NUTRITIONAL SIGNIFICANCE OF LINSEED MUCIN IN RUMINANT RATIONS

by

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INTRODUCTION

Linseed oil meal represents one of several oil meals commonly used in supplementing roughage and grain fattening rations fed to beef cattle. The protein, energy and mineral nutritive properties of these oil meals (linseed oil meal, soybean oil meal, cottonseed meal, etc.) have been well established in the past in cattle experiments and in feeding practice. In addition to these nutritional properties, certain other nutritional properties for linseed oil meal have been claimed by some and disputed by others. In particular, linseed oil meal has been claimed to possess properties beneficial to the appearance (sleekness or "bloom") of the haircoat of cattle and this in turn has been inferred to be an indication that cattle fed linseed meal possess fatter and superior beef carcasses. These claims have been further extended on the basis that the relatively large content of mucin present in linseed meal is the active material responsible for the improved sleekness of the haircoat of cattle (Hayward, 52). However, no satisfactory quantitative data has been developed in substantiating this premise.

In contrast to the mucin theory, the theory has been held by many feeders that the oil present in linseed meal is the active constituent responsible for superior haircoat "bloom". For example, some feeders still express a preference for

hydraulic or expeller processed meals to solvent meals on the basis that the former contains larger amounts of residual oil.

The effect of linseed oil meal upon hair coat "bloom" of cattle has not previously been critically evaluated. The evaluation of haircoat "bloom" has been accomplished in the past by visual comparison alone. This method of evaluation has been satisfactory in establishing large differences in haircoat "bloom", but remains too insensitive to determine small differences often encountered in experimental research. A technique was therefore needed to quantitatively measure small differences in the degree of "bloom" of experimental animals.

The objectives of this study were three-fold. The first objective was to develop a technique and/or an apparatus to quantitatively measure the gloss or "bloom" of an animal's haircoat. A second objective was to quantitatively measure the degree of "bloom", if any, imparted by linseed oil meal and to determine the factor or factors responsible for this condition of "bloom". The third objective was to determine the relative merits of linseed oil meal and fractions of linseed oil meal in ruminant rations upon feedlot performance and carcass quality of meat producing ruminants.

REVIEW OF LITERATURE

The literature concerning the feeding of oil meal supplements is so voluminous that no attempt will be made to give a complete review. Only the literature that is most closely related to this study will be reported in order to give the reader a more complete knowledge of the subject.

Growth and "Conditioning" Properties of Linseed Oil Meal in Ruminant Rations

It has been shown by many workers (Wilson and Wright (104); Guilbert and Rochford (48); Weaver and Oderkirk (102); Blackman (14); Nevens (83)) that linseed oil meal contained growth and "conditioning" properties not normally found in other oil meals. Studies at the Michigan Experiment Station by Branaman (19) indicated that linseed oil meal when added to a ration of corn or other grain, corn silage and hay, greatly increased the rate and efficiency of gains made by steers. Linseed oil meal was also shown to be associated with higher market finish, higher selling price for the finished cattle and greater returns over the cost of calf and feed.

Morrison (80) has made a careful analysis of 36 cattle experiments and found that linseed oil meal produced about 10 per cent more efficient gains and a higher finish and selling price than cottonseed oil meal. The gains on linseed oil meal

and cottonseed oil meal were equal, but because of the higher selling price the net returns were higher for cattle fed linseed oil meal than for those fed cottonseed oil meal. In contrast, Osland et al. (86), in a two-year cattle feeding test found that cottonseed oil meal cake produced slightly greater and cheaper gains than linseed oil meal cake. Linseed cake increased the dressing percentage and carcass grade, but did not increase the selling price.

Wilson and Wright (104) found that tankage was not as palatable as linseed oil meal or cottonseed oil meal in cattle rations and did not produce as rapid gains. A 50-50 mixture of tankage and linseed oil meal was more palatable and improved gains over tankage alone, but did not equal linseed oil meal fed alone.

Watson (101) found that linseed oil meal was equal in feeding value to cottonseed oil meal for feeding cattle but was more expensive feed. Ground flaxseed produced more "bloom" and finish, but was not practical because of the limited quantity available. Similarly, Guilbert and Rochford (48) found that linseed oil meal, although lower in protein than 43 per cent cottonseed oil meal, gave results in cattle feeding experiments equal to or superior to cottonseed oil meal. Linseed oil meal was slightly laxative, appeared to have a "tonic" effect and was particularly credited with the properties of "bloom" and fine condition of hair.

Culbertson et al. (35) in comparing linseed oil meal,

tankage and soybean oil meal found that steer calves gained approximately the same on all the protein supplements. Hinman et al. (57) found that linseed oil meal gave a slight increase in gains over corn gluten meal, soybean oil meal and ground soybeans in a series of four yearly tests.

Culbertson (34) when comparing a linseed oil meal supplement containing varying amounts of urea found that steers receiving a supplement in which all the linseed oil meal had been replaced by urea made the lowest gains. The greatest gains were made in lots where urea replaced half of the linseed oil meal.

Morrison (80) has stated that linseed oil meal is of particularly high value for fattening cattle because it produces rapid gains and excellent finish. Cattle fed linseed oil meal usually have a trifle sleeker hair coat than those fed other common protein supplements. These cattle tend to sell for a slightly higher price though the actual value of their carcasses may be no greater. Because of this conditioning effect, linseed oil meal is commonly included in concentrate mixtures for cattle that are being fitted for show or for sale.

Linseed oil meal was found by Robbins (90) to be worth a little more in the rations of cattle than soybean oil meal or cottonseed oil meal because it puts a smoother finish or

"bloom" on the cattle. A mixture of one or both of these feeds with linseed oil meal, in about equal proportions, gave about the same result as linseed oil meal alone.

A progressive decrease in the apparent digestibility of the carbohydrate fraction was observed by Watson et al. (100) when steers were fed increasing amounts of linseed oil meal (1-5 kg) in combination with timothy hay (3.0 kg). The protein and ether extract fractions showed no significant change in apparent digestibility as the level of linseed oil meal was increased, however, the apparent digestibility of dry matter and organic matter was significantly lowered.

Burroughs et al. (24) in comparing linseed oil meal with and without stilbestrol found that linseed oil meal without stilbestrol performed well, but poorer than other supplements containing stilbestrol. Adding stilbestrol to linseed oil meal transformed it into a top performing cattle supplement. Adding stilbestrol to linseed oil meal increased gains of cattle by 10.3 per cent.

Culbertson (33) in comparing new process linseed oil meal to old process linseed oil meal fed five lots of eight steers for 219 days. It was found that linseed oil or linseed oil fractions were not the fractions in linseed oil meal responsible for its fine conditioning properties. The new process linseed oil meal without added linseed oil was as effective in promoting liveweight gains and producing finish as the old

process linseed oil meal. In further work, Iowa workers (33) found that there was no difference in the growth of steers fed for 210 days on either hydraulic, expeller or extracted linseed oil meals. Similarly, Nebraska workers (82) found no difference in average daily gain or selling price of heifers receiving either expeller or extracted linseed oil meal for 184 days.

