

CORN GLUTEN MEAL AS A PROTEIN SUPPLEMENT
IN CATTLE FATTENING RATIOS

by

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INTRODUCTION

The greatest amount of experimental work with protein supplements in cattle fattening rations has been conducted in Texas, Oklahoma, and the corn belt states because cattle feeding is an important industry in these states. These states are also nearest the centers of production of feed and cattle. Corn gluten meal has received almost no consideration in an experimental way with fattening cattle although the related corn gluten feed has been investigated somewhat. The Ohio Station did some work with corn gluten meal in a cattle fattening ration about 1895, and the Iowa Station did some work in 1902, but since then no work has been reported until 1929, when the Kansas Agricultural Experiment Station made a preliminary report on the first year's work of a three-year test of corn gluten meal as a protein supplement in a cattle fattening ration.

In this experiment the Kansas Station is comparing corn gluten meal with cottonseed meal and linseed oil meal so that it is necessary to consider these other supplements. Cottonseed meal has received by far the greatest attention in experimental work. The stations in the

cotton belt have tried to determine the maximum profitable utilization of it as a basal ration, while the corn belt experiment stations have used it as a protein supplement to corn and other feeds. The great importance of the cottonseed industry and the value of cottonseed meal as a feed and the little actually known about the nutritive and physiological character of cottonseed meal, have materially aided in advancing research work on the subject. About 2,500,000 tons of cottonseed meal are fed annually in this country while only about 500,000 tons of corn gluten meal and corn gluten feed, and 700,000 tons of linseed oil meal are fed annually. In other words there is about twice as much cottonseed meal and cake fed annually as there is linseed oil meal and corn gluten meal and corn gluten feed altogether. About three-fourths of the experiment stations have fed cottonseed meal in cattle feeding experiments.

Experiments with linseed oil meal have been rather limited in number as compared with the number with cottonseed meal. About half of the experiment stations have fed linseed oil meal to cattle experimentally. The greater part of the experimental work with linseed oil meal has consisted of direct comparisons with cottonseed meal. Most

of the work with linseed oil meal has been done in the north central states where linseed is produced in large quantities, and in the corn belt.

Corn gluten meal is produced in the corn belt and is readily available for cattle feeding in Kansas. The large amount of corn gluten meal available and the probable increase in the output of corn gluten meal in the future justify the careful study of its feeding value.

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

Cottonseed Meal

Texas has been outstanding among the stations for its investigations of cottonseed meal. Both the cottonseed and cattle industries are of great importance in that state, so the tendency in that state has been toward maximum utilization of cottonseed and cottonseed products. One of the earliest experiments conducted was a comparison (1) of silage 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. It was

concluded that cottonseed meal at \$27.00 per ton was more profitable than whole cottonseed at \$17.00 per ton for fattening cattle.

In later experiments the Texas Station proved cottonseed feeds better than peanut feeds in steer fattening rations (2). Their experiments tend to show that danger from cottonseed poisoning is lessened by adding silage to the ration. Much work done by the Texas and Oklahoma Stations has pointed out the advantages of supplementing cottonseed products with corn. The advantages were increased rate of gain, better appetites, and more finish (3).

The Kansas Agricultural Experiment Station has been conducting silage feeding investigations to determine the most economical amount of cottonseed meal to supplement a full silage ration for fattening baby beef (4). When fed with corn, silage, and alfalfa hay, one pound of cottonseed meal per head per day is the maximum amount that can be fed economically.

The Illinois Station has found that in a ration with a wide nutritive ratio and without a protein supplement, the gains were much lower and the cost higher than for the medium ration which included 1.64 pounds per steer and the narrow ration which included 4.17 pounds of cottonseed meal

per steer per day (5). The wide ration gave gains of 1.51 pounds per steer daily and returned only \$13.30 per head, while the narrow ration made a daily gain of 2.57 pounds with a return of \$28.15 per steer, and the medium ration made an average daily gain of 2.44 pounds and a return per steer of \$29.52.

