisfactory addition to the ration. It also was fed to weanling calves with good results.

Illinois (10) has also used linseed oil meal in various experimental rations but aside from some tests in direct comparison with cottonseed meal they were not so conducted as to give a knowledge of the economy and feed value of linseed oil meal.

Minnesota (21) has made some tests showing the value of linseed oil meal in a calf fattening ration. In one test, adding linseed oil meal increased the daily gains about 0.3 pounds. The cost of gains were increased, however, and the calves did not return as great a margin as a result. Another experiment in which linseed oil meal was compared to gluten feed, the former was found to be the more efficient. In comparison with a no supplement ration it increased the rate of gain 0.3 pound per head daily and the feed cost about 20 cents per hundred. The linseed oil

meal calves brought more on the market than the others.

The Ohio station (22) in a test comparing an alfalfa-corn silage ration with one having added linseed oil meal, found the addition of linseed oil meal increased the gains from 1.37 pounds per head daily to 1.87 pounds, and the cost from \$7.08 per hundred to \$7.76. Another experiment in which shelled corn, linseed oil meal, corn silage, and hay was compared with a like ration in which part of the corn was replaced by ground oats, showed that the second ration required one-half as much linseed oil meal to produce one hundred pounds gain as did the first and the feed cost was lower. This lot showed higher returns per steer than the others.

Tennessee has reported a limited amount of work with linseed oil meal in which it was found that this feed when fed with an unlimited silage ration, produced a slight laxative effect but that this did not effect the gain or finish of the steers.

Cottonseed Meal versus Linseed Oil Meal

A large share of the experimental work with protein supplements has been direct comparison trials. Of these, cottonseed meal and linseed oil meal have received the greatest amount of investigation. The results of two years'

direct comparison at Wisconsin (23) with steer calves on a basal ration of cracked corn, crushed oats, alfalfa hay, and corn silage showed that linseed oil meal gave slightly better gains and required considerably less feed per hundred pounds gain. The cost per hundred pounds gain from linseed oil meal was lower and the net return greater than for cottonseed meal. In one of these tests, the linseed oil meal calves returned nearly twice as great a profit per head as those receiving the cottonseed meal. The linseed oil meal was just as cheap as cottonseed meal and the better results obtained from its being fed in these trials made it a more profitable source of protein than cottonseed meal.

Following up the two experiments above, the same station made three trials using linseed oil meal in comparison to a mixture of equal parts of oil meal and cottonseed meal. In these tests, cottonseed meal was cheaper in price than linseed oil meal. An average of the results of the three trials showed no difference in the daily gain. The cost per hundred pounds gain for the calves receiving straight linseed oil meal was \$9.67, while for those receiving the mixture it was \$9.43. The selling price for the former however, was \$11.30 per hundred, making a return per head of \$14.94 against a selling price of \$11.08 per

hundred for the mixture-fed calves which returned \$14.34 per head.

Nebraska (8) compared linseed oil cake and cottonseed cake in a 145-day calf feeding experiment. The linseed oil cake-fed calves yielded slightly higher gains but the cost per hundred pounds gain was \$9.19 against \$8.36 for the cottonseed cake-fed calves. The latter calves made a profit of \$10.45 per head while those fed linseed oil cake made a profit of only \$7.13 per head.

Another experiment was conducted the same year, this time for a period of 255 days. The first 145 days all calves were fed a bulky, growing ration in one lot and then divided for the final 110 days full feed. The basal ration was shelled corn and alfalfa hay with silage for the first 40 days. The calves fed linseed oil cake made larger gains than those fed cottonseed cake but the cost per hundred pounds gain was 34 cents higher. However, they brought 20 cents per hundred more on the market, making a profit per calf of \$18.62, against \$15.58 for those fed cottonseed cake.