Workers at the Colorado station (29) have compared linseed oil meal pellets processed by the extraction or solvent method with linseed oil meal pellets processed by the expeller method when fed to steers receiving a fattening ration of barley, corn, dried beet pulp and alfalfa hay. No significant differences were noted in rate of gain, however, the amount and cost of feed required per unit of gain were slightly less for the steers fed the expeller linseed oil meal pellets. Carcass yields and grades for the steers fed the extracted linseed oil meal pellets were higher than those fed the expeller pellets. There was no difference in grade on foot and all lots of cattle sold for approximately the same price. In further work two lots of 10 steers each were fed by the Colorado worker (30) in comparing expeller linseed oil meal pellets and extracted linseed oil meal pellets. After 133 days, no difference was found in average daily gain or dressing per cent, however, the cost of the extracted linseed oil meal pellets was slightly higher. Alexander (1) found that the

performance of extracted linseed oil meal pellets was as satisfactory as expeller linseed oil meal pellets for fattening lambs.

In describing rations for wintering steers, a Nebraska circular (81) has stated that of the protein feeds of plant origin, there is little difference between linseed oil meal, cottonseed oil meal and soybean oil meal. Relative price should be the determining factor.

Weaver and Oderkirk (102), Blackman (14), Davis (38) and Nevens (83) highly recommended the feeding of linseed oil meal to dairy cattle because it was palatable, laxative and produced sleek pliable hides. Because of these merits, linseed oil meal has been especially valuable for animals being fitted for show. Weaver and Oderkirk further stated that linseed oil meal was one of the few feeds in which the protein content could not be employed as a definite criterion of the feeding value. Linseed oil meal possesses advantages not measurable by chemical analysis.

Nevens (83) found that linseed oil meal offset the unfavorable effects of poor quality roughage while Blackman (14) recommended that linseed oil meal should be included in the grain mixture for all dairy cattle. Bohstedt (16) recommended that at midseason dairy calves should have two to three pounds of linseed oil meal plus one to two pounds of bran daily to make up for lack of good pasture at this part of the season.

Linseed oil meal was equal to, but not superior to soybean oil meal, ground soybeans, whitefish meal, corn gluten feed, or urea as a protein supplement for dairy cattle in studies by Monroe and Krauss (78), Bohstedt (16), Rupel et al. (92, 93), Hilton et al. (56), Cunningham and Addington (36) and Hunt (62). Hunt (62) mentioned that linseed oil meal fed cattle had sleeker coats and appeared to be in the best condition.

Russian trials by Denisov (39) showed linseed oil meal to be 98.5 per cent and rape oil cake only 88.5 per cent as good as a standard German cake for milk production. Brouwer (20), however, found linseed oil meal and peanut meal to have equal value for milk production.

Weaver and Oderkirk (102) found that old process and new process linseed oil meal were about equal in feeding value, but the protein of the old process linseed oil meal was more digestible. These workers also found that the old process linseed oil meal was more palatable and had a more pronounced laxative effect. Honcamp et al. (59) disproved this by showing that extracted linseed oil meal was equal to the old process linseed cake for milk and butterfat production. They found the digestibility of the two meals to be about the same. In similar work, Loosli et al. (71) showed that solvent process linseed oil meal could be successfully fed to dairy cattle but milk production was increased when fat was added to the

ration.

Espe and Cannon (42) reported gains of one pound daily per head when calves were fed from three to nine weeks of age on reduced amounts of milk products supplemented by a gruel of oatmeal and linseed oil meal. Morrison (80) has mentioned the palatability of linseed oil meal as favoring its use in calf nutrition.

Milk yields, fat content and quality of butter were studied by Davidov and Aristova (37) on three groups of cows receiving 0, 140 grams and 240 grams of linseed oil meal cake per kilogram of milk produced over a 95-day period. Milk yield and fat content increased progressively as the level of linseed oil meal cake increased. Butter from cows receiving the 240 grams of linseed oil meal cake was yellower in color, had a lower viscosity, a lower saponification number and a higher iodine number than butter from cows receiving 140 grams of linseed oil meal cake. It was recommended that the amount of linseed oil meal cake should not exceed 140 grams per kilogram of milk produced.

Frye et al. (47) found that there was a significant difference in the iodine values of the milk fat from cows fed linseed oil meal and from cows fed cracked soybeans continually at the rate of 11.1 per cent of the concentrate mixture. The iodine values of the milk fat from cows fed the linseed oil meal ration were generally higher than were those of the

milk fat from cows fed the cracked soybean ration.

As observed by Huffman and Moore (61), the hardness or softness of the feces of dairy cows was not altered by changing rapidly from a heavy cottonseed oil meal ration to a heavy linseed oil meal ration. These workers found that cottonseed oil meal was not a constipating feed for dairy cattle or was linseed oil meal found to be a laxative feed for dairy cattle.

The dry fodder of dairy cows was supplemented with 5, 10 or 20 kilograms of carrots per cow per day by Kieferie and Seuss (67) to enrich the winter milk with carotene and vitamin A. When 1 kilogram of linseed oil meal was added an increase of 12 per cent of vitamin A was found in the milk over the carrot fed group. The minimum limit of 50 micrograms per cent of vitamin A in summer milk was not quite reached by the 5, 10 or 20 kilogram supplement, however, the linseed oil meal group gave an average of 51-66 micrograms per cent.

Feeding 7.8-9.0 pounds of cottonseed oil meal or 6.0-12.6 pounds of linseed oil meal with timothy hay and corn silage to Holstein heifers had little effect on hardness or softness of the feces as reported by Moore (79). The consistency of the feces was not affected materially by the amount of either cottonseed oil meal or linseed oil meal with or without a succulent roughage such as corn silage.

Studies by Jordan and Peters (65, 66), Brown (21), Brown and Blakeslie (22) and Willman and Morrison (103) with fatten-

ing lambs showed that linseed oil meal produced greater average daily gains than other protein supplements, such as cottonseed oil meal, corn gluten meal, soybeans or soybean oil meal, distillers dried grains, or brewers dried grains. On the other hand, studies by Alexander and Weber (4), Alexander (3), Dunn and Evvard (40), Cox (31, 32), Watson (101) and Jones et al. (64) pointed toward no difference in weight gains produced by any of these supplements.