The Indiana Station has conducted a series of tests fattening steers on corn, clover hay, and corn silage with and without cottonseed meal. The addition of cottonseed meal increased the gains from 1.92 pounds to 2.16, and from 1.86 pounds to 2.09 pounds per steer per day (6). Essentially the cattle received about the same daily ration of corn, silage, and hay and the cattle receiving cottonseed meal ate their daily allowance of cottonseed meal in addition to the other ingredients.

Linseed Oil Meal

Relatively few experiments have been run with linseed oil meal when one considers the number that have been run with cottonseed meal.

The Iowa Station conducted tests to determine the advisability of adding linseed oil meal in varying amounts to a ration of shelled corn, corn silage, and clover hay

for fattening steers. Adding linseed oil meal increased the gains, feed consumption, and cost of gains. The addition of one and one-half pounds of linseed oil meal increased the cost of a hundred pounds gain, while the addition of three pounds increased it \$1.63 per hundred. The addition of linseed oil meal increased the selling price (7).

A series of experiments testing the advisability of adding linseed cake to a shelled corn and alfalfa hay ration for steer calves have been run at the Nebraska Station (8). Usually the addition of linseed cake increased the gains and the selling price, but the increased cost of gains made the feed uneconomical. For example, in 1927 there was an increased gain per head of 24 pounds and the selling price was increased 35 cents per hundred, but the profit per head was 98 cents lower.

At the Minnesota Station (9), a calf fattening ration containing linseed oil meal was compared with a ration without a supplement. The linseed oil meal increased the rate of gain 0.3 pound per head daily and the feed cost about 20 cents per hundred, and it also increased the selling price.

Corn Gluten Meal

Before last year's work by this Station, there had been no experimental work with corn gluten meal reported for a quarter century or more. In 1894-95 a series of experiments involving corn gluten meal were run at the Ohio Station, but no very significant results were obtained.

Comparisons of These Supplements

No experimental work of any value making direct comparisons of these three is recorded. Mr. Connell, writing on this work last year, described an experiment carried on in Iowa in 1902 as the only one of which he could find any record. The work done in Iowa would have little value under our present conditions.

A great proportion of the experimental work with protein supplements has been direct comparisons of cottonseed meal and linseed oil meal. Nebraska (8) made a comparison of linseed oil cake and cottonseed cake in a 145-day calf feeding experiment. The calves fed linseed oil cake made slightly bigger gains but at a cost of \$9.19 per hundred as compared with \$8.36 for the calves fed cottonseed cake and the linseed oil cake-fed calves made a

profit of \$7.13 per head, while the others made \$10.45 per head. A number of other stations have made these comparisons. In almost all cases the advantages of linseed oil meal were greater for calves than they were for older cattle. Linseed oil meal as compared with cottonseed meal usually increases the gain, the finish, the selling price, and the cost per hundred pounds of gain.

THE EXPERIMENT

The Object

There is a considerable quantity of corn gluten meal available as a protein supplement for livestock feeding purposes. Since no direct comparisons of corn gluten meal, cottonseed meal, and linseed oil meal have been made in any feeding experiments in this country during the last twenty-five years, the Kansas Agricultural Experiment Station decided to make such a comparison for three consecutive years. It was decided that some tests as to the relative value of these supplements in various combinations should be included also. The second year's test was conducted during the winter of 1929-30 and is reported in this thesis.

The Plan

Seven lots of ten head each of high grade Hereford steer calves bred by the S.M.S. Ranch of Stamford, Texas were used in this experiment. The experiment was conducted for a period of 180 days beginning at noon November 27, 1929 and closing at noon May 26, 1930.

These seven lots of calves were fed a basal ration of shelled corn, alfalfa hay, and corn silage to which was added the 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.

This group includes all of the possible combinations of these supplements in equal parts by weight.

At the end of the experiment the steers in each lot were appraised by a representative of the John Clay Commission firm. He had no advanced information as to the rations given the various lots nor as to the various gains in weight, and he appraised them entirely on their merits, chiefly on finish, and using the current Kansas City price level for a base. This method has been found quite superior to actual selling price.