Two experiments were run simultaneously with two-year-old steers at the Iowa station (9) comparing different amounts of cottonseed meal and linseed oil meal fed with two different basal rations. In the first ration of shelled

corn, corn silage, clover hay, and block salt the steers receiving one and one-half pounds of linseed oil meal outgained the one and one-half pound cottonseed meal steers; made this gain at less cost; shrank less on the way to market; sold for 10 cents more per hundred; dressed higher; and returned a greater margin per steer. The linseed oil meal was worth 86 per cent more than the cottonseed meal. The steers receiving three pounds of linseed oil meal outgained the three-pound cottonseed meal steers and sold for 25 cents more per hundred. When fed in these amounts linseed oil meal was worth 47 per cent more than cottonseed meal.

The other experiment in which the basal ration contained no silage, showed that the steers receiving one and one-half pound linseed oil meal outgained the one and one-half pound cottonseed meal steers and at a lower cost; shrank more on the way to market; dressed a little higher; and sold for 25 cents more per hundred. Linseed oil meal fed in this fashion was worth 118 per cent more than cottonseed meal. On the other hand, the steers fed three pounds of cottonseed meal outgained the three-pound linseed oil meal steers and at less cost; shrank more on the way to market; dressed lower; and sold for 15 cents more per hundred. In these lots linseed oil meal was worth 12 per cent less than cottonseed meal.

The results of five years' work at the Missouri (20) station comparing linseed oil meal and cottonseed meal as supplements to corn fed on bluegrass pasture, show linseed oil meal to have been from 0.75 per cent less efficient to 11.5 per cent more efficient for three-year-olds, two-year-olds, and yearlings. Three-year-old steers receiving linseed oil meal gained on an average 2.68 pounds per head daily compared with 2.40 pounds for similar steers fed cottonseed meal. The latter required more corn and supplement to produce 100 pounds gain. Two trials with two-year-old steers showed an average of only 0.03 pounds gain per head daily in favor of linseed oil meal. Yearling steers receiving linseed oil meal made larger daily gains than similar steers fed cottonseed meal in each of these five trials. In two trials in which linseed oil meal and cottonseed meal were compared as supplements to a ration of corn silage and legume hay, the linseed oil meal was somewhat superior. In one trial the steers receiving linseed oil meal gained 0.41 pounds per head daily (20.8%) more than those fed cottonseed meal, while in the other trial both lots were practically the same.

A trial at the Kansas station (24) in which linseed oil meal and cottonseed meal were compared when fed to fattening yearlings in a basal ration of shelled corn, cane silage, and prairie hay, showed linseed oil meal to be

superior. The calves receiving this feed made 0.14 pound more gain per head daily; required less feed to make 100 pounds gain; and showed more finish. They sold for 35 cents per hundred more than the cottonseed meal steers and made a greater profit.

Colorado (25) compared cottonseed cake and linseed oil cake fed to fattening calves with a silage, beet pulp, and barley ration. It was found that although linseed oil cake produced slightly higher gains than cottonseed cake the spread in price made the feeding of linseed oil cake prohibitive. Investigation at the Colorado station has shown that cottonseed meal goes better with beet by-products than linseed oil meal and is usually a cheaper and more efficient feed to use.

The Pennsylvania station (26) compared linseed oil meal and cottonseed meal in a ration of corn silage and corn stover and but very little difference was observed. Cheap linseed oil meal accounted for the slight difference in favor of the linseed oil meal fed steers. The laxative effect of the linseed oil meal did not seem to affect the gains or condition of the cattle.

Investigations at West Virginia compared cottonseed meal and linseed oil meal fed to wintering calves and yearlings. The results of this work were not off the press at the time of writing, but information to the author in-

licated that in general linseed oil meal gave slightly better results with calves and no better results with yearlings than cottonseed meal when fed with corn silage and legume hay.

A study of 29 experiments in which cottonseed meal and linseed oil meal were compared when fed to fattening cattle shows that in six tests the lots fed cottonseed meal made larger daily gains and in 23 trials the ones receiving linseed oil meal made larger gains. An average of these trials indicated that cattle fed linseed oil meal gained about 8 to 10 per cent faster than similar ones that received cottonseed meal. Linseed oil meal was apparently more palatable to the cattle in 12 of the trials studied, as there was a greater consumption of feed in these cases. Larger consumption of feed in the cottonseed meal lots occurred in six trials.

