T H E S I S

GROUND FLAXSEED AS A NITROGENOUS SUPPLEMENT FOR THE FATTENING OF LAMBS

Submitted by

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In partial fulfillment of the requirements

for the Degree of Master of Science

Colorado Agricultural College

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY H. R. LASCELLES

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REASONS FOR THE INVESTIGATION

The Colorado Agricultural Experiment Station (16) at Fort Collins, Colorado, has conducted lamb-feeding experiments at Fort Collins and elsewhere in Colorado for a period of twenty-four years. During this time it has been the purpose of this station to adapt its work, in so far as possible, to the needs of the practical sheep men that this station serves. Accordingly feeding trials have been largely confined to home-grown feeds with the addition of such nitrogenous supplements as appeared possible of profit in the feed lots.

This policy, in so far as it relates to the fattening of lambs, has resulted in the extensive use of sugar beet by-products including wet beet pulp secured from the local Fort Collins factory, alfalfa hay, that is easily and cheaply obtained, and such farm grains as corn, oats and barley.

The extensive experimental work of this station has shown that under certain favorable price conditions it has proved profitable to feed cottonseed meal, and, following the work of this station, a number of feeders have used it as a nitrogenous supplement because of its hay and grain replacement value. In this manner the

value of a nitrogenous concentrate supplement has been demonstrated, provided such supplement could be obtained at a figure in line with local feeds. Table 1, taken from experimental work at the Colorado Station (16), gives the feed required for 100 pounds of feedlot gain with barley and alfalfa as compared with barley, cottonseed meal and alfalfa. It also gives the same comparison with the addition of wet beet pulp to the ration.

Table 1

Feed Required for 100 Lbs. of Feedlot Gain In Lots Fed Cottonseed Meal at The Colorado Experiment Station

Ration	No. of years work	Barley	Cottonseed Meal	Wet Beet Pulp	Alfalfa
Barley, alfalfa	5	297.1			833.1
Barley, cottonseed meal, alfalfa	5	240.6	63.8		745.8
Barley, wet beet pulp, alfalfa	3	238.3		1336.9	510.8
Barley, wet beet pulp, cottonseed meal, alfalfa	3	223.3	54.4	1256.3	415.5

A study of these figures reveals that one ton of cottonseed meal replaces 1771.2 pounds of barley and 2736.7 pounds of alfalfa in a barley and alfalfa ration, and that one ton of cottonseed meal replaces 551.5 pounds of barley, 2963.2 pounds of wet beet pulp and 3503.7 pounds of alfalfa in a barley, wet beet pulp and

alfalfa ration. From these figures table 2 is evolved in which is shown the price that the feeder could afford to pay for cottonseed meal with barley and alfalfa at varying prices.

Table 2

Replacement Values of Cottonseed Meal at Varying Prices in a Barley and Alfalfa Ration

Barley at	.60 cwt.	.80 cwt.	1.00 cwt.	1.20 cwt.	1.40 cwt.	1.60 cwt.
Alfalfa at						
$ 6 ton	18.84	22.38	25.92	29.46	33.01	36.55
$ 8 ton	21.58	25.12	28.66	32.20	35.75	39.29
$10 ton	24.31	27.85	31.39	34.93	38.48	42.02
$12 ton	27.05	30.59	34.13	37.67	41.22	44.76
$14 ton	29.79	33.33	36.87	40.41	43.96	47.50
$16 ton	32.52	36.06	39.60	43.14	46.69	50.29

In like manner table 3 shows the value of cottonseed meal in a barley, wet beet pulp and alfalfa ration with the wet beet pulp constant at $1.70 per ton.

Table 3

Replacement Values of Cottonseed Meal at Varying Prices in a Barley, Wet Beet Pulp, and Alfalfa Ration

Barley at	.60 cwt.	.80 cwt.	1.00 cwt.	1.20 cwt.	1.40 cwt.	1.60 cwt.
Alfalfa at						
$ 6 ton	16.34	17.44	18.55	19.65	20.75	21.85
$ 8 ton	19.84	20.94	22.05	23.15	24.25	25.35
$10 ton	23.35	24.45	25.56	26.66	27.76	28.86
$12 ton	26.85	27.95	29.06	30.16	31.26	32.36
$14 ton	30.36	31.46	32.57	33.67	34.77	35.87
$16 ton	33.86	34.96	36.07	37.17	38.27	39.37

These tables are presented to show the varying price conditions which contribute to the success or failure of feeding cottonseed meal. The object of presenting this material here is simply to show the need for a cheap nitrogenous concentrate supplement that will fit conditions within a favorable price range oftener than does cottonseed meal. This need, together with limited experience on the part of feeders in the Fort Collins locality, which experience is given elsewhere in this work, led to the desire of the Colorado Station to experiment with ground flaxseed, which is grown locally on the dryland sections adjacent to the irrigated valleys of northern Colorado, and which is therefore often available at prices that compare very favorably to

cottonseed meal and linseed oil meal.

Mr. H. H. Simpson, County Extension Agent, Greeley, Colorado, first suggested to the Colorado Station the possibility of using ground flaxseed as a nitrogenous supplement for fattening lambs, mentioning the significant fact that this crop is successfully grown on land lying close to the northern Colorado valleys where lamb feeding is a most important industry. His thought was to experiment with ground flaxseed in the hope that this home-grown feed might prove successful as a nitrogenous supplement. Accordingly, the work was started.

A STATEMENT OF THE PROBLEM

The problem involved consists of determining the feed replacement values of ground flaxseed in rations of wheat and of barley where cottonseed meal and linseed oil meal would normally be used, with and without wet beet pulp; of determining the relative gains made; the relative dressing percentages of the lambs fed; the color of the meat; the optimum amount that should be fed; the comparable rate of gain, and the expectant death loss.

REVIEW OF LITERATURE

Woolman and McGowen (24) (1920) in their book, "Textiles", state that common flax (linum usitatissimum) is a slender and erect annual plant bearing blue flowers,

which flowers are of rare beauty, and they state that the plant is commonly cultivated for its fiber and seed. They point out that the fiber in many sections of the world is used in the manufacture of linen thread and cloths and that in many of the northern states it is intensively cultivated for its fiber as well as its seed, but that lack of persistent care of the soil has resulted in the development of germ diseases which attack the plants and materially affect their value for industrial purposes. The same authors state that flax produced in the United States is, as a rule, not well adapted to the manufacture of fine linens. However, the flax plants of the United States do yield seed abundantly and it is this seed which has become a most important factor in the manufacture of linseed oil which is used extensively in paints, varnishes, oilcloths, linoleum and sundry other similar products. The linseed meal is widely used as a livestock feed, in the manufacture of linseed powder for poultices, and linseed tea for an emollient.

Raw flaxseed as a livestock feed seems to be rather questionable at this time and there appears to be only a small amount of investigational matter available upon the subject.

"Flax Facts" (3) 1930, issued jointly by the University of Minnesota, Montana State College, North Dakota Agricultural College, South Dakota Agricultural

College, and the United States Department of Agriculture, gives information, which, while not strictly pertaining to the subject of this thesis, may prove of value to any who anticipate growing flaxseed in the future to supply any need that may arise for flaxseed as a nitrogenous supplement for fattening lambs.

Table 4, taken from "Flax Facts" (3) (1930), gives the net domestic supply of flaxseed in percent of total consumption as follows, by years:

Table 4

Net Domestic Supply of Flaxseed
in Percent of Total Consumption by Years

1909-1913	65.9%
1914-1918	48.5%
1919-1923	30.0%
1924-1928	53.3%
1929	34.9%

These figures are presented to show that large amounts of money are spent annually in other countries for flaxseed to supply the needs of the United States. The authors of "Flax Facts" also show that the tariff on flaxseed was raised in 1929 from 40 cents to 56 cents which is given as an added inducement to the grower.

It is not within the field of this work to discuss the growing of flaxseed since information pertain-

ing to yield, rust resistant varieties, mode of cultivation and harvesting come under the field of Agronomy, but from what the writer can learn in his review of available literature, such information is indispensable to the success of the grower of flaxseed.

Morton's Work at Wyoming (18) (1904-05)

As has been stated, there is very little available material on the subject of feeding flaxseed to lambs. The work of Morton in 1904-1905 at the Wyoming Experiment Station is given here in considerable detail since his findings are of value, especially in this locality, and constitute no small amount of the available material on the feeding of flaxseed to lambs even though only a few animals were used. His work, reported in the Wyoming Experiment Station Bulletin 68, is quoted as follows: Sixty-six lambs were divided as shown in table 5.

Table 5

Division of Lambs in Morton's Experiment

Lot	No. of lambs	Breeds	Av. Weight Shrops.	Av. Weight Merinos	Ration
1	20	10 S. 10 M.	67.3	58.0	Corn, turnips, alfalfa
2	20	10 S. 10 M.	67.2	57.3	Barley, turnips, alfalfa
3	20	10 S. 10 M.	67.5	57.9	Corn, turnips, native hay
4	3	1 S. 2 M.	78.0	59.0	Corn, turnips, flaxseed, alf.
5	3	1 S. 2 M.	80.0	57.5	Turnips, flaxseed, alfalfa

The flaxseed used was ground without expressing the oil, which is comparable to the experiment reported in this work. Morton states that the flaxseed was fed with the turnips because the lambs refused it, if fed alone, because of its strong taste. He states that after being fed upon it for some time they would eat more of it than what merely stuck to the damp turnips. All lots were fed twice daily.

The feeding period consisted of 16 weeks and table 6 summarizes the amounts fed and gives the average gain per head.

Table 6

Gain for 16-week Period and Amounts Fed In Morton's Experiment

Lot	Alf.	Native hay	Corn	Barley	Turnips	Flaxseed	Average gain
1	192		85		130		31.2
2	191			90	179		33.1
3		151	83		51		20.7
4	143		89		205	7.3	31.8
5	204				426	19.0	25.7

Morton states that any conclusions regarding lots 4 and 5 must be substantiated by future experiments as there were only three lambs in each lot. He adds that these results would indicate that alfalfa with corn, turnips and ground flaxseed make a very good ration

in as much as the gain is large and the addition of ground flaxseed increased the consumption of turnips and lessened the consumption of alfalfa thus cheapening the ration. Subsequent observations on the part of the writer in northern Colorado feedlots appear to substantiate the findings of Morton relative to the increased palatability brought about through the feeding of ground flaxseed. These observations are reported separately elsewhere in this work. (Page 18). Table 7 gives the feed required for 100 pounds of feedlot gain in the two flaxseed lots as taken from Morton's work.

Table 7

Feed Required for 100 Pounds Feedlot Gain
Morton's Experiment (18) (1904-05)

Lot	Ration	Alfalfa	Turnips	Flax-seed	Corn
4	Alfalfa, turnips, flax-seed, corn	454.1	605.8	22.0	267.1
5	Alfalfa, flaxseed, turnips	796.1	1659.7	74.0	

It is readily seen from these figures that the addition of 52.0 pounds of ground flaxseed replaced 267.1 pounds of corn and 342.0 pounds of alfalfa and that this increased the consumption of turnips 1053.9 pounds in the production of 100 pounds of feedlot gain. Morton computes the cost of adding 100 pounds of feedlot gain in ration 4 as $4.86 and in ration 5 as $5.13 with

alfalfa at $5 per ton, ground flaxseed at $2 per cwt., turnips at $2 per ton and corn at $1 per cwt.

Morton (18) goes on to state that the alfalfa and flaxseed ration is of doubtful value where corn or barley can be obtained cheaply and without long hauls, but he says that feeders at points over ten miles from a railroad who can combine farming with feeding might find it profitable to use flaxseed instead of grain.

After killing a lamb from lot 5, Morton found that the meat appeared to be very dark in color and on that account not satisfactory, although it had a very fine flavor. He adds that a noticeable feature of this lamb was the extreme weight of the caul fat, doubtless due to heavy flaxseed feeding. He adds that flaxseed may be fed heavily without experiencing any urinary difficulties.

One lamb in lot 4 in this experiment died due to congestion of the lungs.

Data Furnished by Northern Pacific Railroad Growers

A. J. Dexter (8) (1931), Agricultural Development Agent for the Northern Pacific Railroad, gives in his bulletin, "Sixty Farmers Fatten Range Lambs", the information that flaxseed was used as a nitrogenous concentrate supplement in some instances during the fall and winter of 1930-1931. Table 8 summarizes the informa-

tion pertaining to the feeding of flaxseed and flax screenings and is taken from Mr. Dexter's contribution, which information relates to the experiences of feeders in the trade territory of the Northern Pacific Railroad.

Table 8

Summary of Flaxseed-Fed Lots Along the Northern Pacific Railroad System

Lot No.	Feeding Period Average Number of days in:			Major Grain Ration while in feed yard	Roughages while in feed yard	Number of lambs unfinished	Shelter
	Corn field	Stubble or pasture	Feed lot				
42	0	60	43	1844 lambs fed 200 bu. rye, 1100 bu. wheat, 345 bu. corn, 1095 bu. barley, 50 bu. flaxseed	28 tons alfalfa, 40 tons oat hay	A few	Barn and straw shed
(Fed three times daily on grain and hay fed twice)							
39	0	0	98	323 lambs fed 887 bu. barley, 386 bu. oats, 248 bu. speltz, 29 bu. corn, 22 bu. flax screenings	?	63	Straw shed
60	0	17	115	298 lambs fed 1100 bu. barley, 6 tons flax screenings	15 tons quack grass	16 at 50 cents under	Barn
27	0	0	89	Increased to 2 lbs. barley and flax screenings	Wild hay	15	Shed
33	40	14	44	Corn, rye, barley, flax, av. 2 lbs. per head	2½ lbs. half alfalfa and half prairie hay	Many not quite tops	Frame shed

No specific mention of death loss among these lots is found in Mr. Dexter's presentation, but from the tables given by him it is noted that in lot 39, 323 lambs were apparently on feed. The market data that he gives state that 63 lambs were unfinished and the information is also given in the bulletin that altogether 313 head were marketed at varying prices at South St. Paul. From this it is reasonable to suppose that ten head died, which is a death loss of 3.1 percent. The same source of information states that in lot 60, 298 lambs were fed. The market data account for 16 head that sold under the top market and for 229 head sold at South St. Paul at the same price of $8. This would account for 245 head of the 298 which would be a loss of slightly less than 18 percent. It is also noted that this particular lot was fed the extreme amount of 6 tons of flax screenings in a period of 115 days, which is an average of 3 1/2 pounds per day per lamb. Perhaps it is significant that the death loss as computed from figures given was not larger.