Methods of Procedure

The calves used in this test were received November 1 directly from the S.M.S. Ranch at Stamford, Texas. They were vaccinated immediately and were gradually put on a feed of silage, alfalfa hay, and cottonseed meal until the start of the experiment November 27. The 70 calves used in this experiment were carefully selected from the 105 calves in the shipment on the basis of uniformity of weight, type, and quality and they were divided into seven lots as nearly uniform as possible.

The initial weights of these calves were taken from the average weight of each individual for three consecu-

tive days, November 25, 26, and 27. The final weights were taken in the same manner as the calves were weighed individually May 25, 26, and 27. The calves were also weighed at thirty-day intervals during the experiment.

The calves were divided into lots as uniform as possible by the following method. All of the calves were weighed individually November 25 and a strap with a brass number attached was placed around the neck of each calf to preserve its identify. Two members of the experiment station staff and the author carefully observed each steer as it was being weighed and noted and recorded opposite its weight any characteristic that would affect its grade, such as type, disposition, quality, health, and condition. The steers were then allotted in parallel columns 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 back from lot 7 in the same manner to lot 1. In this way the first 70 steers according to weight were divided with a fair degree of uniformity. Any undesirable steers were rejected including some of the extremes in weight. There was also a certain amount of shifting necessary to avoid having the extreme largest and smallest in the same lot. 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 not more than 0.5 pounds between lots.

The second weigh day the steers were actually allotted according to the plan on paper and particular notice was made of any lots lacking uniformity of individual characteristics. In such cases the steers causing the discrepancies were shifted to other lots or rejected and then replaced by steers more nearly suiting the standard from the cutback group. In doing this care was taken not to affect the average weight of the lots. It was recognized that "top" and "bottom" steers could not be avoided completely, and each lot was made as uniform as possible in this respect.

After the steers had been allotted and before the experiment officially started, the head of the Animal Husbandry Department made a final inspection and noted and corrected any discrepancies previously overlooked. No changes were made during the experiment. This method of allotment 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 shelled corn, protein supplement, and corn silage twice daily -

morning and evening - by the author. The alfalfa hay was fed at noon. Two pounds of alfalfa hay and one pound of protein supplement were fed per head per day throughout the experiment and the other feeds were increased from small amounts at the start. Wheat straw was used for bedding, and the steers ate negligible amounts of it on the days the lots were bedded. Plenty of salt and fresh water were kept before the steers at all times.

The steers were started on feed at the beginning of the test with one pound of shelled corn, 12 pounds of corn silage, 1 pound of protein supplement, and 2 pounds of alfalfa hay per head per day. The steers were already well accustomed to the silage and they ate readily. The amount of silage was increased rapidly until it reached its maximum of 16 pounds per head per day on the fifteenth day after which it was gradually decreased to about 4 pounds in most of the lots during the last thirty days.

Increases in the amount of corn were made much more carefully. Increases usually consisted of one-half pound per head per day and amounted to about a pound a week until the end of 70 days after which increases were less frequent. The maximum which came at the close of the experiment did not exceed $15\frac{1}{2}$ pounds in any lot. The amounts of corn were kept the same in all lots for the

first 90 days and actually remained almost exactly the same for the first 110 days while variations in the appetites of the lots were equalized by varying the amounts of silage. After that time the amounts of both corn and silage were varied between lots.

The shelled corn fed was of good grades and from various sources. No attention was given to its color and most of it was white. It also varied somewhat in its moisture content. The silage was made from good corn fodder and contained a considerable amount of grain. Practically all of the alfalfa hay was of good quality. It was purchased baled from local growers.

The prime cottonseed meal used in this test was guaranteed to be 43% crude protein and was purchased from the Union Cotton Oil Company, Prague, Oklahoma. The linseed oil meal was guaranteed 34% crude protein and was purchased from the Fredonia Linseed Oil Works Company, Fredonia, Kansas. The corn gluten meal was guaranteed to contain 40% crude protein and it was purchased from the Penick and Ford Sales Company, Inc., Cedar Rapids, Iowa.