An average of a series of tests made by seven different states with fattening cattle indicates that those receiving linseed oil meal gained 0.13 pound per head daily more than the cottonseed meal steers and the difference in selling price per hundred in favor of the linseed oil meal lot was 18 cents. A summary of the results of experimental feeding of linseed oil meal and cottonseed meal showed the value of the former over that of the latter expressed in per cent

as follows: In the dry lot for calves the value was 43%; yearlings, 41%; older cattle, 46% more. Fed on bluegrass pasture for yearlings the value was 25%; two-year-olds, 22%; and three-year-olds, 43% more.

Corn Gluten Meal

Until this year's test at the Kansas Agricultural Experiment Station, all the work reported in which corn gluten meal was fed to fattening cattle was done early in this century. One of the first was an experiment at Massachusetts in which only four steers were used, feeding different combinations at different periods. A comparison was made between corn gluten meal and linseed oil meal but no direct conclusions were drawn except to leave the impression they made no preference, the use of either when fed with corn silage and bran producing greater gains than if fed with dry fodder. The small number of animals and the short feeding period involving feed changes made a conclusive statement impossible.

A series of experiments were run in 1894-1895 at the Ohio station (27) attempting to show the value of corn gluten meal in a steer ration. Corn gluten meal steers on a mixed grain ration averaged 2.15 pounds gain and those without corn gluten meal averaged 1.98 pounds. In another experiment adding corn gluten meal to a ration of corn

meal and silage did not apparently increase the rate of gains or efficiency of gains. Corn gluten meal fed with corn meal made greater gains than when fed with wheat meal.

Corn Gluten Meal versus Linseed Oil Meal

Corn gluten meal was also compared to linseed oil meal in the above experiment. The latter made greater gains but at a greater cost, the final value being approximately the same. Feed cost appeared to be a limiting factor.

Corn Gluten Meal versus Linseed Oil Meal versus Cottonseed Meal

The only previous experimental work recorded to the author's knowledge in which all three feeds have been directly compared, was done at the Iowa station in 1902 (28). The steers used were owned by a farmer living near by and fed by him under the direction of the investigators at the college. They were started on snapped corn, then changed to shelled corn and corn and cob meal, and finally to corn meal. Wheat straw was fed for roughage. The cottonseed meal lot was suddenly affected at the end of 42 days and the steers had to be sold. The others were fed 94 days. The short time that the cottonseed meal lot

was fed did not give it a fair comparison and it made no greater gains than did the check lot of corn and straw, the least efficient lot in the test.

The corn gluten meal lot proved to be the most efficient and economical lot in the test. The steers in this lot gained 2.72 pounds per head daily at a cost of \$9.34 per hundred pounds gain. They made a net profit of \$17.99 each. The linseed meal steers gained 2.51 pounds per head daily at a cost of \$11.02 per hundred pounds gain. They returned a net profit of \$14.85. The steers fed cottonseed meal gained 2.38 pounds daily at a cost of \$9.84 per hundred pounds gain. No positive deductions were drawn by the investigators on these results as no other check experiments had been conducted.

THE EXPERIMENT

The following is a detailed report of the test conducted by the Kansas Agricultural Experiment Station in the year 1928-1929 involving a study of the comparative value of cottonseed meal, linseed oil meal, and corn gluten meal as protein supplements in cattle fattening rations.

The Object

Corn gluten meal is available in appreciable quantities as a protein supplement for livestock feeding purposes. In view of the fact that no experiments have been conducted upon which definite conclusions may be based relative to the comparative value of cottonseed meal, linseed oil meal, and corn gluten meal, the Kansas Agricultural Experiment Station decided to make such a comparison for three successive years. The first year's test was conducted during the winter of 1928-1929 and is reported as a part of this thesis.

The Test

Seven lots of high grade Hereford steer calves bred by the Matador Land & Cattle Company of Matador, Texas and dropped in the spring of 1928, were used in making this test. The experiment was conducted for a period of 180 days beginning at noon of November 15, 1928 and closing at noon of May 14, 1929.