It will be observed that, of the five lots given in table 8, flaxseed was fed to two lots and flax screenings to three. It is not stated whether this flaxseed was ground or otherwise. The lots fed flax screenings are listed merely as a matter of interest, especially in view of the unusual amount fed in the case

of lot 60. The information given is not sufficient on which to draw any definite conclusions with the exception that it is apparent that flaxseed and flax screenings were fed successfully without any mention being found of extreme death loss. This, in itself, is significant in view of the popular belief, substantiated by some experimental data given on page 23 in this work, that the feeding of flaxseed causes heavy death losses. Mr. Dexter's work is therefore a distinct contribution to the study of this particular concentrate.

Additional Literature Relating to The Feeding of Flaxseed

W. L. Robison and L. E. Thatcher (20) (1929) used flaxseed in fattening hogs. They secured satisfactory results when compared with linseed oil meal, using enough flaxseed to equal the protein content of the linseed oil meal. Their work shows that the flaxseed lot gained 1.13 pounds daily as compared to 1.03 pounds of gain in the linseed oil meal lot. They also state that no difficulty was experienced from scouring.

The Crookston, Minnesota, sub-station (7) (1910-16) report that they fed ground flaxseed to hogs comparing it with tankage as a protein supplement. Rations consisting of barley, corn and oats, were used. They report that the tankage proved distinctly superior to the flaxseed and they conclude that the results indicated that

flaxseed was not a practical feed for swine.

EXPERIENCES OF NORTHERN COLORADO FEEDERS WITH FLAXSEED

Flaxseed has been fed in limited quantities by a few feeders in northern Colorado to sheep. Mr. Floyd Chandler, Johnstown, Colorado, has fed ground barley, ground flaxseed, cut corn fodder, and alfalfa hay. His lambs were put on a pound of ground barley in a week; the maximum amount of cut corn fodder fed was 1 1/4 pounds and the maximum amount of ground flaxseed fed was one-tenth of a pound. These particular lambs had been on feed previously which accounts for the rapidity with which they were put on a pound of barley. Mr. Chandler reports no bad results, claiming that the feeding of flaxseed increases palatability. The flaxseed used was ground in a hammer mill without a screen. Mr. Chandler states that if a screen is used, the flaxseed gums up so badly that it cannot be ground.

Mr. E. L. Crozier, Greeley, Colorado, states that he first fed flaxseed several years ago at which time he was not especially pleased with it, but during the year 1930-31 he again fed it and reports more success than on previous occasions. He recommends the grinding of corn and flaxseed together because he states that the corn will absorb the oil and reduce loss from scours. It is possible that this method of grinding

might be easier from the standpoint of the grinding operation itself and prevent the tendency for the feed to gum up. Mr. Crozier fed three ounces per head of a mixture which was made up of one-fourth flaxseed and three-fourths finely ground corn; the two being ground together. He also states that he believed that ground flaxseed increased palatability and that he had fed as high as 0.05 pounds daily per lamb to 500 head without experiencing any difficulty. He inclines to the opinion that lambs will eat more grain when fed flaxseed.

The Grinding of Flaxseed

The elevator at Milliken, Colorado, did a considerable amount of flaxseed grinding during the year 1930-31, under the supervision of Mr. Stevenson, who used no screens in a hammer-type of mill. The product was a fine light meal. Mr. Stevenson, and the elevator at Johnstown, Colorado, report that the high oil content does not cause the flaxseed to turn rancid when stored for prolonged periods during the winter months.

The flaxseed used in the experiment reported in this work was ground by the Fort Collins Mill in a hammer mill. A screen was used but considerable difficulty was encountered.

FLAXSEED FEEDING AT THE UNITED STATES EXPERIMENT STATION AT AKRON, COLORADO

A gate cut of the lambs used in the experimental work at Fort Collins, Colorado, 1931-32, was made at Denver prior to the start of the experiment. This gate cut, consisting of lambs from the same flock as used at Fort Collins, was shipped to Akron, Colorado, for experimental work at that station. Out of this cut one lot of nineteen lambs was fed hog millet, ground flaxseed, cane hay, minerals and salt under the supervision of Mr. H. B. Osland, in charge, Mr. J. F. Brandon and Mr. Jack Loosli. These lambs were on feed 128 days. They were compared with lots receiving cottonseed meal and linseed oil meal to determine the value of the flaxseed as a nitrogenous supplement. As at Fort Collins, this flaxseed was fed ground. The maximum feed per day per lamb at Akron consisted of three-tenths of a pound, which was 0.1 pound higher than the maximum reached at Fort Collins on the experiment reported in this work.

Table 9 gives a summary of the results obtained at the United States Experiment Station at Akron and compares the lot fed flaxseed with those fed cottonseed meal and linseed oil meal.

Table 9

Ground Flaxseed Compared With Cottonseed Meal and Linseed Oil Meal at the United States Experiment Station, Akron, Colorado. Table based on one average lamb.

(All lots were fed cane hay, minerals and salt)

	Hog millet Ground flaxseed	Hog millet Cottonseed meal	Hog millet Linseed oil meal
Initial weight	58.75	58.12	57.74
Feedlot gain	27.96	34.99	30.08
Daily gain per lamb	.22	.27	.24
Feed required for 100 pounds of gain			
Hog millet	362.82	303.78	347.47
Ground flaxseed	115.73		
Cottonseed meal		97.44	
Linseed oil meal			114.28
Cane hay	776.83	788.43	969.73
Dressing percent based on warm weights	49.97	50.50	50.80

It is evident from these figures that it required 18.29 pounds more ground flaxseed and 59.04 pounds more hog millet to produce 100 pounds of feedlot gain than in the cottonseed meal lot, but there was a saving of 11.60 pounds of cane hay. With ground flaxseed at $30 per ton, cottonseed meal at $22 per ton, hog millet at $13 per ton and cane hay at $3.50 per ton, the flaxseed ration cost $1.04 more to produce 100 pounds of gain than did the cottonseed meal ration.

Compared with linseed oil meal it required

1.45 pounds more ground flaxseed, 15.35 pounds more hog millet, but 192.90 pounds less cane hay to produce 100 pounds of gain. With the same prices prevailing, and with linseed at $35 per ton, the flaxseed ration cost $0.50 less than the linseed oil meal ration to produce 100 pounds of gain. Table 10 illustrates the comparative values of ground flaxseed, cottonseed meal and linseed oil meal fed under dry-land conditions as taken from this work at the Akron station covering one feeding trial.

Table 10

Cost of Producing 100 Pounds of Feedlot Gain at Akron, Colorado, 1931-32

Ground flaxseed ration	$5.46
Cottonseed meal ration	4.42
Linseed oil meal ration	5.96

The prices on which this computation is made are given in the paragraphs immediately preceding table 10.

THE PROPERTIES OF FLAXSEED

No small amount of speculation exists regarding the safety of feeding flaxseed to farm animals. Henry and Morrison in "Feeds and Feeding" (10) (1923), state, "Recent investigations have shown that in some instances flaxseed may contain a compound which, when acted upon by an enzyme in the seeds, yields a poison, prussic acid. This enzyme is destroyed by the heat to which the ground flaxseed is ordinarily subjected in both the old and new process of oil extraction." These same authors advise subjecting untreated flaxseed to boiling water, keeping the mass hot for an hour or two, to destroy any prussic acid-forming enzyme in the seed.

These statements precipitated further research into the literature of this field and occasion is taken here to report these findings since there is little doubt that under certain conditions flaxseed, ground or otherwise, may be dangerous as a feed for livestock, even though the death loss in the case of the lamb-feeding experiment reported in this thesis was not abnormal.

Shulov and V. Morozov (21) (1915) report that their findings show that flaxseed is apparently not deteriorated by freezing, but S. H. Collins and H. Blair (6) (1915) conclude from an analysis of a large number of samples that seeds of oriental origin and from dry,

hot climates are all high in total hydrocyanic acid and rich in enzymic activity. They state that "changing seed from dry, hot climates to damp and cool conditions reduces the amount of hydrocyanic acid evolved by 20 plus or minus 3% and the rate of evolution by 24 plus or minus 5%." From their findings they report that seed grown in temperate climates is safer as a cattle feed than that coming from hotter climates. They also find that there is a tendency for seeds originating in temperate climates to "give the best yield per acre and to contain the least proportion of cyanogenetic glucosids." It is therefore reasonable to suppose that Colorado-grown flaxseed should be a safer feed for livestock than flaxseed grown in hotter climates.

It is possible that these findings of Collins and Blair (6) may have some significant and practical importance to feeders. In the face of what they have found it might appear unwise to use flaxseed for feeding during hot and dry weather, yet possibly the same flaxseed may prove harmless as a winter feed under colder conditions, especially when aided with the addition of moisture in the form of snow.

E. F. Ladd and Alma K. Johnson (15) of the North Dakota Station report heavy death loss through the feeding of flaxseed screenings to cattle. In one case an entire herd of nineteen cows died; in another five

out of ten died. These same investigators found 0.2169 grams of hydrocyanic acid for each pound of flaxseed screenings analyzed in one test and 0.408 grams per pound in another test. In 1911 they found that immature seed bolls showed a hydrocyanic acid content of 0.7726 grams per pound.

J. W. Ince (12) also reports that the feeding of flaxseed screenings caused death among cattle and sheep and he traced the cause directly to the presence of hydrocyanic acid.

From the work of Ernest Anderson and J. A. Crowder (2) (1930) of the University of Arizona, reported in the American Chemical Society Journal, Volume 52, the following is quoted: "In 1903 Hilger (11) hydolysed flaxseed mucilage and found in the hydolytic products the sugars d-glucose, d-galactose, l-xylose and l-arabinose together with an acid by-product." These same Arizona investigators quote from the Journal of Agricultural Science (14) (1928) and state that Neville (19) (1913) verified this work in 1913, and quoting from Biochemische Handlexikon, Julius Springer, Berlin, they state that Abderhalden (1) (1911) found that in addition this mucilage yields pentoses and hexoses.

In their work entitled "Composition of an aldobionic acid from flaxseed mucilage", Ernest Anderson and J. A. Crowder (2) (1930) state that "flaxseed

mucilage yields on hydrolyses an aldobionic acid consisting of one molecule of d-galacturonic acid and one molecule of l-rhamnose. The molecule is joined together by a glucoside linkage involving the aldehyde group of the d-galacturonic acid and the alcohol group of the l-rhamnose. This mucilage is similar in composition and structure to some of the plant gums." This work on flaxseed mucilage is cited because, in the feeding of ground flaxseed, it is reasonable to suppose that this same chemical composition remains intact in so far as the mucilage of flaxseed is concerned.

In regard to the sugar content of flaxseed, G. R. Van Kampen (22) (1914) found that it varies from 2 percent to 2.5 percent. He found that this sugar may come from the mucilage present in the seed or from the glucosides. Van Kampen found sugar in the flaxseed coat with copper sulphate and potassium hydroxide which, when he heated some of the seed, gave a very noticeable precipitation of cuprous oxide. He brings out the fact that since the greater part of this sugar is found in the seed coat it is lost through germination. In his work he gave a reaction for protein in the cotyledons and states that it was very definite in the aleurine grains.

In view of the fear that most feeders have of the high oil content in flaxseed it seems appropriate that my findings, in the literature that I have reviewed

pertaining to the oil content, should be given here. A. L. Bushey, L. Puhr and A. N. Hume (4) (1927) state that the oil content of nine varieties studied by them ranged from 33.9 percent to 37.4 percent. D. A. Coleman and H. C. Fellows (5) (1927) of the United States Department of Agriculture found large differences to exist in the oil content of the samples that they analyzed. Within a single class they found as high a difference as 15 percent. They also report that they found no close relationship between the test weight per bushel and the oil content. Eyre and Fisher (9) (1915) give the following oil contents for flaxseed from their findings:

Table 11

Eyre and Fisher's Oil Contents in Flaxseed

Seed quite green	21.05%
Seed just beginning to turn brown	30.08%
Seed wholly brown but not loose in capsule	38.03%
Seed fully ripe and loose in capsule	40.88%

W. F. Washburn (13) (1916) found the oil content of forty-nine samples of high-grade flaxseed to average 39.32 percent (water-free basis). The moisture content of these samples averaged 6.67 percent. He found the iodine number to be 185.92, the saponification number to be 191.29, the refractive index at 25 degrees centigrade to be 1.4796, the specific gravity 0.9331, and the acid

number 0.95. The protein content of the different strains of flaxseed that he analyzed was found to range between 23.07 percent and 24.61 percent.

Table 12 gives, in the first column, an analysis of flaxseed made by F. E. Hepner, when assistant chemist at the Wyoming Experiment Station. This analysis is given in connection with the work of Morton (18) (1904-05), previously reported, and is significant because of the bearing it has on western flaxseed. In the second column is given the coefficients of digestibility as taken from Mentzel and Lengertes, Landn. Kalendar for 1898 by courtesy of Henry's "Feeds and Feeding" (17). In the third column is given the analysis of the flaxseed fed in the experiment reported herein, which analysis was made by Max Parshall, State Dairy Commission Chemist, Fort Collins, Colorado.

Table 12

Analyses and Coefficients of Digestibility of Ground Flaxseed

	Hepner's analysis	Coefficient of digestibility	Parshall's analysis	Dry basis
Moisture	7.44		8.67-8.69	
Ash	4.31		4.24-4.18	4.61
Crude protein	19.38	91	22.87-22.80	25.00
Crude fiber	6.36	61	5.02-5.21	5.60
Crude fat (Ether extract)	31.43	86	36.17-36.20	39.62
Nitrogen free extract	31.08	55	23.03-22.92	25.17

D. Breese Jones, C. E. F. Gersdorff and O. Moeller, Bureau of Chemistry, United States Department of Agriculture, Washington (13) (1924), report their work on the tryptophane and cystine content of the various proteins found in a number of commercial feeds. This distinct contribution given in the Journal of Biological Chemistry (Vol. 62) gives the tryptophane content of the flaxseed globulin as 3.98 percent, compared with 2.58 percent in the case of the cottonseed globulin. They also state that the flaxseed globulin contains 1.20 percent cystine compared with 1.07 percent cystine in the case of the cottonseed globulin.