The guaranteed analysis of these protein supplements is as follows:

Feed	Minimum Cr.Prot. %	Minimum Cr. Fat %	Minimum C. H. O. %	Minimum N. F. E. %	Maximum Cr.Fib. %
C.S.M.	43	6	35	23	12
L.O.M.	34	5	35.5	35.5	10
C.G.M.	40	1	44	40	4

The cost of all of these feeds is given in Table I.

The results of this year's test are given in detail in Table I, while last year's results are given in Table II.

Observations

This experiment is a comparison of cottonseed meal, linseed oil meal, and corn gluten meal fed separately and in combinations as a protein supplement to shelled corn, corn silage, and alfalfa hay. The protein supplements used were ranked as follows:

(a) On the basis of average daily gain in pounds:

1929-30			1928-29		
1. Lot 7	-	2.62	1. Lot 6	-	2.26
2. Lot 6	-	2.53	2. Lot 4	-	2.23
3. Lot 3	-	2.40	3. Lot 2	-	2.22
4. Lot 2	-	2.34	4. Lot 7	-	2.18
5. Lot 4	-	2.33	5. Lot 3	-	2.11

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

November 27, 1929 to May 26, 1930 - 180 days							
Lot number	1	2	3	4	5	6	7
Ration fed	: Shelled: corn	: Shelled: corn	: Shelled: corn	: Shelled: corn	: Shelled: corn	: Shelled: corn	: Shelled: corn
	: Cottonseed meal	: Linseed oil meal	: Corn gluten meal	: C.S.M. $\frac{1}{2}$ L.O.M. $\frac{1}{2}$: C.S.M. $\frac{1}{2}$ C.G.M. $\frac{1}{2}$: L.O.M. $\frac{1}{2}$ C.G.M. $\frac{1}{2}$: C.S.M. $\frac{1}{3}$ L.O.M. $\frac{1}{3}$
	: Corn silage	: Corn silage	: Corn silage	: Corn silage	: Corn silage	: Corn silage	: Corn silage
	: Alfalfa hay	: Alfalfa hay	: Alfalfa hay	: Alfalfa hay	: Alfalfa hay	: Alfalfa hay	: Alfalfa hay
Number of steers in lot	: 10	: 10	: 10	: 10	: 10	: 10	: 10
Number of days on test	: 180	: 180	: 180	: 180	: 180	: 180	: 180
Initial weight per steer	: Pounds 385.83	: Pounds 388.67	: Pounds 389.67	: Pounds 388.33	: Pounds 388.67	: Pounds 386.67	: Pounds 390.33
Final weight per steer	: 800.50	: 809.17	: 822.00	: 807.33	: 806.83	: 841.33	: 861.67
Total gain per steer	: 414.67	: 420.50	: 432.33	: 419.00	: 418.16	: 454.66	: 471.34
Daily gain per steer	: 2.30	: 2.34	: 2.40	: 2.33	: 2.32	: 2.53	: 2.62
Av. daily ration:							
Shelled corn	: 9.89	: 9.76	: 9.71	: 9.76	: 9.90	: 9.88	: 10.22
Cottonseed meal	: 1.00	:	:	: .50	: .50	:	: .33
Linseed oil meal	:	: 1.00	:	: .50	:	: .50	: .33
Corn gluten meal	:	:	: 1.00	:	: .50	: .50	: .33
Corn silage	: 8.22	: 8.62	: 8.07	: 8.64	: 8.18	: 9.03	: 10.31
Alfalfa hay	: 2.01	: 2.01	: 2.01	: 2.01	: 2.01	: 2.01	: 2.01
Feed required for 100 pounds gain:							
Shelled corn	: 429.32	: 417.95	: 404.38	: 419.45	: 425.97	: 391.28	: 390.43
Cottonseed meal	: 43.41	:	:	: 21.48	: 21.53	:	: 12.73
Linseed oil meal	:	: 42.81	:	: 21.48	:	: 19.80	: 12.73
Corn gluten meal	:	:	: 41.63	:	: 21.53	: 19.80	: 12.73
Corn silage	: 356.91	: 368.85	: 335.85	: 371.12	: 352.02	: 357.41	: 393.77
Alfalfa hay	: 87.30	: 86.09	: 83.73	: 86.40	: 86.57	: 79.62	: 76.80