These seven lots of calves were fed on a basal ration of shelled corn, alfalfa hay, and corn silage to which was added the three protein supplements used in this test as follows:

- Lot 1 - Cottonseed meal
- Lot 2 - Linseed oil meal
- Lot 3 - Corn gluten meal
- Lot 4 - Cottonseed meal and linseed oil meal equal parts
by weight
- Lot 5 - Cottonseed meal and corn gluten meal equal parts
by weight
- Lot 6 - Linseed oil meal and corn gluten meal equal parts
by weight
- Lot 7 - Cottonseed meal, linseed oil meal, and corn
gluten meal equal parts by weight.

At the close of the experiment the steers in each lot were appraised by a representative of the John Clay & Company commission firm. He had no advanced information as to the rations given the different lots and appraised them solely on their merits, using the current Kansas City market price level for a base.

The results of this test are given in detail in Table I.

Table I. - The comparative value of cottonseed meal, linseed oil meal, and corn gluten meal as protein supplements for fattening steers.

| November 15, 1928 to May 14, 1929 - 180 days | | | | | | | | |
|--|--|---|---|---|---|---|---|---|
| Lot number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Ration fed | : Shelled : corn : Cotton- : seed : meal : Corn : silage : Alfalfa : hay | : Shelled : corn : Linseed : oil : meal : Corn : silage : Alfalfa : hay | : Shelled : corn : Corn : gluten : meal : Corn : silage : Alfalfa : hay | : Shelled : corn : C.S.M. $\frac{1}{2}$: L.O.M. $\frac{1}{2}$: Corn : silage : Alfalfa : hay | : Shelled : corn : C.S.M. $\frac{1}{2}$: Gluten : meal : Corn : silage : Alfalfa : hay | : Shelled : corn : L.O.M. $\frac{1}{2}$: Gluten : meal : Corn : silage : Alfalfa : hay | : Shelled : corn : C.S.M. $\frac{1}{3}$: L.O.M. $\frac{1}{3}$: Gluten : meal : Corn : silage : Alfalfa : hay | : Shelled : corn : C.S.M. $\frac{1}{3}$: L.O.M. $\frac{1}{3}$: Gluten : meal : Corn : silage : Alfalfa : hay |
| Number of steers in lot | : 8 | : 10 | : 7 | : 10 | : 9 | : 10 | : 9 | |
| Number of days on test | : 180 | : 180 | : 180 | : 180 | : 180 | : 180 | : 180 | |
| Initial weight per steer | : 388.13 | : 387.75 | : 391.43 | : 387.00 | : 390.00 | : 388.00 | : 384.44 | |
| Final weight per steer | : 761.88 | : 786.50 | : 772.00 | : 789.17 | : 763.15 | : 793.83 | : 776.67 | |
| Total gain per steer | : 373.75 | : 398.75 | : 380.47 | : 402.17 | : 373.15 | : 405.83 | : 392.23 | |
| Daily gain per steer | : 2.08 | : 2.22 | : 2.11 | : 2.23 | : 2.07 | : 2.26 | : 2.18 | |
| Average daily ration: | | | | | | | | |
| Shelled corn | : 8.59 | : 8.89 | : 8.32 | : 8.83 | : 8.73 | : 8.67 | : 8.63 | |
| Cottonseed meal | : .93 | : | : | : .46 | : .46 | : | : .31 | |
| Linseed oil meal | : | : .93 | : | : .46 | : | : .46 | : .31 | |
| Corn gluten meal | : | : | : .94 | : | : .46 | : .46 | : .31 | |
| Corn silage | : 9.21 | : 8.98 | : 8.85 | : 8.89 | : 8.98 | : 9.11 | : 9.00 | |
| Alfalfa hay | : 1.94 | : 1.95 | : 1.96 | : 1.95 | : 1.95 | : 1.95 | : 1.95 | |
| Feed required for 100 pounds gain: | | | | | | | | |
| Shelled corn | : 413.90 | : 401.50 | : 383.50 | : 395.06 | : 421.34 | : 384.26 | : 395.90 | |
| Cottonseed meal | : 44.92 | : | : | : 20.88 | : 22.50 | : | : 14.30 | |
| Linseed oil meal | : | : 42.11 | : | : 20.88 | : | : 20.68 | : 14.30 | |
| Corn gluten meal | : | : | : 44.31 | : | : 22.50 | : 20.68 | : 14.30 | |
| Corn silage | : 443.60 | : 405.20 | : 418.52 | : 398.04 | : 433.13 | : 403.94 | : 412.82 | |
| Alfalfa hay | : 93.24 | : 88.03 | : 92.72 | : 87.28 | : 94.15 | : 86.43 | : 89.69 | |