Miller and Morrison (75), Miller et al. (76) and Miller (74) determined the apparent digestibility and biological value of linseed oil meal, soybean oil meal and corn gluten meal when fed to lambs. These workers found that urea alone was not well utilized by lambs, but when used in a 50-50 combination with linseed oil meal, the lambs utilized the nitrogen of urea as well as any of the other protein supplements tested. They also concluded that lambs apparently utilized the protein of linseed oil meal about as well as other species of animals since the biological values determined in these studies ranged from 56-68 per cent for lambs on linseed oil meal as compared to 58-73 per cent for lambs on soybean oil meal. In similar work it has been observed by Hamilton et al. (50) that rations containing 16.2 per cent protein (63 per cent protein equivalent from urea) were less efficiently utilized than those containing 11.4 per cent protein (46 per cent protein equivalent from urea). Nitrogen from urea was as well

utilized by growing lambs as was the same amount of nitrogen from dried skimmilk, dried skimmilk plus cystine, gluten feed and casein or casein plus cystine provided the protein equivalent did not exceed 14 per cent and at least 16 per cent of the total nitrogen was from preformed protein. The nitrogen from linseed oil meal was more efficiently utilized than that from urea.

The nitrogen retention of lambs was increased by the addition of 0.2 per cent methionine to a ration in which 40 per cent of the nitrogen was supplied by urea as reported by Lofgreen et al. (70). The lambs utilized egg protein more efficiently than linseed oil meal protein or that synthesized from urea. The biological value of the protein from urea, urea and methionine, linseed oil meal and dried egg were 71, 74, 76 and 80, respectively.

Although most experiments show that linseed oil meal is equal, but no better than other protein supplements for producing weight gains in fattening lambs, there are certain other advantages which linseed oil meal possesses over other protein supplements. Willman and Morrison (103) have indicated that lambs fed linseed oil meal had better "bloom" and finish than those fed other supplements. Because of this better appearance these lambs sold for a higher price. Martynov (72) reported that a mixture of linseed oil meal with the fermented feeds usually fed gave a more aromatic and palatable

feed for lambs than did a mixture of grain wastes with fermented feeds.

Bell and Weir (12) have found that rapeseed oil meal and mustard oil meal compare favorably with linseed oil meal except in palatability. No differences were observed by Burkitt (23) in the apparent digestibility of dry matter in rations consisting of grass hay and linseed oil meal and grass hay and rapeseed oil meal.

Iowa workers (63) have found that a lamb supplement made up of linseed oil meal, soybean oil meal, urea, minerals and vitamin D did not increase lamb gains over those obtained when only linseed oil meal was fed on a protein equivalent basis. The cost of the supplement, however, was in favor of the supplemental blend rather than in favor of linseed oil meal alone. To further study the effects of additional protein supplementation, these workers fed an additional four lots of lambs. The control lot was fed a ration containing 2.5 per cent linseed oil meal. Another lot was fed twice as much linseed oil meal, while a third lot received a blend of equal parts by weight of linseed oil meal and meat and bone scraps. The fourth lot received a supplemental blend of urea and minerals along with linseed oil meal. The lambs fed the blend of linseed oil meal and meat and bone scraps gained more than those fed the lesser amounts of linseed oil meal. The lambs receiving the special supplemental blend which contained linseed oil meal, urea and minerals made the best showing as far

as gains and feed requirements were concerned.

Four lots of 30 lambs each were fed by the Minnesota workers (77) in comparing hydraulic, expeller and extracted linseed oil meals. No differences were observed in average daily gains or selling price. Alexander (1) in a similar comparison found no difference in average daily gain even when silage was fed with the three types of linseed oil meals.

Mucilaginous Properties of Linseed Oil Meal

It has been mentioned by Morrison (80) and Watson (101) that cattle fed linseed oil meal possess a greater degree of "bloom" or have a trifle sleeker coats than those fed other common protein supplements. Hayward (53) has inferred that all the favorable functions contributed by linseed oil meal are due to the mucilage or "mucin" contained in linseed oil meal. Hayward has also stated that extracted linseed oil meal is as good as expeller linseed oil meal in its ability to confer "bloom" and top condition to livestock. Culbertson (33) in a similar comparison found that the oil content of linseed oil meal is not responsible for its "bloom" promoting properties.

It has been reported by Ewing (43) that no other feed of vegetable origin comes close to linseed oil meal in respect to its mucin content. The mucin content of linseed oil meal according to Ewing is around 10-15 per cent. Hayward (51) has stated that the mucin in linseed oil meal is important not

only because of its "bloom" promoting effect but also because it protects the digestive system against harmful irritants and toxins. The mucin in linseed oil meal according to Hayward has improved the performance of dairy cows either directly or indirectly by the following ways:

1. Increased milk flow.
2. Sharpened appetites and maintained animals on full feed.
3. Produced "bloom" and gave a sleek appearance to the animals.
4. Promoted good health.
5. Created good physiological conditions in the rumen because of its bulking and water-holding properties.
6. Increased contractions of the intestine.
7. Soothed and healed mucosa of the intestinal tract.
8. Deleted the animal of irritants and toxic products of digestion.
9. Promoted rapid growth of calves and young dairy animals. (51, p.

Hayward (52) has further stated that mucin aids in the elimination of waste products without irritation. This accounts for the conditioning effect of linseed oil meal and for the "bloom" it imparts to the animal.

The hulls of the flaxseed contain a mucilaginous substance which has had extensive medicinal use throughout the ages according to Oncken (85). Steeping flaxseed or linseed oil meal in water causes it to give up a mucilage which amounts to 15 per cent of the weight of the seed or 25 per cent of the weight of the meal. This material can be dried and will again take up water. Its lubricating and bulk form-

ing properties are not injured by drying.

Andre (9) has mentioned the preparation of a mucilage from solvent process linseed oil meal. He states that the powdered kernel of the flaxseed, which has been separated from the hulls by screening, is rich in phosphorus and nitrogen, and is a good feed for cattle.

Tipson et al. (95) and Kobseff (68) have described processes and equipment for extracting mucilage from flaxseed and linseed oil meal using the technique of soaking in water. Mason and Hall (73) have described a similar technique for obtaining a colloidal gum from linseed oil meal.

The biological effects of mucin have been tested in a few cases. Most of the work has been done with humans, since mucin has been considered a drug. Fogelson (45) has reported that over 70 per cent of 494 patients with peptic ulcer received benefit from gastric mucin treatment. This was not flaxseed mucin, but Oncken (85) has stated that flaxseed mucin has been used successfully for the same purpose.

Bradley and Hodges (18) and Henning and Norpoth (55) have reported that the peptic digestion of protein is retarded by the presence of gastric mucin. The effect of flaxseed mucin on protein digestion was not investigated in these studies.

Anderson and Fogelson (8) reported that when purified gastric mucin was fed to young rats as a source of nitrogen at a 20 per cent level, the average biological value was 60.5 per

cent and the apparent digestion coefficient was 71. The animals did not gain weight and showed only an insignificant nitrogen retention.

Ewing (43) has found that the mucin in linseed oil meal aids in feed pelleting operations when used at substantial levels in formula feeds. Mucin becomes viscous in the presence of either hot or cold water, and this seems to give the pelleting mixture good adhesion. Pellets containing modest to appreciable levels of linseed oil meal have an attractive appearance because of the smooth, glossy surface, and minimum of checking.