This work, showing the high content of these valuable proteins present in flaxseed, may, in part,

account for the good results obtained by feeding ground flaxseed to lambs as reported in this thesis.

From the various sources of information quoted herein, it is evident that commercial flaxseed weighs fifty-six pounds per bushel, contains between 30 percent and 40 percent oil, and yields about two and one-half gallons of oil from one bushel which weighs about 18 3/4 pounds. One bushel of flaxseed will yield about 37 1/4 pounds of linseed cake in addition to the oil. The flax plant is the typical genus Linaceae, a sub-order of Geraniaceae, and consists of more than 140 species of annual and perennial herbaceous plants and small shrubs. Common flaxseed (L. usitatissimum) is the species which is of most concern in feeding work.

MATERIALS AND METHODS

From this point this thesis pertains exclusively to an experiment relative to the feeding of ground flaxseed for fattening lambs at the Colorado Experiment Station during the winter of 1931-1932.

It is specifically stated that all of the data presented herein regarding this experiment cover the investigations as found in one year's feeding trial and for that reason the trial should be duplicated before any definite conclusions can be drawn.

All data given herein relate to feedlot information and all figures, graphs, tables and computations, relating to this experiment, are based on actual gain in the feedlot. Market data are used only for such information as could not be obtained prior to slaughter; this includes dressing percentages, carcass grades, color of meat and similar data.

It is hoped that the work as outlined, and covering one year of investigation, will prove an indication of the value of feeding ground flaxseed as a nitrogenous supplement in a concentrate mixture for fattening lambs and that the results that have been obtained may be of sufficient value and significance to warrant the repetition of the experiment.

Lambs Used

Four hundred and thirty-two lambs were divided into 18 lots. These lambs came from the flock of Mr. Paul Jensen, Meeker, Colorado, and were the feeder end of his flock. They were the progeny of Hampshire rams, for the most part, crossed on white-faced ewes. Suffolk breeding appeared in small amounts since Mr. Jensen has used some Suffolk rams. The characteristic fine bone of this breed with somewhat smaller heads appeared in about 18 percent of the lambs used.

It is significant that the work done at the United States Experiment Station at Akron, Colorado, (1931-1932), was with a gate cut of these same lambs from Mr. Jensen's flock; the cut being made at Denver and the shipment split there. This work at Akron, in so far as it relates to the subject of this thesis, has been summarized on page 20.

It should be stated that these lambs were not quite as even in weight as is desired for experimental purposes. The extreme range in initial weights was from 49.25 pounds to 92 pounds. Because of this factor especial care was given to allotting them and every possible effort was made to sort these lambs into their respective lots without a maldistribution of the heaviest and lightest lambs.

The lambs were not dipped prior to the start

of the experiment nor at any time during the conduct of the experiment.

Allotment

Allotment of the lambs was made on November 19 and 20. On November 19 numbered tags were put in their ears. They were then weighed individually and their sex, condition and type noted in each case. From this information they were satisfactorily allotted. The most important factor considered was weight, then sex, then condition and lastly type. On the following day, November 20, each lamb was again weighed. The average of these two weights constituted the average initial weight. It was not possible to obtain a third day's weight due to a heavy snow storm which came on the night of November 20. The lambs were branded on November 20 and each lamb allotted to its respective lot. The experiment was started at noon on November 20.

Feeding Period

The length of the feeding period from the start of the experiment until "Feeders' Day" was 106 days. The lambs were kept an additional eight days before being marketed. It became necessary to market a few lambs at the end of 70 days due to the fact that at this time a few head were growing to such a size that they would have been too large to market profitably, if held for the

entire feeding period. At the end of the seventieth day all lots were reduced in number from 24, less the number that had died, to 21; the heavy end in every lot being marketed. This procedure removed from two to three lambs out of each lot at the end of the seventieth day. For this reason all results have been computed on a lamb-day basis, which in no way destroys the accuracy of the work or the value of the experiment.

Feeds and Feeding Methods

A complete analysis of all feeds used is given on page 44 under table 14 of this thesis. The barley was of a rather inferior quality being graded as a No. 3; the corn was No. 1; the wheat was No. 2 mixed; the cottonseed meal was of prime quality with a guaranteed analysis of not less than 43 percent protein; the linseed oil meal was also of good quality, having a guaranteed protein content of not less than 34 percent.

The flaxseed used was grown in Weld County, Colorado, and was of an exceptionally fine quality. The alfalfa hay was, for the most part, second cutting and of good quality, but it was necessary at times to substitute first cutting, though only a small percentage of first cutting was fed.

Hay was fed to all lots in a self-feeder, the lambs being permitted to eat hay at any time of the day or night that they desired. The grains were fed twice

daily at 6:30 a. m. and 3 p. m., and wet beet pulp was fed to the pulp lots about 8 a. m. each day. Salt was kept before the lambs at all times in a granulated form and they had free access to water. No minerals were fed.

An effort was made to feed the lots receiving cottonseed meal and linseed oil meal a like amount of protein in the cottonseed meal and linseed oil meal received by each lot. The linseed oil meal used had an actual protein content of 40.19 percent (dry basis) compared with 45.15 percent in the case of cottonseed meal. This is in the ratio of 1:1.123. The cottonseed meal and linseed oil meal were actually fed in the ratio of 1:1.192 throughout the feeding period. Because of the uncertainty of feeding flaxseed in large amounts no effort was made to feed in like proportion to cottonseed meal and linseed oil meal, so far as protein content was concerned, since the ground flaxseed contained only 25 percent crude protein, which would have necessitated the feeding of .45 pound of flaxseed daily to insure the same amount of protein being fed as in the case of the cottonseed meal lot. Two-tenths of a pound daily was the maximum feeding of ground flaxseed actually fed, excepting in the case of a small lot of lambs fed that were not a part of the experiment. These are discussed separately on page 80 of this work.

To clearly show the average amount of feed given per lamb per day, table 13 has been prepared where-

in the average daily feed is given for all lots in the entire experiment. The reason for giving this in full is simply that the reader may make comparisons between the lots fed ground flaxseed and the other lots, if he so desires, and arrive at his own conclusions.

Table 13
The Average Daily Feed per Lamb in Varying Rations

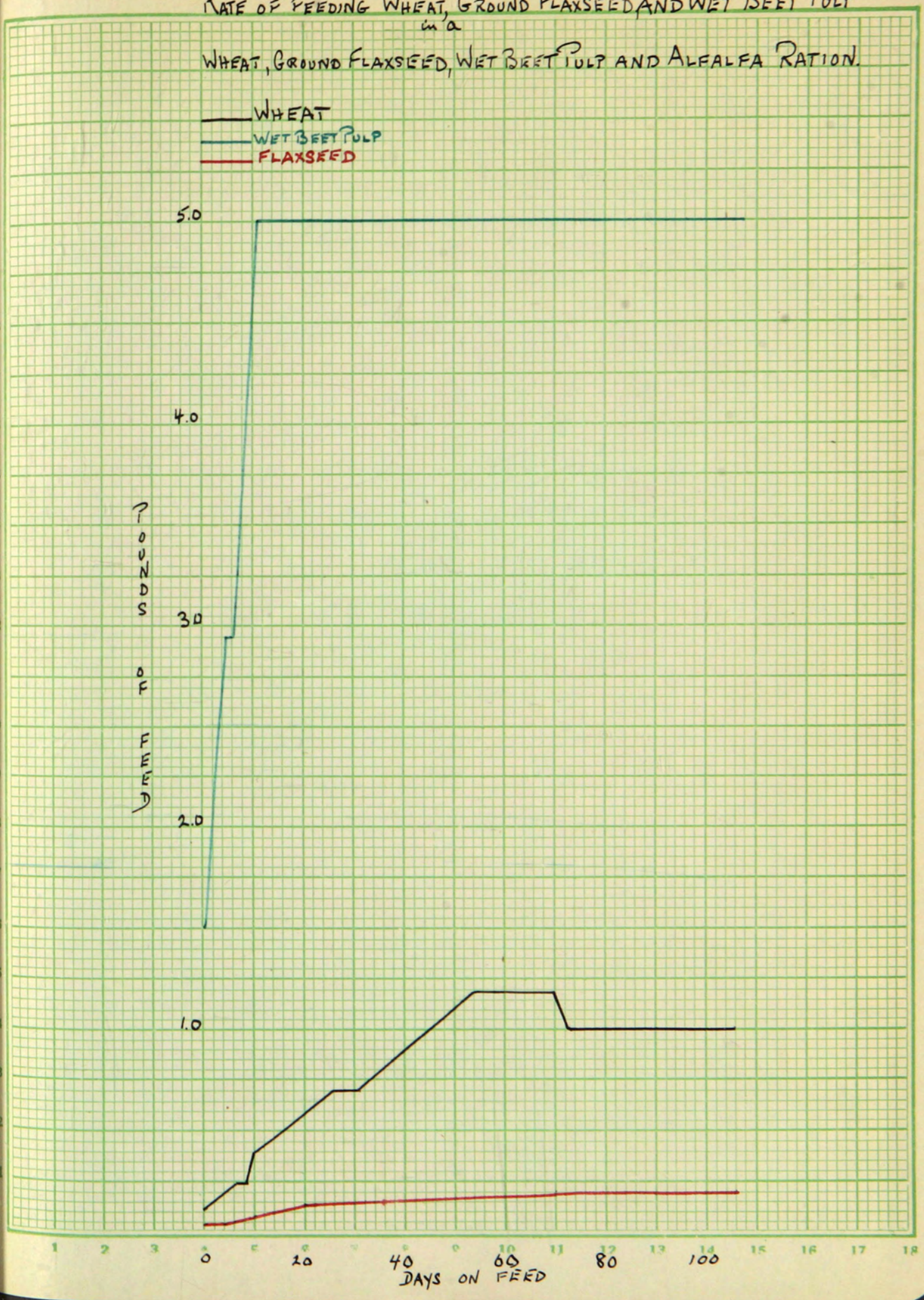
Ration	Ground flax-seed	Barley wheat or corn	Cotton-seed meal	Linseed oil meal	Wheat mixed feed*	Wet beet pulp	Alfalfa
Barley, alfalfa		.96					2.50
Barley, ground flaxseed, alfalfa	.16	.94					2.42
Barley, cottonseed meal, alfalfa		.94	.20				2.23
Barley, linseed oil meal, alfalfa		.94		.24			2.29
Barley, *wheat mixed feed, alfalfa		.94			.61		1.86
Barley, wet beet pulp, alfalfa		.87				4.79	1.62
Barley, ground flaxseed, wet beet pulp, alfalfa	.16	.86				4.79	1.75
Barley, cottonseed meal, wet beet pulp, alfalfa		.86	.20			4.79	1.48
Barley, linseed oil meal, wet beet pulp, alfalfa		.86		.24		4.79	1.38
Barley, *wheat mixed feed, wet beet pulp, alfalfa		.85			.61	4.72	1.31
Wheat, alfalfa		1.02					2.53
Wheat, ground flaxseed, alfalfa	.16	.94					2.28
Wheat, cottonseed meal, alfalfa		.94	.20				2.25
Wheat, linseed oil meal, alfalfa		.94		.24			2.38
Wheat, ground flaxseed, wet beet pulp, alfalfa	.16	.86				4.79	1.85
Wheat, cottonseed meal, wet beet pulp, alfalfa		.86	.20			4.79	1.76
Wheat, linseed oil meal, wet beet pulp, alfalfa		.86		.24		4.79	1.65
Corn, alfalfa		.96					2.54

*This feed is a product of the Fort Collins Flour Mill and is known locally as wheat bran. It contains wheat bran, shorts and ground wheat screenings not in excess of 8%.

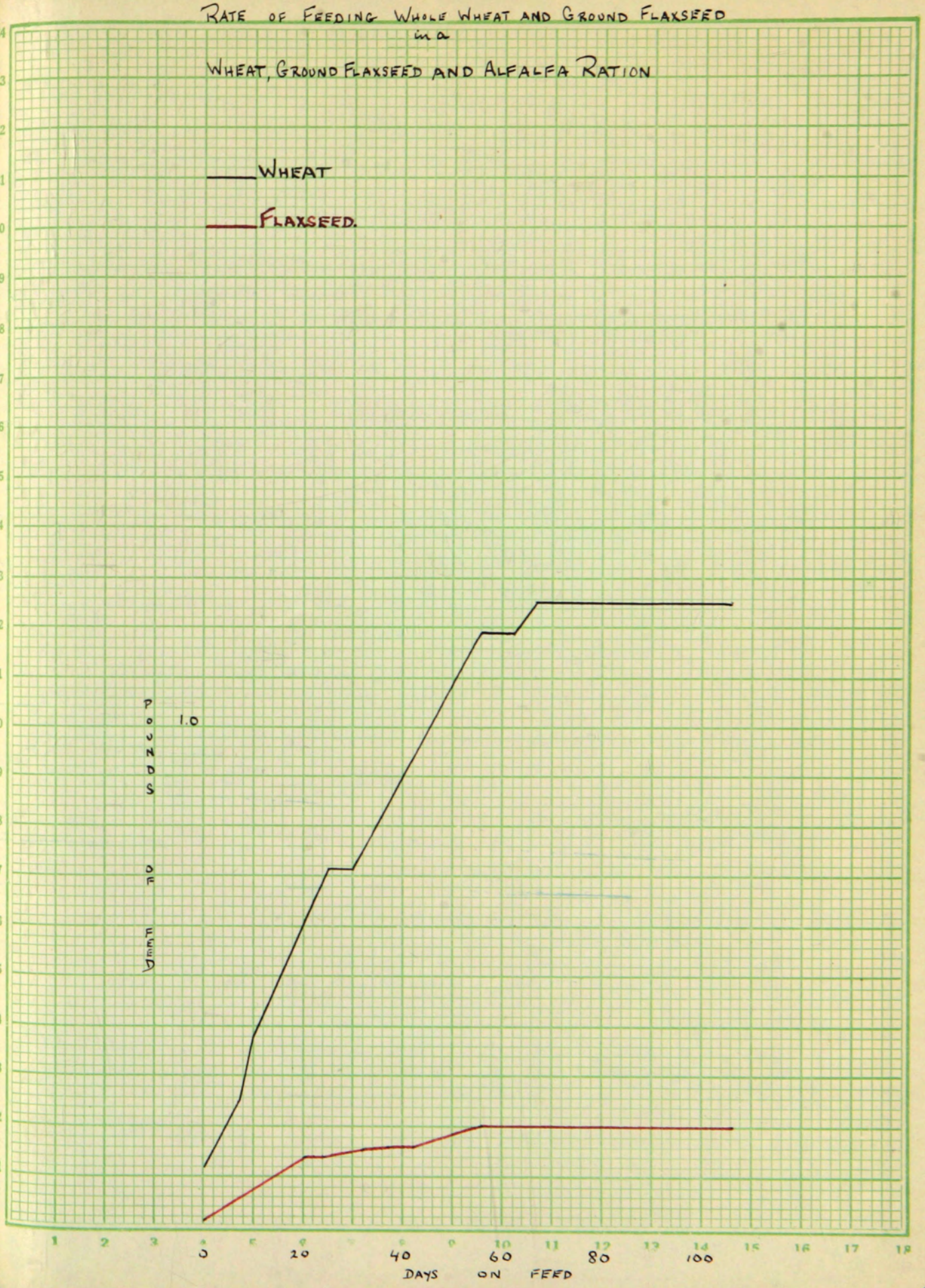
In order that the reader may more clearly comprehend the manner in which the lambs that were fed ground flaxseed were increased by periods, graph A, appearing on page 39, has been prepared which shows the rate of feeding of wheat, ground flaxseed and wet beet pulp in a wheat-flaxseed-wet-beet-pulp-alfalfa-hay ration. These lambs were on a full feed of wet beet pulp by the end of the eleventh day. Grain was increased cautiously in all lots as the graph indicates. In the case of ground flaxseed, full feed was not reached until the fifty-sixth day. With several lots it became necessary to cut back a little on wheat and barley on the seventieth day. This was due in part to unseasonably warm weather and in part to the fact that the heavy end of the lots were shipped at the end of 70 days and it was considered inadvisable to continue the entire lot that remained on quite as high an average feed.