| | | | | | | | |
|--|----------|----------|----------|----------|----------|----------|----------|
| Cost of 100 pounds gain | :\$ 8.70 | :\$ 8.55 | :\$ 8.37 | :\$ 8.35 | :\$ 8.82 | :\$ 8.20 | :\$ 8.40 |
| Initial cost per steer @ | : | : | : | : | : | : | : |
| \$13 per cwt. | : 50.46 | : 50.41 | : 50.89 | : 50.31 | : 50.70 | : 50.41 | : 49.98 |
| Feed cost per steer | : 32.52 | : 34.09 | : 31.85 | : 33.58 | : 32.91 | : 33.30 | : 32.95 |
| Steer cost plus feed | : | : | : | : | : | : | : |
| cost | : 82.98 | : 84.50 | : 82.74 | : 83.89 | : 83.61 | : 83.71 | : 82.93 |
| Value per head at home | :100.95 | :108.14 | :101.13 | :107.72 | :101.12 | :109.15 | :104.85 |
| Margin per head | : 17.97 | : 23.64 | : 18.39 | : 23.83 | : 17.51 | : 25.44 | : 21.92 |
| Necessary value per cwt. | : | : | : | : | : | : | : |
| at feedlot to break even | : 10.89 | : 10.74 | : 10.72 | : 10.63 | : 10.96 | : 10.55 | : 10.68 |
| Value per cwt. at feedlot: | : | : | : | : | : | : | : |
| Kansas City price minus | : | : | : | : | : | : | : |
| \$.75 per cwt. | : 13.25 | : 13.75 | : 13.10 | : 13.65 | : 13.25 | : 13.75 | : 13.50 |
| Margin per cwt. | : 2.36 | : 3.01 | : 2.38 | : 3.02 | : 2.29 | : 3.20 | : 2.82 |
| FEED PRICES: Corn, \$.77 per bushel; cottonseed meal, \$60 per ton; linseed oil meal, \$60 per ton; corn gluten meal, \$50 per ton; corn silage, \$5 per ton; alfalfa hay, \$15 per ton. | | | | | | | |

Observations

These lots involve a comparison of cottonseed meal, linseed oil meal, and corn gluten meal fed separately and in combinations as protein supplements with shelled corn, corn silage, and alfalfa hay. The protein supplements used ranked as follows:

(a) On the basis of average daily gains:

1. Linseed oil meal and corn gluten meal half and half (Lot 6).

2. Cottonseed meal and linseed oil meal half and half (Lot 4).

3. Linseed oil meal (Lot 2).

4. Cottonseed meal, linseed oil meal, corn gluten meal one-third each (Lot 7).

5. Corn gluten meal (Lot 3).

6. Cottonseed meal (Lot 1).

7. Cottonseed meal and corn gluten meal half and half (Lot 5).

(b) On the basis of cost of 100 pounds gain:

1. Linseed oil meal and corn gluten meal half and half (Lot 6).

2. Cottonseed meal and linseed oil meal half and half (Lot 4).

3. Corn gluten meal (Lot 3).

4. Cottonseed meal, linseed oil meal, and corn gluten meal one-third each (Lot 7).

5. Linseed oil meal (Lot 2).

6. Cottonseed meal (Lot 1).

7. Cottonseed meal and corn gluten meal half and half (Lot 5).

(c) On the basis of necessary selling price to break even:

1. Linseed oil meal and corn gluten meal half and half (Lot 6).

2. Cottonseed meal and linseed oil meal half and half (Lot 4).

3. Cottonseed meal, linseed oil meal, and corn gluten meal one-third each (Lot 7).

4. Corn gluten meal (Lot 3).

5. Linseed oil meal (Lot 2).

6. Cottonseed meal (Lot 1).

7. Cottonseed meal and corn gluten meal half and half (Lot 5).

(d) On the basis of appraised value. Value Kansas City price minus \$.75 per cwt. to cover shrinkage and shipping expenses:

1. Linseed oil meal and corn gluten meal half

and half (Lot 6).

1. Linseed oil meal (Lot 2).

2. Cottonseed meal and linseed oil meal half and half (Lot 4).

3. Cottonseed meal, linseed oil meal, and corn gluten meal one-third each (Lot 7).

4. Cottonseed meal (Lot 1).

4. Cottonseed meal and corn gluten meal half and half (Lot 5).

5. Corn gluten meal (Lot 3).

(e) On the basis of margin per steer:

1. Linseed oil meal and corn gluten meal half and half (Lot 6).

2. Cottonseed meal and linseed oil meal half and half (Lot 4).

3. Linseed oil meal (Lot 2).

4. Cottonseed meal, linseed oil meal, and corn gluten meal one-third each (Lot 7).

5. Corn gluten meal (Lot 3).

6. Cottonseed meal (Lot 1).

7. Cottonseed meal and corn gluten meal half and half (Lot 5).

(f) On the basis of net returns:

1. Linseed oil meal and corn gluten meal half and

half (Lot 6) \$25.44.

2. Linseed oil meal and cottonseed meal half and half (Lot 4) \$23.83.

3. Linseed oil meal (Lot 2) \$23.64.

4. Linseed oil meal, cottonseed meal, and corn gluten meal one-third each (Lot 7) \$21.92.

5. Corn gluten meal (Lot 3) \$18.39.

6. Cottonseed meal (Lot 1) \$17.97.

7. Cottonseed meal and corn gluten meal half and half (Lot 5) \$17.51.

Interpretations

The above observations indicate that the addition of linseed oil meal to a ration in comparison with cottonseed meal and corn gluten meal has a tendency to increase the efficiency of the ration. Linseed oil meal, however, is considerably higher in price than the other two supplements and therefore a mixture with either one of the other two feeds cut down the costs and increased the margin per steer.

A statistical treatment of the above results is interesting in that it shows the limitations of the statistical method now in use when applied to selected rather than random groups. The mean total gains and probable errors

for each lot, figured on the basis of the formula used for random samples, are as follows:

| Lot | Mean total gain per head (pounds) |
|-----|-----------------------------------|
| 1 | 373.75 ± 7.23 |
| 2 | 398.75 ± 8.90 |
| 3 | 380.47 ± 10.99 |
| 4 | 402.17 ± 8.46 |
| 5 | 373.15 ± 5.35 |
| 6 | 405.83 ± 5.06 |
| 7 | 392.23 ± 7.41 |

It is generally conceded that any difference in experimental data based upon random samples to be significant, should be at least four times its probable error. By comparing each lot with all the others in this experiment only two comparisons showed a difference approaching the point of significance and nine comparisons showed a difference of two or more times its probable error. The following table shows these nine comparisons in which $m-m'$ is the difference between the mean total gains of the two lots compared, and $\frac{m-m'}{\text{P.E. } m-m'}$ is this difference divided by the probable error of the difference. The last column shows the probability of this difference being either zero or twice the amount, and is the index to its significance.

| Lots Compared | m-m' | $\frac{m-m'}{P.E. m-m'}$ | Probability |
|---------------|-------|--------------------------|-------------|
| | | | |
| 2 and 1 | 25.00 | 2.180 | 1 to 7.26 |
| 2 and 5 | 25.60 | 2.466 | 1 to 10.89 |
| 4 and 1 | 28.42 | 2.553 | 1 to 10.89 |
| 4 and 3 | 21.70 | 1.980 | 1 to 5.64 |
| 4 and 5 | 29.02 | 2.873 | 1 to 19.80 |
| 6 and 1 | 32.08 | 3.637 | 1 to 65.79 |
| 6 and 3 | 25.36 | 2.096 | 1 to 6.38 |
| 6 and 5 | 32.68 | 4.440 | 1 to 333.00 |
| 7 and 5 | 19.08 | 2.632 | 1 to 12.58 |