Bartley (11) has used linseed oil meal effectively in preventing bloat in cattle grazing pasture. Bartley postulates that it is the mucin in linseed oil meal that affords this protection.

Analysis of Linseed Oil Meal and Linseed Oil Meal Mucin

A flaxseed mucilage suitable for use in medicinal preparations, water paints, and the manufacture of soluble fibers has been prepared by Bolley and McCormack (17). The flaxseed was separated into kernel and hull fractions, the kernel being high in protein and the hull being high in mucilaginous material. The hull fraction, containing 11.0 per cent protein, was mixed with water in a ratio of one part of hull to 30

parts of water. The pH was adjusted to 4.5 and the mass was heated under agitation at 60-80° C for one hour. The liquid was extracted by centrifuging and adjusted to pH 7.0, concentrated by evaporation under reduced pressure, and spray dried. The dried mucilage was substantially protein- and fiber-free.

Fractionation of purified, ash-free mucilage by Easterby and Jones (41) into a water-insoluble calcium (45 per cent) salt and a water soluble fraction (55 per cent) with calcium acetate, and paper partition chromatography of the acid hydrolysis products of the soluble fraction, suggested the presence of 12 per cent galactose, 12 per cent arabinose, 27 per cent xylose, a trace of ribose and 29 per cent rhamnose. Similar methods utilized with the insoluble fraction indicated the presence of 8 per cent galactose, 9 per cent arabinose, 25 per cent xylose and 13 per cent rhamnose.

Vassel (98) has found that the mucilaginous substance present in flaxseed could be completely removed by soaking in 0.3 N hydrochloric acid or 0.3 N sodium hydroxide at temperatures below 100° C. The seed could then be dried, the oil extracted, and the residue treated with a dilute alkali-metal hydroxide solution. This could be filtered and the extracted portion could be removed by neutralizing the residue to a pH of 3.5 to 4.0.

Anderson and Lowe (7) have prepared flaxseed mucilage and the free acid of flaxseed mucilage (linseed acid) directly from flaxseed. The procedure involved a hot water extraction,

heating with dilute hydrochloric acid and precipitation with alcohol. A yield of around 5.8 per cent linseed acid was obtained from the seed. The flaxseed mucilage and linseed acid contained molar equivalent amounts of d-galacturonic acid, l-rhamnose, l-galactose, and d-xylose. During hydrolysis of the mucilage, d-xylose was the first and l-galactose the second sugar to be liberated. Also isolated from the mucilage was an aldotrionic acid composed of molar equivalents of d-galacturonic acid, l-rhamnose, and l-galactose. Anderson stated that flaxseed mucilage seemed to be a slat of a polymerized aldotetronic acid composed of molar equivalent of d-galacturonic acid, l-rhamnose, l-galactose, and d-xylose. The physical properties of the mucilage suggested a branched-chain structure. Tipson et al. (95) in similar work isolated an aldobionic acid from an ash-free flaxseed mucilage. Tipson found that this acid was a methyl ester of pentamethyl 2-d-galacturonido-methyl-l-rhamnoside and could be hydrolyzed with a mineral acid to give equimolar proportions of 3,4-dimethyl-l-rhamnose and 2,3,4-trimethyl-d-galacturonic acid.

Anderson and Crowder (6) have isolated an aldobionic acid during the partial hydrolysis of flaxseed mucilage. These workers found that this particular aldobionic acid contained one molecule of d-galacturonic acid joined through its aldehyde group to a molecule of l-rhamnose.

A yield of 6.3 per cent mucilage was obtained from

flaxseed by Neville (84). This material was a greyish-white powder having an equivalent weight of 710. The ash portion of this mucilage contained calcium, potassium, magnesium, iron and phosphorous. In analyzing this mucilage material, Neville found that it was slowly hydrolyzed by boiling mineral acids, but was not attacked by hot alkali. The material gave no coloration with iodine, did not reduce Fehlings solution and gave no reaction with phenylhydrazine. The material did not melt below 250° C and was unchanged by heating for some time at 150° C. When heated above 200° C for a long period of time it became brown and decomposition took place. Neville found that the heat of combustion of one gram of the mucilage was 3925 calories, which compared with cane sugar, starch and cellulose. The mucilage contained 41.96 per cent carbon and 6.37 per cent hydrogen. Neville likewise found that certain enzymes such as Toka diastase, barley diastase, "zymine", saliva, and pepsin had no effect on the mucilage. Approximately 75 per cent of the mucilage passed through the rat undigested.

Painter and Nesbitt (87) have obtained protein yields as high as 65 per cent of the total nitrogen by sodium hydroxide extraction of flaxseed. The yield was not as high when sodium chloride was used. The protein yields from flaxseed were limited because approximately 20 per cent of the nitrogen was non-protein-nitrogen.

A mucilage similar to flaxseed mucilage has been isolated from cress seed by Bailey (10). This particular cress seed mucilage contained l-arabinose, d-galactose, l-rhamnose, d-glucose, and d-galacturonic acid.

Ewing (43) has stated that perhaps the physical properties of linseed oil meal are additional to its other advantages as an ingredient in feed supplements. Linseed oil meal has an extremely high water-holding capacity of 8.1 parts of water to 1 part meal as compared to 1.75 for cottonseed oil meal and 3.25 for soybean oil meal. Ewing states that this high water absorption of linseed oil meal is associated with its conditioning properties and probably due largely to its mucin content.

In a study of the protein, minerals and vitamins of oil cakes, Ferrando (44) found that linseed oil meal cake was deficient in methionine and lysine for which to support normal rat growth. Ferrando found that the oil cakes were rich in phosphorous and low in calcium so that the calcium:phosphorous ratio was not biologically adjusted. The oil cakes lacked vitamin A, C, and D entirely but contained vitamin E and the vitamins of the B group.

Fraps (46) found that linseed oil meal contained 56 therms of productive energy per 100 pounds and 22.5 per cent of digestible protein.

Holmes (58) has found that in comparison to whole egg

protein, linseed oil meal was deficient in isoleucine and methionine.

Hayward and Witz (54) have found that linseed oil meal processed from Northern-grown flaxseed contains approximately 34.5-36.6 per cent protein, 1.1-4.3 per cent fat, 8.3-8.5 per cent crude fiber, 36.6-37.4 per cent nitrogen-free extract and 5.8-5.9 per cent ash depending upon whether the linseed oil meal was processed by the expeller or solvent method. Anderson (5) has found that solvent-processed linseed oil meal contains approximately 10 per cent more protein, 76 per cent less fat and 9.5 per cent less crude fiber than expeller processed linseed oil meal. Hayward (53) has observed that linseed oil meal as commonly produced in the United States by mechanical methods of oil extraction contains 28-39 per cent protein, 3.5-5.0 per cent fat, 7-12 per cent crude fiber, 34.5 per cent nitrogen-free extract, 5.0-6.5 per cent ash and 10-15 per cent mucin.