Graph B, which appears on page 40, indicates the rate of feeding in the wheat-ground-flaxseed-alfalfa-hay lot without wet beet pulp. It was found possible here to maintain wheat considerably in excess of one pound daily after the fiftieth day and a maximum of 1.25 pounds daily was fed after the seventieth day. Here again a full feed of ground flaxseed was not reached until the fifty-sixth day, but was continued at the rate of 0.2 pound until the end of the period.

Rate of Feeding Wheat, Ground Flaxseed and Wet Beet Pulp in a Wheat, Ground Flaxseed, Wet Beet Pulp and Alfalfa Ration.



Rate of Feeding Whole Wheat and Ground Flaxseed in a Wheat, Ground Flaxseed and Alfalfa Ration



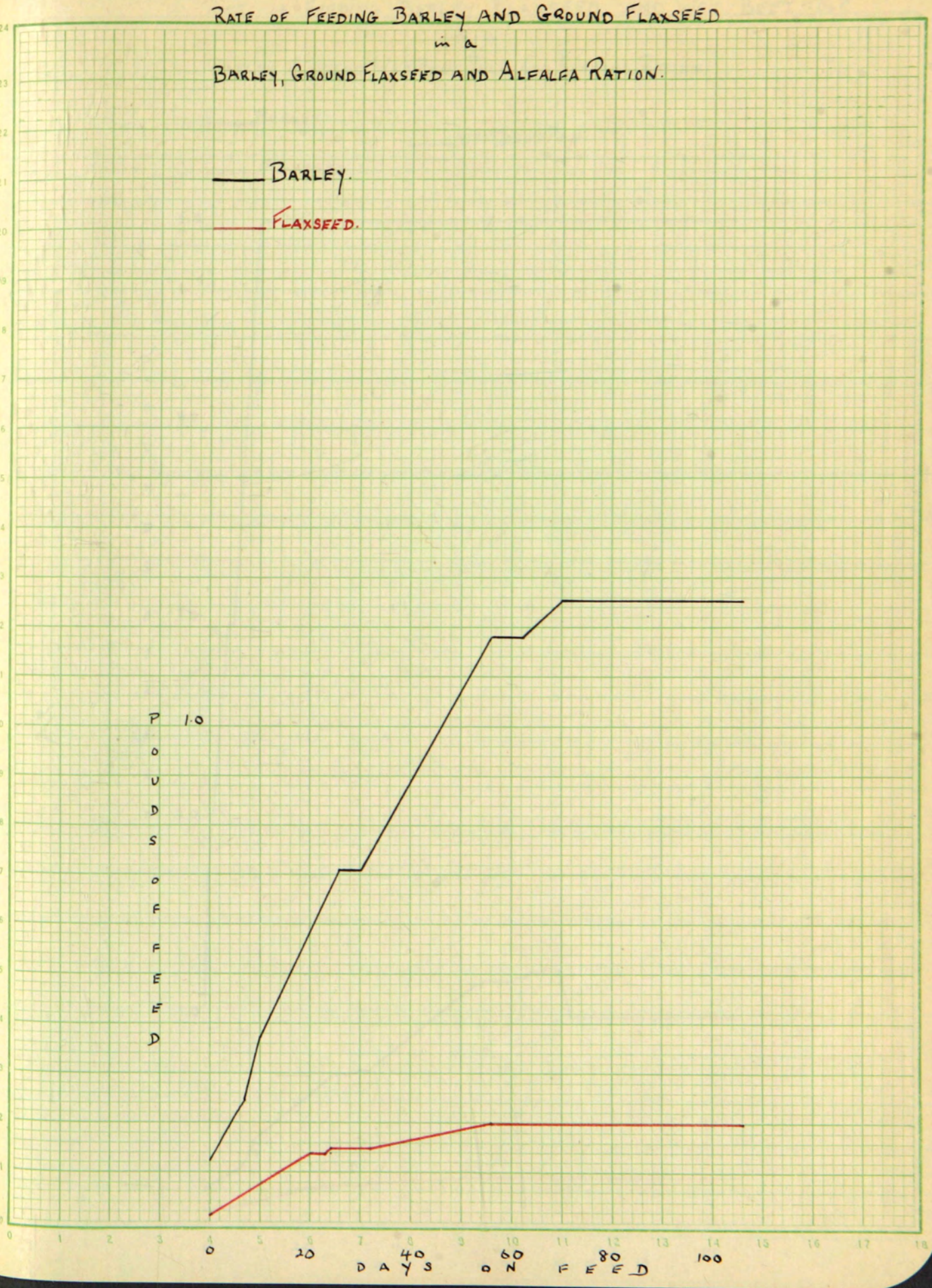
Graph C, comprising page 42, indicates that the lot fed flaxseed with barley was increased at practically the same rate as in the wheat-flaxseed lot.

Graph D, comprising page 43, illustrates the rate of feeding with barley, ground flaxseed, wet beet pulp and alfalfa and shows a marked similarity in rate of feeding to that of the wheat, ground flaxseed, wet beet pulp and alfalfa ration for the same reasons as previously given.

In all wet beet pulp lots the maximum feed was five pounds daily per lamb. During warm weather some difficulty was experienced in getting the lambs to consume the entire maximum feed of pulp during the latter part of the period. The barley-wet-beet-pulp-alfalfa-hay lot, however, kept their pulp cleaned up at all times.

Table 14 follows, which gives the analyses of all feeds used in the experiment as made by Mr. Max Parshall, State Dairy Commission Chemist, Fort Collins, Colorado.

RATE OF FEEDING BARLEY AND GROUND FLAXSEED
in a
BARLEY, GROUND FLAXSEED AND ALFALFA RATION.



GRAPH D

RATE OF FEEDING BARLEY, FLAXSEED AND WET BEET PULP
in a
BARLEY, FLAXSEED, WET BEET PULP AND ALFALFA RATION.

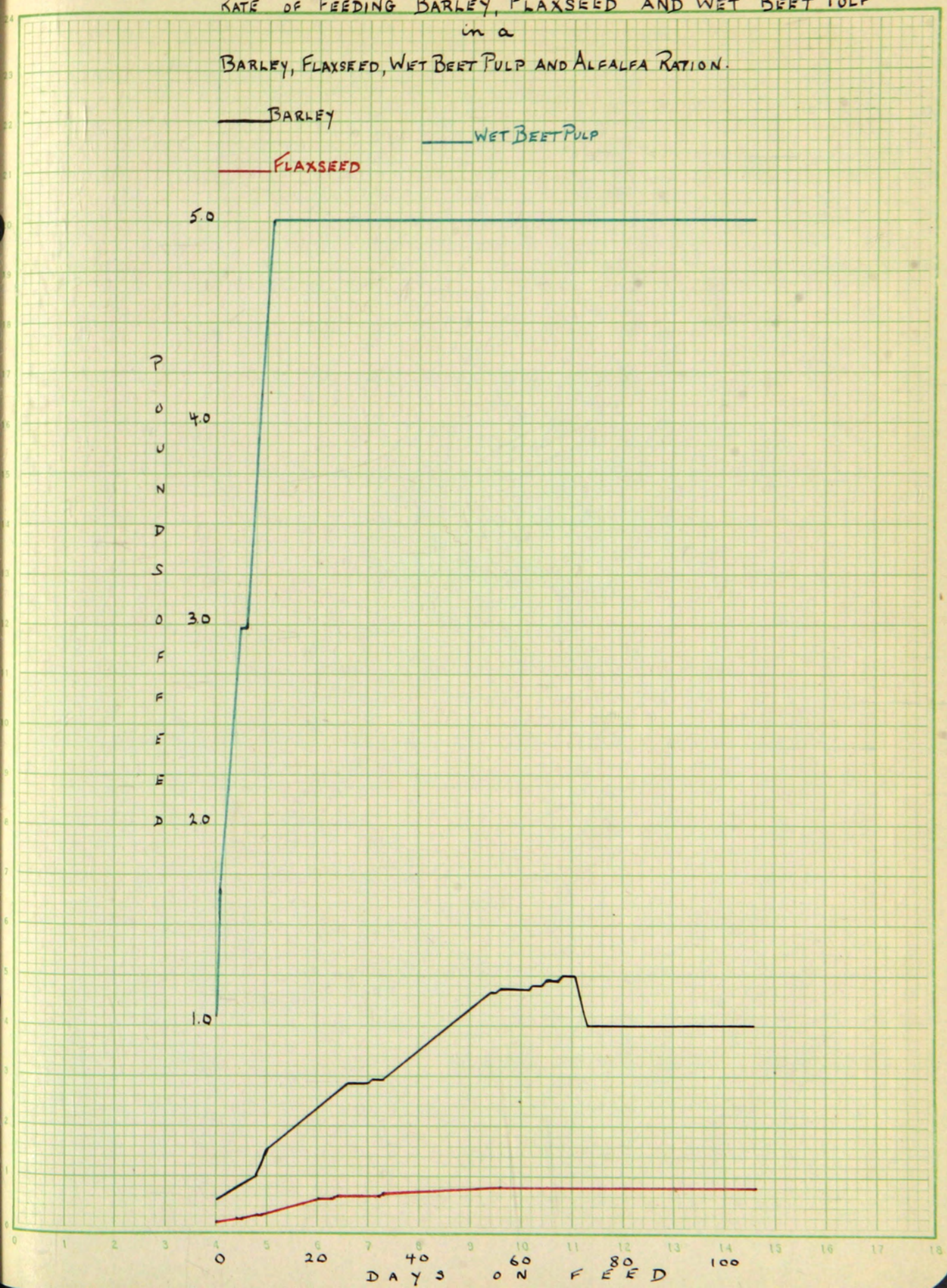


Table 14

Analyses of Feeds Used

Feed	Moisture	Ash	Crude fat	Crude protein	Crude fiber	Nitrogen free extract
Corn	12.335%	1.345%	3.52%	9.80%	1.995%	71.015%
Dry basis		1.530	4.00	11.17	2.27	81.03
Barley	12.255	2.225	1.755	12.905	6.025	64.835
Dry basis		2.53	2.00	14.71	6.86	73.90
Wheat	11.870	1.77	1.845	14.285	2.485	67.715
Dry basis		2.01	2.09	16.24	2.82	76.84
Cottonseed meal	7.545	5.13	8.11	41.75	10.93	26.535
Dry basis		5.55	8.77	45.15	11.82	28.71
Linseed oil meal	8.755	6.355	5.460	36.675	7.475	35.280
Dry basis		6.96	5.98	40.19	8.19	38.68
*Wheat mixed feed and screenings	11.21	5.79	4.94	16.68	8.415	52.965
Dry basis		6.52	5.56	18.78	9.47	59.67
Wet beet pulp			2.63	3.00	45.53	34.36
Alfalfa	4.515	8.185	1.68	14.16	39.025	32.435
Dry basis		8.57	1.76	14.66	40.87	34.14
Flaxseed	8.68	4.21	36.185	22.835	5.115	22.975
Dry basis		4.61	39.62	25.00	5.60	25.17

*The wheat mixed feed and screenings used in this experiment is the product of the Fort Collins Flour Mills. This product contains wheat bran, shorts, and ground wheat screenings not over 8%, and is commonly called wheat bran in the locality immediately adjacent to Fort Collins, Colorado.

Shelter

No shelter was provided in the form of sheds. The lamb-feeding lots at the Colorado Agricultural College are located in a sheltered spot away from wind. All along the north, south and east sides of the lots a high board-fence has been erected which is most effective in breaking the wind. To the north and west there are also a number of buildings which serve to break the wind and the self-feeders for hay located within the lots also serve as a windbreak and a shelter from storms.

Lot Weights

Following the average initial weights, computed from weights taken on November 19 and 20, lot weights were taken every ten days. Individual weights were taken every 30 days. When a 30-day weight was taken and each lamb was weighed lot weights were not taken, but the individual weights were added to arrive at the lot weights. Period weights were taken in every case after the feeding of grain at 6:30 a. m. and wet beet pulp at 8 a. m., with the exception of the final feedlot weights which were taken prior to the feeding of wet beet pulp. Final feedlot weights were computed from the average of three consecutive individual daily weights taken on all lambs. In the case of those marketed at the end of the 70 days, these weights were taken on January 30 and 31 and

February 1. In the case of the remainder the weights were taken on March 4, 5 and 6. If a lamb died for any reason whatever a post mortem examination was made and the feed that the lamb had eaten until the time of its death removed as a part of the experiment, so that the results given herein cover the total number of lamb-days for the total number of lambs finishing the experiment, both at the end of 70 days and at the end of 106 days.