In this analysis it is noted that the comparisons more nearly approaching a significant difference in total gains are lots 4 and 6 compared to lot 5, and lot 6 compared to lot 1. It is interesting to note that lots 4 and 6 were fed linseed oil meal in combination with cottonseed meal and corn gluten meal respectively, while lot 5 received a mixture of the two latter feeds and lot 1 received cottonseed meal alone. The result of adding linseed oil meal to either cottonseed meal or corn gluten meal compared to a mixture of these two feeds apparently gave a significant difference.

All other comparisons failed to give a difference of three times its probable error and in no case was the difference between a lot receiving cottonseed meal and corn gluten meal alone or mixed compared to one receiving only

linseed oil meal significant. On the other hand, in all comparisons in which the difference equaled twice the probable error or more, the rations making the larger gains contained linseed oil meal.

While these differences were not on the whole significant according to the statistical method used, nevertheless the fact that the differences were uniformly in favor of the linseed oil meal, and in view of the preponderance of evidence in favor of linseed oil meal over cottonseed meal found at other stations, it is the belief of the author that these differences are significant. It must be remembered that the statistical formulae used in this treatment were evolved for use with random samples having a larger population than was the case in this experiment. It must also be remembered that the lots used in this experiment, while relatively small in population, were carefully selected for uniformity and therefore could not be classed as being strictly random samples. This would indicate that there is a need for new statistical formulae for the treatment of experimental data obtained from tests similar to the one under discussion.

In this connection it must be emphasized that the statistical treatment just discussed involves only one of several factors that determine the value of a constituent

in a cattle fattening ration. The factor treated was total gains. In addition one must consider cost of gain, type of gain (whether growth or finish), type of finish, thrift of the cattle, and selling price per hundred.

Conclusions

No definite conclusions should be drawn from this experiment relative to the comparative value of cottonseed meal, linseed oil meal, and corn gluten meal.

Indications

1. Linseed oil meal appeared to be more efficient than either cottonseed meal or corn gluten meal on the basis of average daily gains and returns per steer.

2. The addition of either cottonseed meal or corn gluten meal to linseed oil meal in the ration apparently tended to cheapen the cost of gains and increased the net returns.

3. Linseed oil meal added to either cottonseed meal or corn gluten meal in the ration fed seemed to increase the efficiency of gains.

4. A mixture of cottonseed meal and corn gluten meal did not increase the economy of gains over either feed alone.

5. Since protein supplements are necessary in profitable cattle feeding operations and since these feeds are high in price, the need for a careful study of the actual value of available protein feeds is imperative. Additional tests must be completed.

Methods of Procedure

The calves used in this test were received November 1, 1928 direct from the range of the Matador Land & Cattle Company at Matador, Texas. They were vaccinated for hemorrhagic septicemia immediately and were gradually put on a feed of silage and hay until the start of the experiment November 15. There were 150 calves in the shipment and from these 70 calves were carefully selected for uniformity of weight, type, and quality and divided into seven lots as nearly uniform as possible. A few individuals were later removed from the experiment because of accident and sickness.

The initial weights for these steers were taken on an average weight of each individual for two consecutive days, November 14 and 15. The usual third day's weight was not taken because of a severe rain storm November 16. The final weights were obtained in like manner, using an average of three days' weights, the experiment officially

closing on the second day. The steers were weighed individually every 30 days after the start of the test.

The method employed in lotting was such as to make all lots as uniform as possible. The entire 170 head were weighed individually November 14 and a strap with a brass number attached was placed around the neck of each to preserve its identity. Two members of the experiment station staff and the author carefully observed each steer as it was being weighed and any characteristic that would affect its grade, such as type, disposition, quality, health, and condition, was noted and recorded opposite its weight.