The amino acid composition of linseed oil meal cake expressed as a per cent of the cake was found by Yoichnickov et al. (105) to be as follows: tryptophane, 1.13; lysine, 3.15; arginine, 9.37; tyrosine, 1.32; cystine, 1.98; histidine, 1.52. Block and Mitchell (15) have found that the most common amino acids found in linseed oil meal protein were arginine, phenylalanine, tyrosine, threonine, leucine, valine, isoleucine and lysine.

Mason and Hall (73) have obtained a collodial gum from linseed oil meal by water-extraction and alcohol precipitation. Yields as high as 15-19 per cent have been obtained. The finished collodial gum contained 5-6 per cent ash, 3-4 per cent total nitrogen, 19-25 per cent protein (N x 6.25), 57-65 per cent nitrogen-free extract and no crude fiber or reducing sugars. The ash contained 8.0-8.5 per cent P_2O_5 and 0.75-1.00 per cent chlorides. The pH of a one per cent solution was 8.7.

In Vitro Cellulose Digestion As Affected by Water Extracts of Natural Feedstuffs

Burroughs *et al.* (25) improved the digestibility of corncob dry matter from 34.4 per cent to 48.9 per cent by the feeding of a water extract of dehydrated alfalfa meal to four Hereford steers over a 30-day period. Each steer received the extract from four pounds of alfalfa meal daily. Using the artificial rumen technique Burroughs *et al.* (27) have demonstrated a stimulation in urea utilization and cellulose digestion by the addition of a water extract of dehydrated clover. These stimulatory influences were more evident in fermentations beyond five days, probably due to the disappearance or diluting out of nutrient substances carried into the artificial rumen with the large volume (450 ml) of inoculating material.

Bentley *et al.* (13) using the artificial rumen technique

found that cellulose digestion was significantly increased when water extracts of alfalfa leaf meal, timothy hay, fresh-cut ladino clover, ground yellow corn, ground corn cobs, corn silage, beef muscle, yeast, or liver were added to the artificial rumen tubes. The factor(s) responsible for this stimulation in cellulose digestion seem to be especially rich in alfalfa leaf meal, molasses, yeast and rumen juice.

It has been reported by Burroughs et al. (26) that an autoclaved water extract of manure increased the cellulose digestion in the artificial rumen over a 36-hour fermentation period. This was confirmed by Ruf et al. (91) when studying unidentified factors that stimulate cellulose digestion in the artificial rumen. Ruf and associates found that a water extract of soybean oil meal would likewise increase the digestion of cellulose in the artificial rumen. The stimulatory factors studied by Ruf and associates were found to be heat stable, water soluble, and soluble in dilute ethanol. They were absorbed on Norite and were eluted with acetone and ethanol. These eluates were not as active as the original material. Since these factors were not absorbed on ion-exchange resins and ashing was found to destroy them, it was concluded that the factors were organic rather than mineral or inorganic. Precipitation of the proteins in water extracts of manure and yeast with hydrochloric acid or alkaline-zinc sulfate did not remove the active principle indi-

cating that they were non-protein.

Tosic (96) studied the effect of small quantities of a yeast preparation on the recovery of appetite in sheep. A water extract of bakers' yeast containing 2.3 grams of dry matter and 247 milligrams of nitrogen was introduced into the rumen of a sheep which had lost its appetite and considerable weight as well. Soon after the yeast treatment, this sheep almost doubled its feed intake and regained its body weight. Two other sheep in a similar condition were also treated with equal effectiveness, however, attempts to experimentally induce a loss of appetite in sheep so that this problem could be studied more extensively failed.

EXPERIMENTAL AND RESULTS

Preparation of Flaxseed Extract and Linseed Oil Meal Mucin

The flaxseed extract and linseed oil meal mucilage or "mucin"* used in the following experiments were prepared by a modification of the method described by Mason and Hall (73). This method consisted essentially of a hot water extraction of flaxseed or linseed oil meal and precipitation of the "mucin" by ethyl alcohol. Flaxseed was used in all of the experiments reported herein as the starting material for obtaining flaxseed extract and mucin primarily because of its high mucin content and larger particle size which facilitated better separation of the particles from the water in the water extraction process.

A steam-jacketed kettle with a capacity of approximately 55 gallons was used in the water extraction process. An 18 mesh copper-wire basket was molded around a steel frame and fitted within the kettle so that only 1-1 1/2 inches remained between the wall of the kettle and the basket. This basket was used to hold the flaxseed during extraction. A rubber air hose with holes spaced at approximately 3-inch intervals was attached to the underside of the basket and was used to

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*The term "mucin" will hereafter refer to the mucilaginous material in flaxseed or linseed oil meal which contains about 57-60% true mucin.

agitate the flaxseed during extraction. The kettle was equipped with a drain at the bottom so that the water extract could be drained into a container, leaving the flaxseed in the basket. The extraction apparatus is shown in operation in Figure 1.

Two hot water extractions were made on each quantity of flaxseed that went into the kettle. During the first extraction approximately 10 parts of water by weight was added to one part of flaxseed by weight. Due to the capacity of the kettle this amounted to 42 pounds of flaxseed and 50 gallons of water. The temperature was brought to 70-75° C and maintained for one hour. The flaxseed-water mixture was kept under gentle agitation by the air hose previously described. After the water extract had been drained from the first extraction, 25 gallons of water were added to the flaxseed remaining from the first extraction. The ratio of water to seed by weight during the second extraction was approximately 20:1. The second extraction was conducted similarly to the first extraction. Approximately 60 gallons of flaxseed extract were obtained from the two extractions. Around 15 gallons of water were absorbed by the seed and was retained in the kettle. The water extracts from the two extractions were then homogenized and comprised the flaxseed extract used either in the preparation of mucin or used in feeding experiments. The homogenized flaxseed extract was stored in a milk

Figure 1. Flaxseed extraction equipment in operation

cooler at 15-18° C until used.

The homogenized or blended flaxseed extract from the two extractions was analyzed and found to contain 0.1 per cent protein, 0.82 per cent dry matter and 0.77 per cent mucin. The flaxseed extract had a pH of approximately 5.0. Using a value of around 12-15 per cent as the content of mucin in flaxseed, the two extractions account for approximately 75-80 per cent of the total mucin present.

An equal volume of cooled flaxseed extract was mixed with either 95 per cent ethyl alcohol or methyl alcohol for the preparation of mucin. This mixture was agitated vigorously for approximately one minute and allowed to settle for three to five minutes. This precipitated the mucilaginous carbohydrates and alcohol insoluble proteins which we have termed mucin. The mucin was then separated from the mixture by filtration through four layers of cheese cloth under suction. The mucin was then dried in a forced air oven at 70-74° C for a period of 24-36 hours. The dried mucin was then ground by the use of a Waring blender.

An analysis of the dry matter fraction of the blended flaxseed extract is presented in Table 1. An analysis of the mucin from the blended flaxseed extract is presented in Table 2.