Additional Experimental Methods Employed

All alfalfa was weighed into each self-feeder, and at the conclusion of the experiment it was weighed back so that a careful check was made on the alfalfa consumed. The amount of alfalfa wasted by lambs was considered negligible. All grain was weighed prior to every feeding and a complete daily record kept and checked. All wet beet pulp fed was weighed into each lot prior to feeding and every effort to make the work as accurate as possible was exercised.

Throughout the entire period the lambs were fed in the same way by the same men at the same hours. The grain mixtures were weighed by the same man for every feed during the period. On weigh days it was necessary to disturb the lambs to some extent but after the first two or three weigh days little trouble was encountered and the lambs were moved with a minimum of confusion.

As has been stated, numbered tags were placed in the ear of each lamb and each lamb was branded with branding paint to designate its lot. At no time did the lot ever become mixed, and each lamb was rebranded prior to shipment to Denver so that no error was made in the Denver Stock Yards in making the sorts into lots, so that accurate market data, including selling weights, dressing percentages and grades in the cooler were obtained. We are indebted to Armour and Company for their help in keeping this data straight in their plant on the large shipment made at the end of the period and to Swift and Company for similar service on the lambs they bought at the conclusion of the 70-day period.

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RESULTS

The foregoing material has been presented in an effort to give the reader the impression that the chief subject of this experiment is the feasibility of feeding ground flaxseed to lambs for fattening purposes. If it is assumed that ground flaxseed can be fed without danger from disastrous death losses (pp. 16-18), the question next arises as to its relative feeding value as compared with other nitrogenous concentrates. The results will be presented so as to show this clearly, even though it will be necessary to repeat some of the figures obtained in different tables.

Death Loss

It should be mentioned at the start that death loss was not a factor of any consequence in this experiment. It has been shown in the review of literature that death loss sometimes is a factor when flaxseed is fed, and under certain conditions it is apparent that abnormal death loss does take place. No great amount of death loss was incurred during this feeding trial, but to present the matter in accurate form, table 15 has been prepared.

Table 15

Death Losses

Ration	Number died	Cause
Barley, ground flaxseed, alfalfa	0	
Barley, cottonseed meal, alfalfa	0	
Barley, linseed oil meal, alfalfa	0	
Barley, ground flaxseed, wet beet pulp, alfalfa	0	
Barley, cottonseed meal, wet beet pulp, alfalfa	0	
Barley, linseed oil meal, wet beet pulp, alfalfa	0	
Barley, alfalfa	1	Overeating
Barley, wet beet pulp, alfalfa	0	
Wheat, ground flaxseed, alfalfa	0	
Wheat, cottonseed meal, alfalfa	2	(1 Overeating (1 Drowned
Wheat, linseed oil meal, alfalfa	0	
Wheat, alfalfa	0	
Wheat, ground flaxseed, wet beet pulp, alfalfa	1	Overeating
Wheat, cottonseed meal, wet beet pulp, alfalfa	1	Overeating
Wheat, linseed oil meal, wet beet pulp, alfalfa	0	
Corn, alfalfa (Standard ration)	1	Overeating

From this table it is readily seen that only one lamb receiving ground flaxseed died. In all cases but one death was due to overeating, the symptoms of which were rather typical in their early stages. In nearly every case the brain seemed to be affected and the lambs appeared to be comfortable only when lying on one particular side. If turned over on the other side, the lamb would squirm about until lying on the side that it appeared to be most comfortable. In a number of cases considerable pain was evidenced and the animal

would last for a long time before dying or being put out of its misery. Two or three days of this abnormal condition were not uncommon, but when it appeared that the animal could not possibly live it was killed and a post mortem made. Large amounts of grain were found in the first two stomachs in all cases. Several large hemorrhages usually appeared on the peritoneum; and the urine, upon analysis, showed a sugar content in nearly every case. This sugar content was sometimes as high as 1.67 percent.

Prices

Before discussing the value of ground flaxseed in the various rations fed, it seems advisable to present a table giving the prices of feeds used in this work.

Due to the fact that prices vary so greatly, an effort has been made to give results in terms other than price. Price, however, has to enter in as a factor in giving replacement values and wherever current prices are used they are in accordance with those given in table 16. Table 16 is, therefore, a reference table of current prices.

Table 16

Prices of Feeds Used

(Ton Basis)

Alfalfa	$ 8.00
Wheat	15.00
Barley	15.00
Linseed oil meal	35.00
Cottonseed meal	25.00
Ground flaxseed	30.00
Wet beet pulp	1.70

Biometrical Equations Employed

When F = Frequency

D = Deviation from the estimated mean

n = Number of lambs in the lot

$w = \frac{FD}{F}$, being a correction factor for the calculation of the true mean

True Mean = Estimated mean + w

σ (Standard deviation) $= \sqrt{\frac{\Sigma F.D^2}{n} - w^2}$

Em(Probable error of the mean) $= \pm \frac{.6745 \times \sigma}{\sqrt{F}}$

In order to arrive at whether or not a significant difference is shown, the difference between the true means must equal or exceed three times the square root of the sums of the squares of the probable errors.

It is specifically stated that all biometrical calculations shown relate only to the lambs that were fed the entire feeding period. Those lambs marketed at the end of 70 days are not made a part of any biometrical analyses. This accounts for the differences that exist between the biometrical true mean gains and the average gains given in the tables.

Comparison of Ground Flaxseed with Linseed Oil Meal in a Barley and Alfalfa Ration

Table 17 shows the direct comparison of ground flaxseed and linseed oil meal with the check lot--barley and alfalfa.

Table 17

The Relative Values of Ground Flaxseed and Linseed Oil Meal in a Barley and Alfalfa Ration

	Barley Alfalfa	Barley Flaxseed Alfalfa	Barley Linseed Oil Meal Alfalfa
Initial weight per lamb	64.35	64.57	65.15
Feedlot gain per lamb	31.25	38.52	36.60
Biometrical mean gain on 21 lambs	31.43	39.24	37.71
Daily gain per lamb	.30	.38	.36
Feed required for 100 lbs. feedlot gain			
Barley	317.14	247.95	261.39
Flaxseed		43.21	
Linseed oil meal			67.31
Alfalfa	823.39	640.95	658.70
Dressing percent based on cold weights	48.10	48.54	50.05

On the basis of the data presented in table 17, one ton of ground flaxseed replaced 3202.50 pounds of barley plus 8444.34 pounds of alfalfa in a barley-alfalfa ration. At the current prices for barley and alfalfa given in table 16, linseed oil meal had a feed replacement value of $34.37 per ton and ground flaxseed had a feed replacement value of $57.80 per ton in this ration.

Based on the replacement value of ground flaxseed, the following table indicates the value of one ton of ground flaxseed at varying prices for barley and alfalfa.

Table 18

Replacement Values of One Ton of Ground Flaxseed in a Barley and Alfalfa Ration at Varying Prices

Barley at	.60 cwt.	.80 cwt.	1.00 cwt.	1.20 cwt.	1.40 cwt.
Alfalfa at					
$ 4 ton	36.11	42.52	48.92	55.32	61.73
$ 6 ton	44.55	50.95	57.96	63.76	70.17
$ 8 ton	53.00	59.40	66.41	72.21	78.62
$10 ton	61.44	67.84	74.85	80.65	87.06
$12 ton	69.89	76.29	82.70	89.10	95.51
$14 ton	78.33	84.73	94.14	97.14	103.95
$16 ton	86.77	93.17	99.58	105.98	112.39

It is interesting to note that ground flaxseed, when fed with barley and alfalfa, produced a feedlot gain

per lamb of 1.92 pounds more than the comparable lot fed linseed oil meal, resulting in a higher daily gain per lamb.

Applying biometry to this difference it was found that the standard deviation of the flaxseed-fed lot was 8.02, the biometrical true mean was 39.24 and the probable error of the mean was ± 1.18. In the linseed oil meal lot the standard deviation was 6.83, the biometrical true mean was 37.71 and the probable error of the mean was ± 1.01. This indicates that, while the difference between the gains of these two lots is of considerable interest, it was not significant because the square root of the sum of the squares of the probable errors was ± 1.55 and the difference between the biometrical true means was 1.53. One and fifty-three hundredths is not three times 1.55. The difference is therefore assumed to be insignificant.

Data pertaining to the relative dressing percentages and grades of the carcasses of the lambs in these lots are presented in table 29 on page 83.

Comparison of Ground Flaxseed with Cottonseed Meal in a Barley and Alfalfa Ration

Table 19 compares ground flaxseed with cottonseed meal in a similar manner to that shown for linseed oil meal in table 17.

Table 19

The Relative Values of Ground Flaxseed and Cottonseed Meal in a Barley and Alfalfa Ration

	Barley Alfalfa	Barley Ground flaxseed Alfalfa	Barley Cottonseed meal Alfalfa
Initial weight per lamb	64.35	64.57	64.44
Feedlot gain per lamb	31.25	38.52	35.64
Biometrical mean gain on 21 lambs	31.43	39.24	36.57
Daily gain per lamb	.30	.38	.35
Feed required for 100 pounds gain			
Barley	317.14	247.95	267.98
Flaxseed		43.21	
Cottonseed meal			57.99
Alfalfa	823.39	640.95	637.18
Dressing percentage based on cold weights	48.10	48.54	49.96

Here again it required less barley in the case of the ground-flaxseed lot than in the case of the cottonseed-meal lot to produce 100 pounds of gain. The saving in this case was larger, being 8.1 percent. The saving on ground flaxseed over cottonseed meal was not as large as in the case of linseed oil meal, being 34 percent. Again it is found that it required a small amount (0.6 percent) more alfalfa in the case of the flaxseed-fed lambs than those fed cottonseed meal. From these figures it is computed that cottonseed meal had a feed replacement value of $38.41 per ton, since one ton

of cottonseed meal replaced 1695.5 pounds of barley and 6422.1 pounds of alfalfa in this ration. This compares with $34.37 per ton in the case of linseed oil meal and $57.80 per ton in the case of ground flaxseed with barley and alfalfa at current prices given in table 16.

An analysis of the comparative gains of these two lots reveals that the ground flaxseed lot outgained the cottonseed meal lot by 2.88 pounds. A biometrical analysis of this difference shows that the biometrical true mean in the lot fed cottonseed meal is 36.57; the standard deviation is 7.00 and the probable error of the mean is ± 1.03. Comparing this with the lot fed ground flaxseed, which lot shows a biometrical true mean gain of 39.24, a standard deviation of 8.02 and an error of the probable mean as ± 1.18, it is found that the difference between the means is 2.67 and the square root of the sum of the squares of the probable errors is ± 1.56. This indicates that, while the gain in favor of the lot fed ground flaxseed is interesting, it is not significant since 2.67 does not equal or exceed three times 1.56.

Data pertaining to the relative dressing percentages and grades of the carcasses of the lambs in these lots are presented in table 29 on page 83.

Significant Difference Shown by the Addition of Ground Flaxseed to a Barley and Alfalfa Ration

Tables 17 and 19 indicate that a materially higher gain was obtained when ground flaxseed was fed as a nitrogenous supplement in a barley-alfalfa ration. It is interesting to determine whether this gain is significant or not. To do this biometry was applied to the figures of both lots and it was found that the lot fed barley and alfalfa showed a biometrical true mean gain of 31.429. In this lot the standard deviation was found to be 6.36 and the probable error of the mean was ± .937. Comparing these calculations with the same data relative to the lot fed barley, ground flaxseed and alfalfa, which has been given in the discussion comparing ground flaxseed with both cottonseed meal and linseed oil meal, it was found that the difference of the means between the lot fed ground flaxseed and the lot fed no nitrogenous supplement was 8.80 and the square root of the sum of the squares of the probable errors of the means of both lots was found to be ± 1.51. Since 8.80 exceeds 1.51 by more than three times, it is evident that a significant difference is shown favoring the feeding of ground flaxseed.

Comparison of Ground Flaxseed with Linseed Oil Meal in a Barley-Wet-Beet-Pulp-Alfalfa Ration

The data for the comparison between the lots fed ground flaxseed and linseed oil meal in a barley-

wet-beet-pulp-alfalfa ration are given in table 20 as follows:

Table 20

The Relative Values of Ground Flaxseed and Linseed Oil Meal in a Barley-Wet-Beet-Pulp-Alfalfa Ration

	Barley Wet beet pulp Alfalfa	Barley Ground flaxseed Wet beet pulp Alfalfa	Barley Linseed oil meal Wet beet pulp Alfalfa
Initial weight per lamb	64.56	64.46	64.41
Feedlot gain per lamb	35.82	42.29	40.45
Biometrical mean gain on 21 lambs	36.24	43.57	41.52
Daily gain per lamb	.35	.42	.40
Feed required for 100 pounds gain			
Barley	246.20	207.18	216.59
Ground flaxseed		39.08	
Linseed oil meal			60.80
Wet beet pulp	1361.58	1153.38	1205.77
Alfalfa	459.48	420.76	348.70
Dressing percent based on cold weights	50.64	51.18	51.24

Added to barley, alfalfa and wet beet pulp at current prices, linseed oil meal had a replacement value of $26.24, since one ton of linseed oil meal replaced 974.0 pounds of barley, 5125.33 pounds of wet beet pulp, and 3644.1 pounds of alfalfa in this ration. With ground flaxseed added to barley, alfalfa and wet beet pulp at current prices, one ton of ground flaxseed had a

replacement value of $31.97 per ton, since one ton of ground flaxseed replaced 1996.96 pounds of barley, 10,655.06 pounds of wet beet pulp and 1981.58 pounds of alfalfa.

Considering wet beet pulp as constant at $1.70 per ton, table 21 shows the replacement values of ground flaxseed in a barley-wet-beet-pulp-alfalfa ration at varying prices.