The steers were then lotted on paper from this record according to weight beginning with the heaviest in lot 1 and continuing down in order to lot 7, then continuing from lot 7 in the same manner back to lot 1. In this way the first 70 steers according to weight were divided with a fair degree of uniformity. Any undesirable steers noted were rejected. The average initial weight of each lot was then determined and any discrepancies corrected by shifting individuals from one lot to another until the final average weight per steer varied only 0.5 pound between lots.

The second weigh day the steers were actually lotted according to the plan on paper and particular notice was

made of any lots not as uniform in individual characteristics as the others. In such cases the steers causing the discrepancies were again shifted to other lots or rejected and substituted with steers from the cutback group more nearly suiting the standard, in order to make all as uniform as possible. In doing this care was taken not to affect the average weight of the lots.

After the steers were all lotted, final inspection was made by the head of the Department of Animal Husbandry in charge of the experiment, and any discrepancies overlooked by the first three were noted and corrected. This method of lotting gave similar groups in each lot with as much uniformity of weight and type between lots as possible.

All lots in the experiment were hand-fed the corn, protein supplement, and silage twice daily - morning and evening - at regular hours. The alfalfa hay was fed at noon. Two pounds of alfalfa hay was fed per steer daily throughout the experiment and the other feeds were gradually increased from small amounts at the start until the steers were on full feed at the end of 70 days. Wheat straw was used for bedding in the lots during stormy weather at which time the steers would eat it to some extent, seeming to relish the change. Plenty of fresh water and salt was kept before them at all times.

The steers were started on feed at the beginning of the test with 1 pound of corn, 8 pounds of silage, 0.5 pound of protein supplement, and 2 pounds of alfalfa hay. They had already become accustomed to the silage and it was rapidly increased until the maximum consumption of about 16 pounds per head daily was reached in the first 10 days of the test, after which it was fed ad. libitum. The protein supplement was increased the fourth day to 1 pound per head daily, which amount was kept constant throughout the remainder of the experiment.

Great care was taken in feeding the corn to increase it at such a rate that the steers would not "burn out" and "stick" in their feed consumption. On the fourth day, the corn was increased from 1 pound to $1\frac{1}{2}$ pounds per head daily and thereafter it was increased $\frac{1}{2}$ pound about every four days until at the end of 70 days they were consuming an average of about 9 pounds of corn per head daily. It was then fed ad. libitum. for the remainder of the test.

A good grade of shelled corn purchased at the local market was used. No attention was given as to its color, some of which was white, some yellow, and some mixed. The silage was made of good corn fodder and contained a considerable amount of grain. It was estimated to produce about 50 bushels of corn per acre in the field. The

alfalfa was of fair average quality, ranging from a fine leafy grade to a somewhat coarse, stemmy quality. No attempt was made to pick out the best for this experiment but was fed as it was thrown down from the loft. It was purchased from local growers.

The cottonseed meal used in this test was guaranteed to be 43% crude protein and was purchased from the Chickasha Cotton Oil Company of Chickasha, Oklahoma. The linseed oil meal was guaranteed 34% crude protein and was produced by the Auber-Daniels-Midland Company of Minneapolis, Minnesota. The corn gluten meal was purchased from the Penick and Ford Sales Company, Inc. of Cedar Rapids, Iowa and was guaranteed to contain 40% crude protein.

The following table gives the guaranteed analysis of these protein feeds:

| Feed | Minimum Cr. Prot. % | Minimum Cr. Fat. % | Minimum Cr. Carb. % | Minimum Cr. N.F.E. % | Maximum Cr. Fib. % | Ash % |
|--------|---------------------------|--------------------------|---------------------------|----------------------------|--------------------------|----------|
| C.S.M. | 43 | 6 | 35 | 23 | 12 | |
| L.O.M. | 34 | 5 | 45 | 37 | 9 | 5 |
| C.G.M. | 40 | 1 | 44 | 40 | 4 | |

The cost of these feeds is given in Table I.

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