Table 1. Composition of the dry matter fraction of flaxseed extract

Component	Per cent
Moisture	5.11
Protein	12.50
Ash	15.70
Calcium	1.71
Phosphorus	0.34
Thiamin[a]	3.91
Riboflavin[a]	10.75
Non-protein-nitrogen	--
pH[b]	7.65
Mucin	22.90

[a]Listed as parts per million.

[b]Determined with a 10 per cent solution in distilled water.

Table 2. Composition of mucin from flaxseed extract

Component	Per cent
Moisture	8.29
Protein	18.30
Ash	7.80
Thiamin[a]	0.60
Riboflavin[a]	4.50
True mucin	58.50
Ether extract	--
Non-protein-nitrogen	--
Crude fiber	--
Organic matter	83.91
Nitrogen-free-extract	65.61

[a]Listed as parts per million.

Lamb Experiments

Methods and results

The effect of flaxseed extract upon growth rate and feed efficiency (Lamb Trial 1). Burroughs et al. (25) have shown that the digestibility of corncob dry matter could be increased by feeding steers a water-extract of dehydrated alfalfa meal. Other workers (Bentley et al., 13; Burroughs et al., 26; Burroughs et al., 27; Ruf et al., 91) have shown that water extracts of various plant feeds would improve in vitro cellulose digestion. To accurately determine the merits of linseed oil meal and fractions of linseed oil meal in ruminant rations, a pilot trial was conducted with sheep to determine the total consumption of flaxseed extract and to determine the effect of the flaxseed extract upon feed consumption and body weight gains.

Twenty-four western crossbred wether lambs weighing around 94 pounds were randomly assigned to four lots of six animals each. All the animals were individually fed the ration shown in Table 3 for a period of 42 days. The individual feeding stalls used were similar to those described by Preston (88). The lambs were fed in the individual pens for approximately two hours twice a day. Liquid was consumed by each lot of lambs as a group. Iodized salt was kept in front of the animals at all times. Two of the four lots of

Table 3. Composition of ration used in Lamb Trial 1[a]

Ingredient	Per cent
Corncobs	40.0
Chopped alfalfa	20.0
Molasses	10.0
Ground shelled corn	23.8
Soybean oil meal	5.5
CaH_2PO_4	0.2
NaH_2PO_4	0.5

[a]Ration contained 8.5 per cent total protein. Cobalt was fed as $CoSO_4$ at the rate of 0.1 ppm of cobalt. Vitamins A and D were added to meet the National Research Council's recommendations.

lambs received water as their daily liquid, while the other two lots received a flaxseed extract as their daily liquid. Feed consumption, liquid consumption and body weight gains were measured throughout the trial. The animals were weighed at 14-day intervals, at which time feed refusals were weighed and discarded. The lambs were vaccinated for enterotoxemia and sore mouth prior to the start of the experiment. Approximately seven days was allowed for the animals to become adjusted to the ration and to the feeding stalls before the trial was initiated.

The results of this 42-day lamb trial are shown in Table 4. The oral consumption of flaxseed extract increased the average daily gains of the lambs by 100 per cent while lowering the feed required per pound of gain by 44.2 per cent.

Table 4. Feedlot performance of lambs in Trial 1

Treatment	Average daily gain (lbs.)	Feed per pound of gain (lbs.)	Daily feed consumed (lbs.)	Daily liquid consumed (lbs.)
Control	0.22	15.6	3.20	5.42
Flaxseed extract	0.44	8.7	2.91	5.00

The control lambs consumed 0.29 pounds more feed per day and 0.42 pounds more liquid per day. None of these differences were statistically significant as analyzed by the methods of Snedecor (94).

The effect of flaxseed extract in a 12 per cent protein ration with and without stilbestrol upon growth rate, feed efficiency and carcass quality (Lamb Trial 2). The increased gains and feed efficiency observed in the pilot trial made it seem feasible to test the merits of flaxseed extract for ruminants against a substance known to stimulate gains and increase feed efficiency in ruminants. Stilbestrol was chosen for this substance. Observations by Preston (88), Hale et al. (49) and Light et al. (69) indicated that two milligrams of stilbestrol daily would increase the average daily gains of lambs without producing serious side effects.

Thirty-six crossbred wether lambs weighing around 96 pounds were randomly assigned to six lots of six animals each.

All of the animals were individually fed in feeding stalls similar to those previously described. The stalls were housed in an environmentally controlled barn in which the temperature was maintained at 60-65° F.

Half of the animals received the basal ration shown in Table 5 and half of the animals received the ration shown in Table 6. The statistical design of the experiment was a completely randomized 2 x 3 factorial. This design is illustrated in Table 7.

All the animals were allowed to eat in their individual stalls for one hour three times a day. They were then turned into a community pen and received water and iodized salt free choice. At the morning and evening feeds, each animal was limited to 1.5 pounds of ration per feeding plus either water

Table 5. Composition of ration fed one-half of the lambs in Trial 2[a]

Ingredient	Per cent
Corncobs (finely ground)	33.3
Chopped alfalfa	16.7
Soybean oil meal	12.0
Ground shelled corn	37.8
NaH_2PO_4	0.2

[a]Ration contained 12.0 per cent total protein. Cobalt was fed as $CoSO_4$ at the rate of 0.1 ppm of cobalt. Vitamins A and D were added to meet the National Research Council's recommendations.

Table 6. Composition of ration fed one-half of the lambs in Trial 2[a]

Ingredient	Per cent
Corncobs (finely ground)	33.300
Chopped alfalfa	16.700
Soybean oil meal	12.933
Ground shelled corn	37.800
NaH_2PO_4	0.200
Stilbosol[b]	0.067

[a]Ration contained 12.0 per cent total protein. Cobalt was fed as $CoSO_4$ at the rate of 0.1 ppm of cobalt. Vitamins A and D were added to meet the National Research Council's recommendations.

[b]Contained one gram of diethylstilbestrol per pound.

Table 7. Experimental design of Lamb Trial 2

Milligrams of stilbestrol daily	Pounds of flaxseed extract daily		
	0	3	6
0			
2			

or flaxseed extract which was mixed with the ration at the time of feeding. Approximately one-third of dry feed was mixed with two-thirds of liquid at this time. The treatments and amount of feed and liquid received daily are listed in Table 8. Water was mixed with the rations containing no

Table 8. Amount of feed and liquid given daily in Lamb Trial 2

Treatment	Pounds of feed and liquid given daily per animal
1	3.0 pounds of basal + 6 pounds of water
2	3.0 pounds of basal + 3 pounds of water + 3 pound of flaxseed extract
3	3.0 pounds of basal + 6 pounds of flaxseed extract
4	3.0 pounds of basal + stilbestrol + 6 pounds of water
5	3.0 pounds of basal + stilbestrol + 3 pounds of water + 3 pounds of flaxseed extract
6	3.0 pounds of basal + stilbestrol + 6 pounds of flaxseed extract

flaxseed extract to equalize the daily liquid intake. A third feeding was made at noon at which time the animals were fed free choice their respective rations mixed only with water in the aforementioned 1:2 ratio. The lambs remained on this trial for a period of 56 days. Feed consumption and body weight gains were measured throughout the trial. The animals were weighed at 14-day intervals. Feed refusals were weighed and discarded daily. The lambs were vaccinated for enterotoxemia and sore mouth prior to the start of the experiment. Approximately 10 days were allowed for the lambs to become accustomed to the rations and their feeding stalls before the trial was initiated.