Table 21

Replacement Value of Ground Flaxseed in a Barley-Wet-Beet-Pulp-Alfalfa Ration at Varying Prices with Wet Beet Pulp Constant at $1.70 per Ton

Barley at	.60 cwt.	.80 cwt.	1.00 cwt.	1.20 cwt.	1.40 cwt.
Alfalfa at					
$ 4 ton	24.46	28.46	32.45	36.44	40.44
$ 6 ton	26.44	30.44	34.43	38.42	42.42
$ 8 ton	28.43	32.43	36.42	40.41	44.41
$10 ton	30.41	34.41	38.40	42.39	46.39
$12 ton	32.39	36.39	40.38	44.37	48.37
$14 ton	34.37	38.87	42.36	46.35	50.35
$16 ton	36.35	40.35	44.34	48.33	52.33

A biometrical analysis of the gains of these two lots shows that the biometrical true mean gain in the barley-linseed-oil-meal-wet-beet-pulp-alfalfa lot was 41.52; the standard deviation was 7.17 and the probable error of the mean was ± 1.06. With the lot fed

barley, ground flaxseed, wet beet pulp and alfalfa the biometrical true mean gain was 43.57; the standard deviation was 5.53 and the probable error of the mean was ± .814.

The difference between the true means of these lots is 2.05. The square root of the sum of the squares of the probable errors of the means is 1.34. Since 2.05 does not equal or exceed three times 1.34 the difference favoring the feeding of ground flaxseed when compared with linseed oil meal in a wet beet pulp ration is interesting but not significant.

Data pertaining to carcass grades and dressing percentages on both of these lots are given in table 29 on page 83.

Comparison of Ground Flaxseed with Cottonseed Meal in a Barley-Wet-Beet-Pulp-Alfalfa Ration

Table 22 presents the information from which a comparison of ground flaxseed and cottonseed meal can be made in a barley-wet-beet-pulp-alfalfa ration.

Table 22

The Relative Values of Ground Flaxseed and Cottonseed Meal in a Barley-Wet-Beet-Pulp-Alfalfa Ration

	Barley Wet beet pulp Alfalfa	Barley Ground flaxseed Wet beet pulp Alfalfa	Barley Cottonseed meal Wet beet pulp Alfalfa
Initial weight per lamb	64.56	64.46	64.42
Feedlot gain per lamb	35.82	42.29	38.42
Biometrical mean gain on 21 lambs	36.24	43.57	38.90
Daily gain per lamb	.35	.42	.38
Feed required for 100 pounds gain			
Barley	246.20	207.18	228.04
Ground flaxseed		39.08	
Cottonseed meal			53.80
Wet beet pulp	1361.58	1153.38	1269.62
Alfalfa	459.48	420.76	393.71
Dressing percent based on cold weights	50.64	51.18	50.51

One ton of cottonseed meal replaced 675.1 pounds of barley, 3422.3 pounds of wet beet pulp and 2445 pounds of alfalfa hay in the production of 100 pounds of gain, and at current prices had a replacement value of $17.75 per ton in this ration.

One ton of ground flaxseed replaced 1996.93 pounds of barley, 10,655.06 pounds of wet beet pulp, 1981.58 pounds of alfalfa and had a feed replacement value at current prices of $31.97 per ton. See table 21

for replacement values at varying prices.

The lot receiving barley, ground flaxseed, wet beet pulp and alfalfa made a biometrical mean gain on the 21 head finishing the feeding period of 43.57 pounds. (The actual gain on the entire lot is given in table 22). The standard deviation was found to be 5.53 and the probable error of the mean was found to be ± .814.

The lot receiving barley, cottonseed meal, wet beet pulp and alfalfa made a biometrical mean gain on the 21 head finishing the feeding period of 38.90 pounds. The standard deviation was calculated to be 6.61 and the probable error of the mean was found to be ± .973.

The difference between the means is 4.67 and the square root of the sum of the squares of the probable errors is 1.27, indicating that the gain in favor of ground flaxseed, when fed with barley and alfalfa in a wet-beet-pulp ration, is not only interesting but is significant in view of the fact that 4.67 exceeds three times 1.27.

Market data is given in detail in table 29 on page 83.

Significant Difference Shown by the Addition of Ground Flaxseed to a Barley-Wet-Beet-Pulp-Alfalfa Ration

A brief comparison of the lot fed barley, wet beet pulp and alfalfa with the lot fed barley, ground flaxseed, wet beet pulp and alfalfa, indicates that the

flaxseed-fed lot outgained the lot fed no nitrogenous concentrate by 7.33 pounds when the biometrical true means were computed on the 21 head finishing the feeding period.

It was found that the standard deviation on the barley-wet-beet-pulp-alfalfa-hay lot was 5.90 and the probable error of the mean was ± .869. A comparison with the lot fed ground flaxseed showed that the square root of the sum of the squares of the probable errors of the means was 1.19 which, when compared with the difference between the means of 7.33 pounds, indicates a significant difference, favoring the feeding of ground flaxseed in a barley-wet-beet-pulp ration.

Comparison of Ground Flaxseed with Linseed Oil Meal in a Wheat and Alfalfa Ration

Table 23 presents this material comparing ground flaxseed with linseed oil meal in a wheat and alfalfa ration together with the wheat and alfalfa check lot.

Table 23

The Relative Values of Ground Flaxseed and Linseed Oil Meal in a Wheat and Alfalfa Ration

	Wheat Alfalfa	Wheat Ground flaxseed Alfalfa	Wheat Linseed oil meal Alfalfa
Initial weight per lamb	64.66	64.80	64.93
Feedlot gain per lamb	36.92	37.01	39.27
Biometrical mean gain for 21 lambs	37.24	37.86	40.38
Daily gain per lamb	.36	.36	.39
Feed required for 100 pounds of gain			
Wheat	280.67	258.05	243.21
Ground flaxseed		44.97	
Linseed oil meal			62.65
Alfalfa	696.89	627.08	617.56
Dressing percent based on cold weights	48.98	50.73	48.24

Not as favorable a showing is made with ground flaxseed when used with wheat as with barley.

One ton of ground flaxseed replaced 1006.00 pounds of wheat and 3104.74 pounds of alfalfa in a wheat and alfalfa ration which, when computed at current prices, gives one ton of ground flaxseed a replacement value of $25.00 per ton.

In like manner linseed oil meal replaced 1195.8 pounds of wheat and 2532.5 pounds of alfalfa hay and had a replacement value of $25.08 per ton at current prices in this ration.

To further illustrate the value of ground flaxseed in a wheat and alfalfa ration, table 24 has been compiled which shows its replacement value at varying prices for wheat and alfalfa.

Table 24

The Replacement Value of Ground Flaxseed in a Wheat and Alfalfa Ration at Varying Prices

Wheat at	.60 cwt.	.80 cwt.	1.00 cwt.	1.20 cwt.	1.40 cwt.
Alfalfa at					
$ 4 ton	12.25	14.26	16.27	18.28	20.29
$ 6 ton	15.35	17.36	19.37	21.38	23.39
$ 8 ton	18.46	20.47	22.48	24.49	26.50
$10 ton	21.56	23.57	25.58	27.59	29.60
$12 ton	24.67	26.68	28.69	30.70	32.71
$14 ton	27.77	29.78	31.79	33.80	35.81
$16 ton	30.88	32.89	34.90	36.91	38.92

The standard deviation of the lot fed wheat, linseed oil meal and alfalfa was 8.02 and the probable error of the mean was ± 1.18. The biometrical true mean of this lot was 40.38.

An analysis of the lot fed wheat, ground flaxseed and alfalfa shows that the biometrical true mean was 37.86; the standard deviation was 5.74 and the probable error of the mean was ± .845. The difference between the means was found to be 2.52 and the square

root of the sum of the squares of the probable errors was calculated as 1.45. Since the difference between the means does not equal or exceed three times the square root of the sum of the squares of the probable errors, the gain favoring the feeding of linseed oil meal in a wheat and alfalfa ration is insignificant.

Market data is given in detail in table 29 on page 83.

Comparison of Ground Flaxseed with Cottonseed Meal in a Wheat and Alfalfa Ration

Table 25 illustrates the comparison between ground flaxseed and cottonseed meal in a wheat and alfalfa ration as follows:

Table 25

The Relative Values of Ground Flaxseed and Cottonseed Meal in a Wheat and Alfalfa Ration

	Wheat Alfalfa	Wheat Ground flaxseed Alfalfa	Wheat Cottonseed meal Alfalfa
Initial weight per lamb	64.66	64.80	64.35
Feedlot gain per lamb	36.92	37.01	39.72
Biometrical mean gain of 21 lambs	37.24	37.86	40.90 (20 lambs)
Daily gain per lamb	.36	.36	.39
Feed required for 100 pounds of gain			
Wheat	280.67	258.05	243.53
Ground flaxseed		44.97	
Cottonseed meal			52.81
Alfalfa	696.89	627.08	583.86
Dressing percent based on cold weights	48.98	50.73	50.11

One ton of cottonseed meal replaced 1406.6 pounds of wheat and 4280.6 pounds of alfalfa hay and had a replacement value of $34.70 at current prices, as given in table 16. Ground flaxseed had a feed replacement value of $25.00 per ton in this ration which does not compare as favorably for the ground flaxseed when fed with wheat as when fed with barley. See table 24 for the replacement value of flaxseed at varying prices in this ration.

A biometrical analysis of the lot fed wheat, ground flaxseed and alfalfa compared with the lot fed wheat,

cottonseed meal and alfalfa shows that the biometrical mean gain in the cottonseed meal lot was 40.90; the standard deviation was 5.34 and the probable error of the mean was ± .805. These calculations are made on the basis of the 20 lambs finishing the feeding period. This is compared with the lot fed ground flaxseed with wheat, which lot showed a biometrical mean gain of 37.86, a standard deviation of 5.74 and a probable error of the mean of ± .845, based on the 21 lambs finishing the feeding period.

The difference between the means is 3.04. The square root of the sum of the squares of the probable errors is 1.17, indicating that the difference of gain in favor of the lot fed cottonseed meal is not significant since 3.04 is not three times 1.17.

Market data relative to these lots is given in table 29 on page 83.

Ground Flaxseed Added to a Ration of Wheat and Alfalfa Shows Insignificant Gains

It has been shown that the addition of ground flaxseed to a barley and alfalfa ration produced a significant gain over the ration fed no nitrogenous supplement. The reverse is true when ground flaxseed is added as a nitrogenous supplement to a wheat and alfalfa ration.

The wheat and alfalfa ration produced a

biometrical mean gain of 37.24 pounds. The standard deviation was 6.37 and the probable error of the mean was ± .939 based on the 21 lambs finishing the entire feeding period. When this is compared with the calculations given on page 67 for the lot fed wheat and alfalfa with the addition of ground flaxseed as a nitrogenous supplement, it is found that the difference between the means is .62 and the square root of the sum of the squares of the probable errors is 1.26 which is indicative of an insignificant difference.

One of the most significant things that this work would seem to indicate is the fact that ground flaxseed, when fed with barley as the basic grain, is productive of gains which are clearly significant, but when fed with wheat as the basic grain, the gains are clearly insignificant. No explanation is offered for this though an opinion is ventured on page 76 under the discussion relating to graph F.

Comparison of Ground Flaxseed with Linseed Oil Meal and Cottonseed Meal in a Wheat-Wet-Beet-Pulp-Alfalfa Ration

It is not possible to give as complete data on this phase of the experiment as has been possible in the discussion of ground flaxseed when fed with the barley rations and with wheat without wet beet pulp for the reason that no lot was fed wheat, wet beet pulp and alfalfa, and consequently accurate replacement values

cannot be computed. It is very interesting to note, however, that ground flaxseed, when fed with wheat and wet beet pulp, compares much more creditably than when fed without the pulp. This is more especially true when compared with linseed oil meal than when compared with cottonseed meal.

Table 26 gives the results obtained with three rations, namely,

1. Wheat, ground flaxseed, wet beet pulp and alfalfa hay.
2. Wheat, cottonseed meal, wet beet pulp and alfalfa hay.
3. Wheat, linseed oil meal, wet beet pulp and alfalfa hay.

Table 26

The Relative Values of Ground Flaxseed, Cottonseed Meal and Linseed Oil Meal When Fed with Wheat, Wet Beet Pulp and Alfalfa

	Wheat Ground flaxseed Wet beet pulp Alfalfa	Wheat Cottonseed meal Wet beet pulp Alfalfa	Wheat Linseed oil meal Wet beet pulp Alfalfa
Initial weight per lamb	64.71	64.50	64.81
Feedlot gain per lamb	42.79	42.62	40.24
Biometrical mean gain of 21 lambs	43.524	43.29	41.238
Daily gain per lamb	.41	.41	.39
Feed required for 100 pounds of gain			
Wheat	207.65	208.09	218.04
Ground flaxseed	39.21		
Cottonseed meal		49.31	
Linseed oil meal			61.22
Wet beet pulp	1154.79	1159.60	1213.67
Alfalfa	446.70	425.65	417.33
Dressing percent based on cold weights	52.06	51.09	51.21

At current prices, the cost of producing 100 pounds of gain in the feedlot with the lot fed ground flaxseed was $4.92; with the lot fed cottonseed meal the cost per 100 pounds of feedlot gain was $4.87; and with the lot fed linseed oil meal the cost of producing 100 pounds of feedlot gain was $5.41.

A biometrical comparison of the lambs finishing the feeding period in these three lots is presented in

table 26a as follows:

Table 26 a

Biometrical Comparison of the Differences of Gains Obtained by the Feeding of Three Wheat-Fed Lots With Three Different Nitrogenous Supplements

Ration	Wheat Ground flaxseed Wet beet pulp Alfalfa	Wheat Cottonseed meal Wet beet pulp Alfalfa	Wheat Linseed oil meal Wet beet pulp Alfalfa
Biometrical true mean difference of gain with 21 lambs (Initial minus final)	43.524	43.29	41.238
Standard Deviation	6.14	5.99	5.22
Probable error of the mean	± .904	± .882	± .769

A comparison of the gain secured by the lot fed ground flaxseed and the lot fed cottonseed meal shows that the difference between the biometrical true mean gains of these two lots is .23 pound. The square root of the sum of the squares of the probable errors of the means is ± 1.26, indicating that the difference of gain between these lots is insignificant.