Feed cost of 100 pounds gain	: \$ 8.96	: \$ 9.08	: \$ 8.46	: \$ 8.97	: \$ 8.87	: \$ 8.37	: \$ 8.36
Initial cost per steer @ \$13 per cwt.	: 50.16	: 50.53	: 50.66	: 50.48	: 50.53	: 50.27	: 50.74
Feed cost per steer	: 37.15	: 38.18	: 36.58	: 37.58	: 37.09	: 38.06	: 39.40
Steer cost plus feed cost	: 87.31	: 88.71	: 87.24	: 88.06	: 87.62	: 88.33	: 90.14
Value per head at home	: 82.05	: 86.99	: 86.31	: 88.00	: 86.73	: 92.55	: 95.65
Margin per head	: -5.26	: -1.72	: -.93	: -.06	: -.89	: +4.22	: +5.51
Necessary value per cwt. at feed lot to break even	: 10.91	: 10.96	: 10.61	: 10.91	: 10.86	: 10.50	: 10.46
Value per cwt. at feed lot Kansas City price minus \$.75 per cwt. for shipping, shrinkage, etc.	: 10.25	: 10.75	: 10.50	: 10.90	: 10.75	: 11.00	: 11.10
Margin per cwt.	: -.66	: -.21	: -.11	: -.01	: -.11	: +.50	: +.64

FEED PRICES: Corn \$.84 per bushel; cottonseed meal \$45 per ton; linseed oil meal \$58 per ton; corn gluten meal \$44 per ton; corn silage \$5 per ton; alfalfa hay \$15 per ton.

Values per pound in cents:

Corn	-	1.5 ¢
Cottonseed meal	-	2.25¢
Linseed oil meal	-	2.90¢
Corn gluten meal	-	2.20¢
Corn silage	-	0.25¢
Alfalfa hay		0.75¢

Table II. - 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. : L. O. M. : Corn : silage : Alfalfa : hay	: Shelled : corn : C. S. M. : Gluten : meal : Corn : silage : Alfalfa : hay	: Shelled : corn : L. O. M. : Gluten : meal : Corn : silage : Alfalfa : hay	: Shelled : corn : C. S. M. : L. O. M. : C. G. M. : meal : Corn : silage : Alfalfa : hay	: Shelled : corn : C. S. M. : L. O. M. : C. G. M. : 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	: Pounds : 388.13	: Pounds : 387.75	: Pounds : 391.43	: Pounds : 387.00	: Pounds : 390.00	: Pounds : 388.00	: Pounds : 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	
Av. 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 feed	:	:	:	:	:	:	:
lot to break even	: 10.89	: 10.74	: 10.72	: 10.63	: 10.96	: 10.55	: 10.68
Value per cwt. at	:	:	:	:	:	:	:
feed lot 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.

6. Lot 5	-	2.32	6. Lot 1	-	2.08
7. Lot 1	-	2.30	7. Lot 5	-	2.07
Average all lots 2.41			Average all lots 2.16		

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

1929-30			1928-29		
1. Lot 7	-	\$8.36	1. Lot 6	-	\$8.20
2. Lot 6	-	8.37	2. Lot 4	-	8.35
3. Lot 3	-	8.46	3. Lot 3	-	8.37
4. Lot 5	-	8.87	4. Lot 7	-	8.40
5. Lot 1	-	8.96	5. Lot 2	-	8.55
6. Lot 4	-	8.97	6. Lot 1	-	8.70
7. Lot 2	-	9.08	7. Lot 5	-	8.82
Average all lots \$8.72			Average all lots \$8.48		