The results of this trial are given in Table 9. Statis-

Table 9. Results of Lamb Trial 2

Treatment	A.D.G.[a] (lbs.)	Feed per pound of gain (lbs.)	Dressing per cent	Carcass grade[b]
No stilbestrol, no FE[c]	0.41	9.0	49.7	7.6
No stilbestrol, 3 pounds FE	0.37	9.8	50.3	7.3
No stilbestrol, 6 pounds FE	0.36	10.4	50.5	7.6
2 mg. stilbestrol, no FE	0.44	8.8	49.5	7.7
2 mg. stilbestrol, 3 pounds FE	0.44	7.9	50.3	7.7
2 mg. stilbestrol, 6 pounds FE	0.38	14.4	50.8	8.0

[a]Average daily gain.

[b]Prime = 10, choice = 8, good = 6.

[c]Flaxseed extract.

tical analyses of the data by the analysis of variance method as described by Snedecor (94) is listed in the Appendix.

Statistical analyses of the data reveal that the addition of stilbestrol had no significant effect upon average daily gain, feed efficiency, dressing per cent or carcass grade, although all of these qualities were improved slightly by the feeding of stilbestrol with the exception of feed efficiency. The feeding of flaxseed extract significantly ($P < 0.05$) increased dressing percentage, but had no significant effect upon average daily gain, feed efficiency or car-

cass grade.

The effect of flaxseed extract in a ration fed at two levels of protein upon growth rate, feed efficiency and carcass quality (Lamb Trial 3). There was an apparent increase in average daily gains and feed efficiency in the first trial when flaxseed extract was fed with an 8.5 per cent protein ration and a lack of any significant difference in average daily gain, feed efficiency and carcass quality when a 12 per cent protein ration was fed. These results indicated that perhaps the level of protein might have an effect upon the response from feeding flaxseed extract to ruminants.

A completely randomized 2 x 2 factorial experiment was set up as shown in Table 10. Twenty-four crossbred wether lambs weighing around 69 pounds were randomly assigned to four lots of six animals each. The lambs were kept in individual pens with water and salt available at all times. All the animals were fed three times a day as described in the previous trial. Flaxseed extract was included in the ration only at the morning and evening feeds. The treatments and amount of feed and liquid received daily are listed in Table 11.

The rations used in this trial are listed in Table 12. Urea was added to the rations to which no flaxseed extract was added to make the ration at each protein level isonitro-

Table 10. Experimental design of Lamb Trial 3

Per cent protein	Pounds of flaxseed extract daily	
	0	6
9		
12		

Table 11. Amount of feed and liquid given daily in Lamb Trial 3

Treatment	Pounds of feed and liquid given daily per animal
1	3 pounds of 9 per cent protein ration + 6 pounds of flaxseed extract
2	3 pounds of 9 per cent protein ration + 6 pounds of water
3	3 pounds of 12 per cent protein ration + 6 pounds of flaxseed extract
4	3 pounds of 12 per cent protein ration + 6 pounds of water

Table 12. Composition of rations fed in Lamb Trial 3[a]

Ingredient	Treatment			
	1 lb.	2 lbs.	3 lbs.	4 lbs.
Corncobs (finely ground)	33.3	33.3	33.3	33.3
Chopped alfalfa	16.7	16.7	16.7	16.7
Soybean oil meal	3.5	3.5	11.6	11.6
Ground shelled corn	46.3	46.2	38.2	38.1
NaH_2PO_4	0.2	0.2	0.2	0.2
Urea	--	0.1	--	0.1

[a]Cobalt was fed as $CoSO_4$ at the rate of 0.1 ppm of cobalt. Vitamins A and D were added to meet the National Research Council's recommendations.

genous. The rations were mixed with either flaxseed extract or water at the time of feeding as previously described. The lambs were on trial for a period of 70 days.

The animals were weighed at 14-day intervals. Feed refusals were weighed and discarded daily. The lambs were vaccinated for enterotoxemia and sore mouth prior to the start of the experiment. Approximately 10 days were allowed for the lambs to become accustomed to the feed and their surroundings before starting them on trial.

The results of this study are given in Table 13. The

Table 13. Results of Lamb Trial 3

Treatment	A.D.G. (lbs.)	Feed per pound of gain (lbs.)	Carcass grade[a]	Dressing per cent
1	0.34	7.7	3.7	45.7
2	0.30	8.7	4.7	47.5
3	0.26	10.1	4.2	46.5
4	0.33	7.7	3.0	47.2

[a]Low-good = 5, high-utility = 4, average-utility = 3.

feeding of flaxseed extract increased average daily gains on the low protein ration, but either depressed average daily gains or had no effect on the high protein ration. Feed efficiency followed the same pattern as average daily gains.

Carcass grades were increased by the feeding of flaxseed extract on the high protein ration but were depressed on the low protein ration. Dressing per cent was decreased by the feeding of flaxseed extract at both levels of protein. Statistical analyses of the data is listed in Table 52 in the Appendix. There was a significant interaction ($P<0.01$) between protein and flaxseed extract on feed efficiency resulting in an increase of 16 per cent in the pounds of feed required per pound of gain. There was a significant interaction ($P<0.05$) between protein and flaxseed extract on carcass grade, lowering carcass grade by 11 per cent or approximately 0.16 of a grade. There was also a significant interaction ($P<0.05$) between flaxseed extract and protein causing average daily gains to be lowered by 13 per cent. Feed consumption was approximately the same for all treatments, however the consumption was very low, averaging only 2.6 pounds daily for all treatments.

The effect of flaxseed extract in a nine per cent protein ration with and without stilbestrol upon growth rate, feed efficiency and carcass quality (Lamb Trial 4). Results from previous trials indicated that the feeding of flaxseed extract lowered average daily gains, feed efficiency and carcass grade when fed with a 12 per cent protein ration. Trial 2 was re-run to re-evaluate the merits of flaxseed extract for

ruminants against the gain stimulator, stilbestrol, using a nine per cent protein ration rather than a 12 per cent protein ration.