When the lot fed flaxseed is compared with the lot fed linseed oil meal the difference between the means is found to be 2.286. The square root of the sum of the squares of the probable errors is found to be ± 1.18, indicating that between ground flaxseed, linseed oil meal and cottonseed meal as nitrogenous supplements in a

wheat-wet-beet-pulp-alfalfa-hay ration, no significant differences exist so far as relative gains of weight are concerned.

Detailed market data relating to the grades of carcasses on these lots are given in table 29 on page 83.

Comparative Average Daily Gains

To this point ground flaxseed has been discussed in the various rations in which it was fed. Table 27 shows the average daily feedlot gains made in each of the lots discussed in this work.

Table 27

Daily Gains by Lots

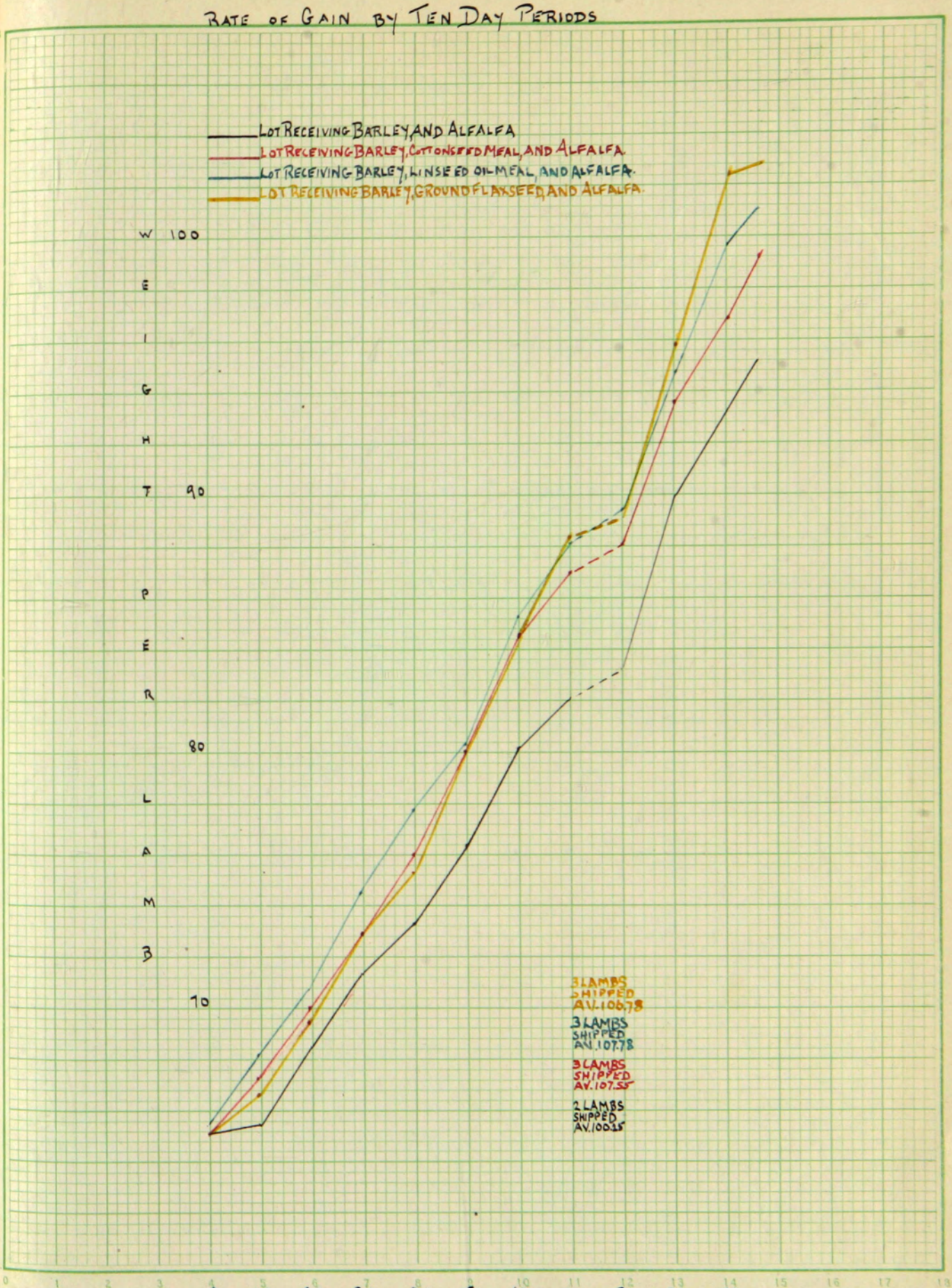
Ration	Daily Gain
Corn, alfalfa (Standard ration)	.36
Barley, alfalfa	.30
Barley, flaxseed, alfalfa	.38
Barley, cottonseed meal, alfalfa	.35
Barley, linseed oil meal, alfalfa	.36
Barley, wet beet pulp, alfalfa	.35
Barley, flaxseed, wet beet pulp, alfalfa	.42
Barley, cottonseed meal, wet beet pulp, alfalfa	.38
Barley, linseed oil meal, wet beet pulp, alfalfa	.40
Wheat, alfalfa	.36
Wheat, flaxseed, alfalfa	.36
Wheat, cottonseed meal, alfalfa	.39
Wheat, linseed oil meal, alfalfa	.39
Wheat, flaxseed, wet beet pulp, alfalfa	.41
Wheat, cottonseed meal, wet beet pulp, alfalfa	.41
Wheat, linseed oil meal, wet beet pulp, alfalfa	.39

Graph E, which comprises page 75, indicates the rate of gain in the barley-fed lots without wet beet pulp. It is interesting to note that a study of this graph indicates that the lot fed flaxseed failed to make comparable gains with the lots fed cottonseed meal and linseed oil meal until after the expiration of 60 days, at which time they were on full feed of ground flaxseed. As has been previously mentioned, care was exercised in the feeding of ground flaxseed more so than in the feeding of the other nitrogenous concentrates, and while lots fed the linseed oil meal and cottonseed meal were not up to full feed much sooner than the flaxseed lots, yet it must be realized that 0.2 pound per lamb was the maximum feed of ground flaxseed in all cases, which, without much question, was not by any means the maximum that could have been safely fed. This statement is made in view of work done with 14 head of the poor lambs which were considered too poor to use for experimental purposes and which were fed as high as 0.6 pound daily. A summary of this work appears on page 80 of this thesis. It is reasonable to suppose, therefore, that, with the addition of another 0.1 pound daily, more satisfactory results with flaxseed might easily have been obtained without adding greatly to the cost of the rations.

In presenting the graphs showing the rate of gain it has been necessary to indicate the time of ship-

GRAPH E

RATE OF GAIN BY TEN DAY PERIODS



ment at the end of the 70-day period and this has been done by means of broken lines with the notation on the graphs of the numbers of animals shipped and their average feedlot weights.

Graph F, which comprises page 77, shows similar material relative to the wheat-fed lots without wet beet pulp. As has been previously brought out in the preceding data presented in tables 23, 24, 25 and 26, ground flaxseed very evidently did not compare as favorably with linseed oil meal and cottonseed meal in the wheat rations. No explanation is offered for this phenomenon but the speculation is advanced by Professor B. W. Fairbanks of the Colorado Agricultural College that possibly the proteins of flaxseed are of such a character as to fail to "nick" with the proteins of wheat. It would be of interest to experiment with corn as the basic grain.

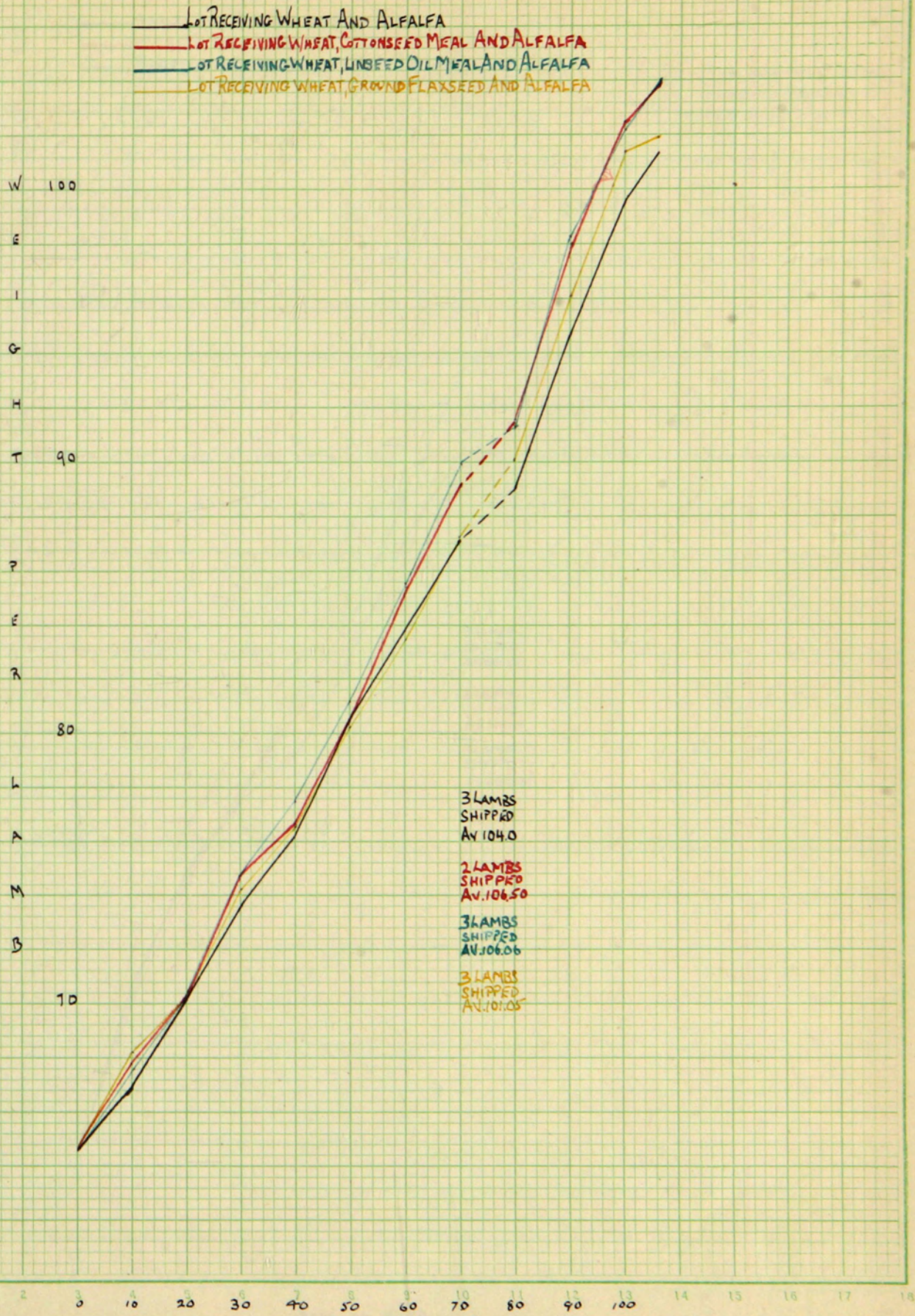
Graph G, which comprises page 78, indicates the rate of gain in the barley lots which were fed wet beet pulp. Here ground flaxseed makes its best showing when compared with linseed oil meal and cottonseed meal. From the start of the experiment to the finish the flaxseed-fed lot gained at a greater rate and successfully held their gains.

Graph H, which comprises page 79, shows similar results obtained with the wheat-fed lots that received wet beet pulp. While the rate of gain was somewhat more

GRAPH F

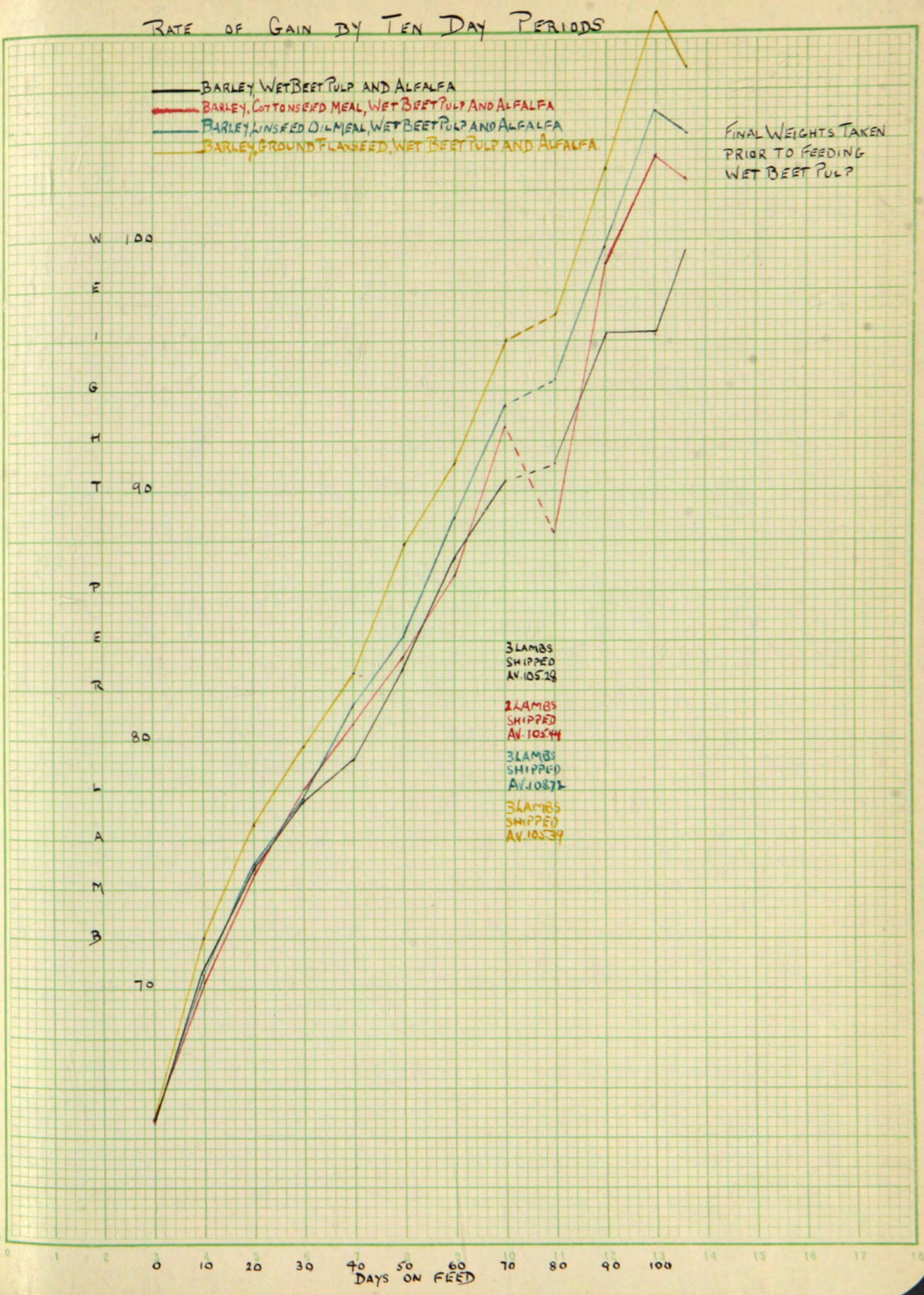
11.