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

1929-30			1928-29		
1. Lot 7	-	\$10.46	1. Lot 6	-	\$10.55
2. Lot 6	-	10.50	2. Lot 4	-	10.63
3. Lot 3	-	10.61	3. Lot 7	-	10.68
4. Lot 5	-	10.86	4. Lot 3	-	10.72
5. Lot 4	-	10.91	5. Lot 2	-	10.74
6. Lot 1	-	10.91	6. Lot 1	-	10.89
7. Lot 2	-	10.96	7. Lot 5	-	10.96
Average all lots \$10.74			Average all lots \$10.74		

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

1929-30		1928-29	
1. Lot 7	- \$11.10	1. Lot 6	- \$13.75
2. Lot 6	- 11.00	2. Lot 2	- 13.75
3. Lot 4	- 10.90	3. Lot 4	- 13.65
4. Lot 2	- 10.75	4. Lot 7	- 13.50
5. Lot 5	- 10.75	5. Lot 1	- 13.25
6. Lot 3	- 10.50	6. Lot 5	- 13.25
7. Lot 1	- 10.25	7. Lot 3	- 13.10
Average all lots \$10.75		Average all lots \$13.46	

(e) On the basis of margin per steer:

1929-30		1928-29	
1. Lot 7	+ \$ 5.51	1. Lot 6	+ \$25.44
2. Lot 6	+ 4.22	2. Lot 4	+ 23.83
3. Lot 4	- .06	3. Lot 2	+ 23.64
4. Lot 5	- .89	4. Lot 7	+ 21.92
5. Lot 3	- .93	5. Lot 3	+ 18.39
6. Lot 2	- 1.72	6. Lot 1	+ 17.97
7. Lot 1	- 5.26	7. Lot 5	+ 17.51
Average all lots \$+.12		Average all lots \$21.24	

Interpretations

A statistical treatment of these two years' results in total gains is interesting in that during the two years there were only four comparisons that approach significance when one uses the formulae to be applied to random samples. Theoretically, when selected samples are used, the variations within samples are supposed to be lessened and consequently the Standard Deviation and the Probable Error should be lessened so that smaller differences should be necessary for significant results between selected samples than between random samples. In our method of selecting samples which is described in detail under Methods of Procedure, the selection is by necessity largely for uniformity between lots and not within lots. In other words, the method of selection gives greater significance to differences and yet the method retains wide variations within each lot and there is no compensation through lessening of the Probable Error. The mean total gains and probable errors for each lot, figured on the basis of the formula used for random samples are as follows:

Mean total gain per head in pounds.

Lot	1929-30		1928-29	
1	414.67	± 9.73	373.75	± 7.23
2	420.50	± 7.38	398.75	± 8.90
3	432.33	± 14.08	380.47	± 10.99
4	419.00	± 12.65	402.17	± 8.46
5	418.16	± 10.69	373.15	± 5.35
6	454.66	± 7.68	405.83	± 5.06
7	471.34	± 12.61	392.23	± 7.41

It is generally believed that any difference in experimental data of this type to be significant should be at least four times its probable error. The following table shows all of the comparisons which approach significance. In this table $m-m'$ is the difference between the mean total gains of the lots compared, and $\frac{m-m'}{\text{P.E. } m-m'}$ is this difference divided by the probable error of the difference.

Lots Compared	$m-m'$	P.E. $m-m'$	$\frac{m-m'}{\text{P.E. } m-m'}$
7 and 1	56.67	15.92	3.56
7 and 1 (Last year)	18.48	10.40	1.78
7 and 5	53.18	16.53	3.22
7 and 5 (Last year)	19.08	7.25	2.63

6 and 1	40.00	12.40	3.23
6 and 1 (Last year)	32.08	8.81	3.64
6 and 5	36.50	13.17	2.77
6 and 6 (Last year)	32.68	7.36	4.44
3 and 1	17.67	17.13	1.03
3 and 1 (Last year)	6.72	13.16	.51
2 and 1	5.83	12.22	.48
2 and 1 (Last year)	25.00	11.47	2.18

The results gave significant differences in only one of the 21 possible comparisons last year, that of lot 6 and lot 5, and there were no significant differences this year. There have been no significant differences between lot 3 (corn gluten meal alone) and lot 1 (cottonseed meal alone), nor have there been any significant differences between lot 2 (linseed oil meal alone) and lot 1, although lots 3 and 2 have made bigger gains during both years. Lots 3 and 2 have reversed their standing during the two years and there is very little difference between them.

The study of the combinations shows more differences. Cottonseed meal alone (lot 1) was improved in only one of the two years by the addition of corn gluten meal (lot 5), but cottonseed meal was improved almost significantly during both years by the addition of both linseed

oil meal and corn gluten meal (lot 7). Last year cottonseed meal alone was surpassed almost significantly by its combination with linseed oil meal (lot 4), but the difference in favor of the combination was very slight this year.

Linseed oil meal alone (lot 2) made slightly larger gains than its combination with cottonseed meal (lot 4) this year, but the reverse was true last year. The combination with both corn gluten meal and cottonseed meal (lot 7) surpassed linseed oil meal alone this year but not last year. The combination with corn gluten meal (lot 6) gave better but not significantly better results both years.

Corn gluten meal alone (lot 3) gave better results than its combination with cottonseed meal (lot 5) but not significant results during both years. Both its combination with linseed oil meal (lot 6) and its combination with linseed oil meal and cottonseed meal (lot 7) gave better results in both years, but the results were not significant.

In general, better results were obtained during both years with linseed oil meal and corn gluten meal than with cottonseed meal, both alone and in the various combinations. In comparing general results for linseed oil

meal and corn gluten meal one must discard combinations where both were present (lots 6 and 7). Last year linseed oil meal gave bigger gains than corn gluten meal alone, and its combination with cottonseed meal gave almost significantly bigger gains than that of corn gluten meal and cottonseed meal. This year corn gluten meal alone gave bigger gains than linseed oil meal alone, and there was practically no difference between the two combinations with cottonseed meal.

About the most important point among the other comparisons is that linseed oil meal, because of its higher cost, increases the cost of a hundred pounds of gain and therefore the necessary selling price per hundred pounds to break even. The linseed oil meal lot has had a higher selling price per hundred than either the cottonseed meal or corn gluten meal lots during both years. The combinations in general have been more profitable as judged by margin per head than have the various supplements alone, although this was not strictly true last year.

The value of a protein is believed to depend directly upon the kind and quantity of amino acids it contains. The amino acid requirements for cattle of this class have not been worked out. No very complete and accurate analyses of the amino acid contents of the various protein

supplements and other feeds used in this ration are available. The author studied work by Chittenden and Osborne (10), by Osborne (11), and by Plimmer (12). The amounts of amino acids never total near one hundred per cent, and in many cases amino acids are simply indicated as present or absent. The corn grain is believed to contain all of the necessary amino acids although some of them are present in only very small amounts. Corn gluten meal with its higher percentage of protein, serves to concentrate the amount of amino acids present.

If one considers the rations fed in this experiment one can observe that a rather large amount of protein was fed and this would serve to make up deficiencies of any particular amino acid. In lot 3 (corn gluten meal alone), the calves had an average weight for the entire period of 605.84 pounds, and they made an average daily gain per steer of 2.40 pounds. The following table shows their supply of protein per head daily:

Feed	Av. Daily Ration in Pounds	<u>Digestible Cr. Protein</u> <u>% in Feed</u>	<u>Total Lbs. Da.</u>
Corn	9.71	7.5	.73
Corn gluten meal	1.00	30.2	.30
Corn silage	8.07	1.1	.09
Alfalfa hay	2.01	10.6	.21
			<u>1.33</u>

The 0.21 pound of digestible crude protein supplied daily by the alfalfa hay would help considerably in supplementing the other proteins which were supplied entirely by corn.

According to Armsby (13) about 0.34 of a pound of digestible true protein is required daily for maintenance by calves of this weight. Deducting 0.34 pound from 1.33 pounds would leave practically one pound a day for growth. Armsby's calculations on the percentage of protein in the gain would indicate that not more than half of this would be required for the average daily gain per head of 2.40 pounds.