RATE OF GAIN BY TEN DAY PERIODS

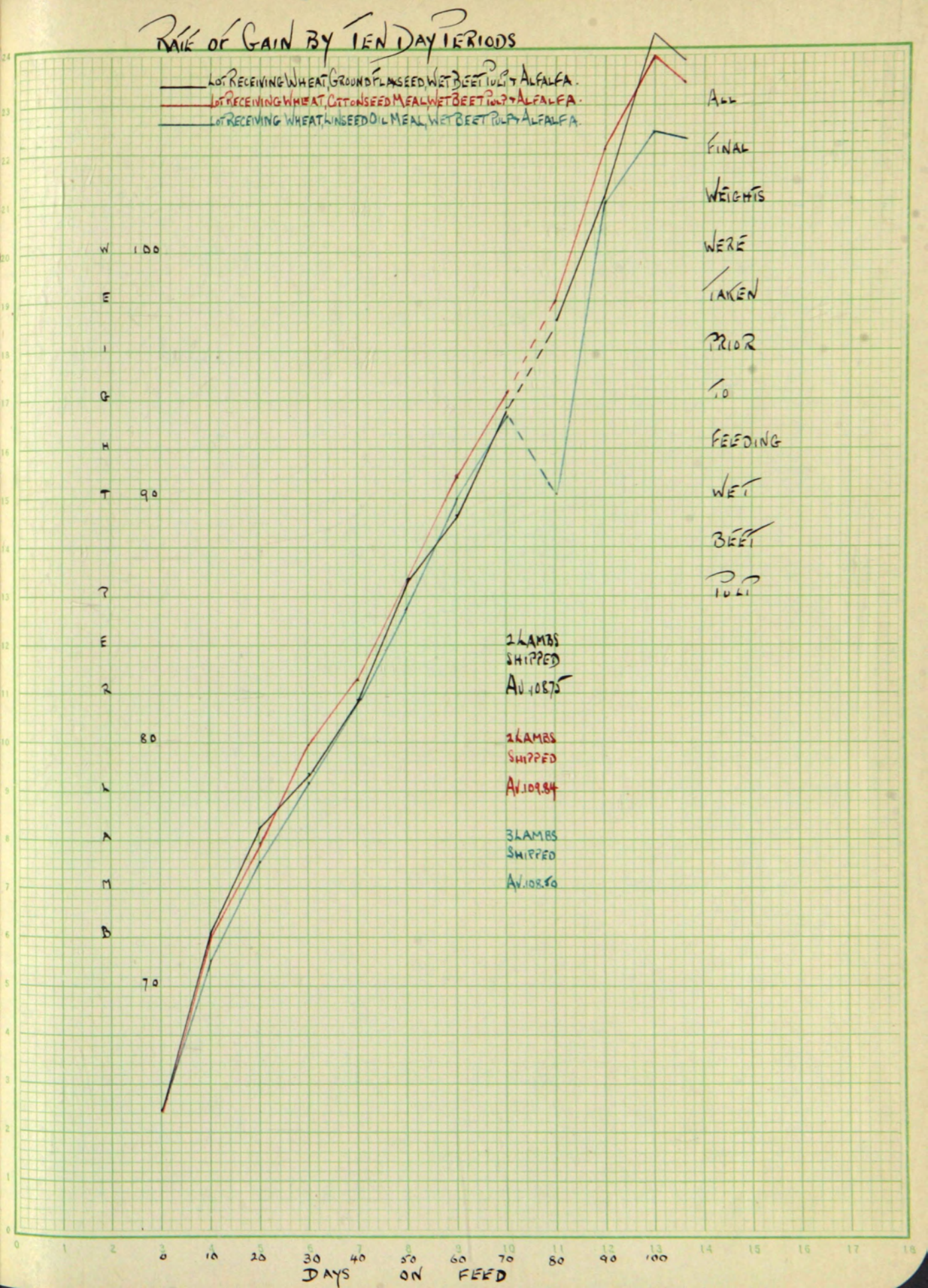


GRAPH G

RATE OF GAIN BY TEN DAY PERIODS



Rate of Gain By Ten Day Periods



satisfactory in the wheat lots that received wet beet pulp than in those wheat lots not receiving pulp, there is not the clear advantage over cottonseed meal and linseed oil meal in the lot fed wheat and wet beet pulp with ground flaxseed, such as exists in the lot fed barley and wet beet pulp with ground flaxseed.

Significant Results from Maximum Feeding of Ground Flaxseed

It has been previously mentioned that 14 lambs were in such poor condition at the start of the experiment that it was considered inadvisable to allot them as a part of the experiment. One of these lambs died within a week after being separated from the flock, undoubtedly due to its emaciated condition.

The remaining 13 lambs were placed in a lot by themselves and fed wet beet pulp and alfalfa hay with a little oats and barley until they seemed improved in health. They were then fed a ration of barley, wet beet pulp and alfalfa hay with the addition of a small amount of ground flaxseed. Since there was nothing to be lost by increasing the ground flaxseed content of the ration, this was done until each lamb was receiving 0.6 pound daily at the end of the seventieth day. At this point they refused to eat more ground flaxseed, but it is significant that they did very well and suffered no irregularity whatever. The condition of the feces was

slightly oily but well formed; otherwise, normal. No scours were encountered at any time; in fact, the ration was so successful that it brought these lambs out of their weakened condition and by market time all but one had made substantial gains and compared favorably with the lambs marketed from the experimental lots.

Ground flaxseed was fed in this lot up until thirty-five days prior to marketing. By this time it had been found that the lambs would not consume in excess of 0.6 pound of ground flaxseed daily, so the amount of flaxseed was gradually reduced and finally discontinued a full month prior to marketing.

It is regrettable that no initial weight on these 13 lambs was taken but a close estimate of their weight at the start can be taken as 55.0 pounds. They were kept on feed 116 days to market and, while no final feedlot weight was taken, the following comparison given in table 28, based on market weights, gives an idea of how these heavily-fed flaxseed lambs finished.

Table 28

Comparison of Lambs Weighed at Market

Average weight of all lambs in experimental lots at market	99.54
Average weight of heavily-fed flaxseed lambs (too poor for experiment at start) at market	94.23

It is possible and altogether probable that the difference in the final market weight of these lambs as compared with the lambs finishing in the experimental lots is due in large measure to the difference between their average initial weights. It is estimated that the average initial weight of the poor lambs was 55.0 pounds. The average of the lots on the experiment had an initial weight of 64.59.

At market one of this lot was cut at the plant of Armour and Company and the meat compared favorably with another lamb from a lot that had received no flaxseed. While the meat of the flaxseed-fed lamb was a shade darker in color, both were graded as "bright". The average dressing percentage of these flaxseed-fed lambs was 51.40, based on cold weights.

Market Data

Table 29 is presented to show the comparative market data by lots.

Table 29

Comparative Market Data by Lots

Ration	Dressing percent	Grades				
		Choice	Good	Medium	Common	Heavy
Heavily-fed flaxseed lot not on experiment	51.40	11	1	0	1	0
Barley, ground flaxseed, alfalfa	48.54	21	1	1	0	1
Barley, ground flaxseed, wet beet pulp, alfalfa	51.18	19	0	0	0	5
Wheat, ground flaxseed, alfalfa	50.73	24	0	0	0	0
Wheat, ground flaxseed, wet beet pulp, alfalfa	52.06	18	0	0	0	5
Barley, alfalfa	48.10	21	2	0	0	0
Barley, cottonseed meal, alfalfa	49.96	21	1	0	0	2
Barley, linseed oil meal, alfalfa	50.05	22	2	0	0	0
Barley, cottonseed meal, wet beet pulp, alfalfa	50.51	22	0	0	0	1
Barley, linseed oil meal, wet beet pulp, alfalfa	51.24	20	1	0	0	3
Barley, wet beet pulp, alfalfa	50.70	19	2	0	0	0
Wheat, alfalfa	48.98	22	1	0	0	1
Wheat, cottonseed meal, alfalfa	50.11	21	0	0	0	1
Wheat, linseed oil meal, wet beet pulp, alfalfa	51.21	19	0	0	0	5
Wheat, linseed oil meal, alfalfa	48.24	19	3	0	0	2
Wheat, cottonseed meal, wet beet pulp, alfalfa	51.09	19	0	0	0	4
Corn, alfalfa (Standard ration)	49.42	20	3	0	0	0

This table shows that from the standpoint of dressing percentage the lots fed ground flaxseed were fully as good as the other lots in the experiment. Wheat, ground flaxseed, wet beet pulp and alfalfa produced the highest dressing percentage of the lots compared, although this lot was heavy and five of the 23 head were graded as heavy.

SUMMARY AND CONCLUSIONS

In summarizing the data pertaining to this work attention is called to the statement of the problem as presented early in the thesis. Death loss in the flaxseed-fed lots was one percent. This loss is considered very low in view of the widely accepted theory that the feeding of flaxseed causes heavy death loss. The literature pertaining to this subject states that flaxseed does have properties which, when combined with certain weather conditions, undoubtedly develop a higher hydrocyanic acid content and an increased enzymic action than is apparently developed under the conditions under which these lambs were fed and, because the death loss in this case was not large, it should not be assumed that it never would be abnormal. For reasons given it is reasonable to expect that lambs that are fed under hot and dry conditions might suffer unusual losses from death caused by hydrocyanic acid and enzymic activity.

The maximum daily feed of flaxseed per lamb was 0.2 pound. Indications are that ground flaxseed could be fed in somewhat larger amounts safely. It is probable that the feeding of larger amounts of ground flaxseed would induce somewhat quicker gains. The average feed per lamb was 0.16 pound daily and the maximum feed was not reached until the fifty-fourth day. It is probable that the maximum feed could be beneficial-

ly reached at an earlier date.

It is significant that ground flaxseed fed with wheat as the basic grain ration was not as productive of as good results as when fed with barley as the basic grain, although when pulp was added to the wheat-alfalfa-flaxseed ration the flaxseed produced better results than without the addition of pulp.

It was found that one ton of ground flaxseed replaced 3202.50 pounds of barley and 8444.34 pounds of alfalfa in a barley-alfalfa ration, giving it a feed replacement value of $57.80 per ton at current prices, compared with $34.37 per ton for linseed oil meal and $38.41 per ton for cottonseed meal. (Prices used throughout the entire work were as follows: Wheat, $15.00 per ton; barley, $15.00 per ton; cottonseed meal, $25.00 per ton; linseed oil meal, $35.00 per ton; ground flaxseed, $30.00 per ton; alfalfa, $8.00 per ton; and wet beet pulp, $1.70 per ton).

When fed with barley, wet beet pulp and alfalfa, one ton of ground flaxseed replaced 1996.96 pounds of barley, 10,655.06 pounds of wet beet pulp, and 1981.58 pounds of alfalfa, giving it a feed replacement value at current prices of $31.97 per ton compared with $26.24 for linseed oil meal and $17.75 for cottonseed meal.

In a wheat and alfalfa ration one ton of

ground flaxseed replaced 1006.00 pounds of wheat and 3104.74 pounds of alfalfa, having a feed replacement value at current prices of $25.00 per ton compared with $25.08 for linseed oil meal and $34.70 for cottonseed meal.

When ground flaxseed was fed with wheat, wet beet pulp and alfalfa it cost $5.98 to produce 100 pounds of feedlot gain compared to $5.93 for the lot fed cottonseed meal and $6.53 for the lot fed linseed oil meal.

The application of biometry to the various gains made by those lambs completing the entire feeding period indicates the following summary:

Significant Differences

1. The addition of ground flaxseed to a barley-alfalfa ration.
2. The addition of ground flaxseed to a barley-wet-beet-pulp-alfalfa ration.
3. The substitution of ground flaxseed for cottonseed meal in a barley-wet-beet-pulp-alfalfa ration.

Insignificant Differences

1. The addition of ground flaxseed to a wheat-alfalfa ration.
2. The substitution of ground flaxseed for either cottonseed meal or linseed oil meal in a wheat-wet-beet-pulp-alfalfa ration.
3. The substitution of ground flaxseed for linseed oil meal in a barley-wet-beet-pulp-alfalfa ration.
4. The substitution of ground flaxseed for either cottonseed meal or linseed oil meal in either a barley-alfalfa ration or a wheat-alfalfa ration.

A maximum of 0.6 pound of ground flaxseed was given daily to 13 head of lambs considered too poor to place in experimental lots. The lambs refused to eat larger quantities of ground flaxseed but thrived well and made excellent gains. No abnormal condition of the feces was noted at any time and these lambs appeared to be in excellent health. Market data show that the dressing percentage of the flaxseed-fed lots compared favorably with the other lots.

While this work covers experimental data for one feeding trial, and for this reason should be duplicated before any definite conclusions can possibly be formed, it does show that ground flaxseed has possibilities as a nitrogenous concentrate supplement in the fattening of lambs. Favorable comparisons were made by the lots fed ground flaxseed, especially when used with barley as the basic grain. Feedlot results and market data both show that it is reasonable to believe that ground flaxseed can profitably be fed in northern Colorado for fattening lambs during the winter time.

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