Summary of Results

1. While no definite conclusions should be drawn from the experiments of these two years as to the comparative value of corn gluten meal, cottonseed meal, and linseed oil meal fed with this basal ration, indications are that there are no very striking differences.

2. Cottonseed meal has been improved by combination with linseed oil meal, excepting for necessary selling price and cost of gains during this last year, and it has been improved in every comparison by combination with both linseed oil meal and corn gluten meal.

3. Linseed oil meal has been improved in every comparison by combination with corn gluten meal, while combinations with cottonseed meal and with both have made little difference in gains but have decreased both the cost of gain and the selling price.

4. Corn gluten meal has been improved in nearly all comparisons by combinations with linseed oil meal and with a mixture of linseed oil meal and cottonseed meal, but it has not been improved by combination with cottonseed meal alone.

5. The four lots receiving some linseed oil meal were the four highest ranking lots in appraised value per hundred both years.

6. Corn gluten meal alone has surpassed cottonseed meal alone in every respect excepting appraised value last year.

7. Linseed oil meal alone has surpassed cottonseed meal alone on every basis but that of cost per hundred pounds gain and necessary selling price.

8. While corn gluten meal alone has surpassed linseed oil meal alone during the two years in cost per hundred pounds of gain and necessary selling price to break even and the reverse has been true in appraised value per hundred, the results in gains and margin per head have been contradictory.

9. Because of the importance of protein supplements, additional work should be done. In future work it might be well to compare these protein supplements in a ration not containing alfalfa hay in order that the sources of proteins be more limited in number.

10. Apparently much of the value of the various supplements and combinations of supplements to this basal ration comes from increased feed consumption.

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LITERATURE CITED

- (1) Burns, J. C.
1913. Steer feeding. Texas Agr. Expr. Sta. Bul. 159. 34 pp.
 - (2) Jones, J. M., Black, W. H., and Keating, F. E.
1927. Sorgo silage, sorgo fodder, and cottonseed hulls as roughages in rations for fattening calves. Texas Agr. Expr. Sta. Bul. 363. 35 pp.
 - (3) Jones, J. M., Lush, J. L., and Jones, J. H.
1923. Fattening steers on cottonseed meal and cottonseed hulls with and without corn. Texas Agr. Expr. Sta. Bul. 309. pp. 1-20.
 - (4) McCampbell, C. W., and Horlacher, W. R.
1923. Silage feeding investigations. Kansas Agr. Expr. Sta. Cir. 105. 1:1-6.
 - (5) Rusk, H. P., and Snapp, R. R.
1928. The utilization of soft corn in beef cattle feeding. Illinois Agr. Expr. Sta. Bul. 313. pp. 27.
 - (6) Skinner, J. H., and King, F. G.
1922. Winter steer feeding. Purdue University Agr. Expr. Sta. Bul. 281. pp. 12-13.
 - (7) Culbertson, C. C., Evvard, J. W., Hammond, W. E., and Wallace, J. W.
1924. Iowa Agr. Expr. Sta. Unpublished data.
 - (8) Gramlich, H. J.
1927. Nebraska Agr. Expr. Sta. Unpublished data.
 - (9) Selvig, C. C.
1926. Fattening baby beef for market. Minnesota Crookston Substation Report. pp. 3-55.
- Dowell, A. A.
1927. Fattening beef calves for market. Minnesota Crookston Substation Report. pp. 50-52.

- (10) Chittenden and Osborne, Dr. T. B.
1909. Vegetable Proteids. The Friedenwald Co.
- (11) Osborne, Dr. T. B.
1917. The Vegetable Proteins. Longmans, Green,
and Company.
- (12) Plimmer, Dr. R. H. A.
1892. The Chemical Constitution of the Proteins.
Longsman, Green, and Company.
- (13) Armsby, H. P.
1917. The nutrition of farm animals. Table I of
the Appendix. The Macmillan Company.