Twenty-four crossbred wether lambs weighing around 88 pounds were randomly divided into six lots of four animals each. A completely randomized 2 x 3 factoral design was used for the experiment as shown in Table 14. All the animals

Table 14. Experimental design of Lamb Trial 4

Milligrams of stilbestrol daily	Pounds of flaxseed extract daily		
	0	3	6
0			
2			

were individually fed three times a day for a period of 69 days by procedures previously described. The rations and treatments are shown in Table 15. Rations containing no flaxseed extract contained urea to account for the nitrogen added by the flaxseed extract in the other rations, making all rations isonitrogenous. The feeding technique and the mixing of the feed and liquid was conducted as previously described. The treatments and daily feed given to the lambs are shown in Table 16. Weighing of the animals, handling of refused feed and pre-trial treatment were similar to that described for

Table 15. Composition of rations fed in Lamb Trial 4[a]

Ingredient	Treatment 1 lbs.	2 lbs.	3 lbs.	4 lbs.	5 lbs.	6 lbs.
Corncobs (finely ground)	33.30	33.30	33.30	33.30	33.30	33.30
Chopped alfalfa	16.70	16.70	16.70	16.70	16.70	16.70
Soybean oil meal	3.47	3.47	3.40	3.41	3.53	3.53
Ground shelled corn	46.25	46.29	46.40	46.24	46.16	46.20
NaH_2PO_4	0.20	0.20	0.20	0.20	0.20	0.20
Stilbosol[b]	--	--	--	0.07	0.07	0.07
Urea	0.08	0.04	--	0.08	0.04	--

[a]Cobalt was fed as $CoSO_4$ at the rate of 0.1 ppm of cobalt. Vitamins A and D were added to meet the National Research Council's recommendations.

[b]Contained one gram of diethylstilbestrol per pound.

Table 16. Amount of feed and liquid given daily in Lamb Trial 4

Treatment	Pounds of feed and liquid given daily per animal
1	3 pounds basal + 6 pounds of water
2	3 pounds basal + 3 pounds of water + 3 pounds of flaxseed extract
3	3 pounds basal + 6 pounds of flaxseed extract
4	3 pounds basal + stilbestrol + 6 pounds of water
5	3 pounds basal + stilbestrol + 3 pounds of water + 3 pounds of flaxseed extract
6	3 pounds basal + stilbestrol + 6 pounds of flaxseed extract

previous trials.

The results of this trial are presented in Table 17. The feeding of stilbestrol resulted in a 2.5 per cent increase in average daily gain, 1.7 per cent increase in dressing per cent, 1.4 per cent increase in feed efficiency, but

Table 17. Results of Lamb Trial 4.

Treatment	A.D.G. (lbs.)	Feed per pound of gain (lbs.)	Dressing per cent	Carcass grade[a]	Daily consumption (lbs.)
1	0.30	11.7	50.5	5.3	3.56
2	0.27	12.4	49.9	4.8	3.34
3	0.33	10.4	49.3	5.3	3.38
4	0.30	10.8	52.2	4.8	3.20
5	0.27	13.1	49.1	5.3	3.10
6	0.36	10.1	50.9	4.5	3.46

[a]Utility = 2, good = 5, choice = 8.

resulted in a 3.3 per cent decrease in carcass grade or about 0.07 of a grade. The feeding of flaxseed extract significantly ($P<0.05$) increased average daily gains. Six pounds of flaxseed extract daily increased average daily gains 20.0 per cent. The feeding of flaxseed extract slightly decreased dressing per cent, slightly lowered carcass grade, increased the feed required per pound of gain when fed at the three pound level, but decreased the feed required per pound of gain

at the six pound level. The feeding of flaxseed extract in this experiment showed up very favorably in comparison to stilbestrol when fed in a ration containing only nine per cent total protein.

The effect of flaxseed extract, stilbestrol, and level of protein upon growth rate, feed efficiency and carcass quality (Lamb Trial 5). Flaxseed extract, stilbestrol and level of protein had been fed in previous trials in combinations of two factors, but had never been fed in a three-factor experiment. Significant interaction between flaxseed extract and protein has been previously shown. A trial was designed in which all three of the aforementioned factors were present, to see if there was any significant interaction among these factors when in combination.

Twenty-four crossbred wether lambs weighing around 72 pounds were randomly divided into eight lots of four animals each. A completely randomized 2 x 2 x 2 factoral design was used for the experiment as shown in Table 18. All animals were individually fed for a period of 93 days by procedures previously described. The rations and treatments are shown in Table 19. Rations to which no flaxseed extract was added contained urea to account for the nitrogen added by flaxseed extract. Thus, all rations at each protein level were isonitrogenous. The feeding technique and the mixing of the feed and liquid were conducted as previously described. The

Table 18. Experimental design of Lamb Trial 5

Milligrams of stilbestrol daily	Per cent protein	Pounds of flaxseed extract daily
0	9	0 6
	12	0 6
2	9	0 6
	12	0 6

treatments and daily feed given to the lambs are listed in Table 20. Weighing of the animals, handling of refused feed and pre-trial treatment were similar to that described for previous trials.

The results of the trial are presented in Table 21. The feeding of two milligrams of stilbestrol had no significant effect upon average daily gains, feed efficiency or carcass quality, however the feeding of stilbestrol did increase gains 12 per cent and decreased the feed required per pound of gain by 3.8 per cent. The feeding of stilbestrol likewise decreased dressing per cent 9.7 per cent and lowered carcass grade 5.5 per cent or approximately 0.2 of a grade. The feeding of protein at a level of 12 per cent had no

Table 19. Composition of rations fed in Lamb Trial 5[a]

Ingredient	Treatment 1 lbs.	2 lbs.	3 lbs.	4 lbs.	5 lbs.	6 lbs.	7 lbs.	8 lbs.
Corncobs (finely ground)	33.30	33.30	33.30	33.30	33.30	33.30	33.30	33.30
Chopped alfalfa	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70
Soybean oil meal	3.49	3.80	1.39	2.99	11.57	12.09	10.74	11.28
Ground shelled corn	46.23	46.00	48.26	46.74	38.15	37.71	38.91	38.45
NaH_2PO_4	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Urea	0.08	--	0.08	--	0.08	--	0.08	--
Stilbosol[b]	--	--	0.07	0.07	--	--	0.07	0.07
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[a]Cobalt was fed as $CoSO_4$ at the rate of 0.1 ppm of cobalt. Vitamins A and D were added to meet the National Research Council's recommendations.

[b]Contained one gram of diethylstilbestrol per pound.

Table 20. Amount of feed and liquid given daily in Lamb Trial 5

Treatment	Pounds of feed and liquid given daily per animal
1	3 pounds of 9 per cent protein basal + 6 pounds of water
2	3 pounds of 9 per cent protein basal + 6 pounds of flaxseed extract
3	3 pounds of 9 per cent protein basal + stilbestrol + 6 pounds of water
4	3 pounds of 9 per cent protein basal + stilbestrol + 6 pounds of flaxseed extract
5	3 pounds of 12 per cent protein basal + 6 pounds of water
6	3 pounds of 12 per cent protein basal + 6 pounds of flaxseed extract
7	3 pounds of 12 per cent protein basal + stilbestrol + 6 pounds of water
8	3 pounds of 12 per cent protein basal + stilbestrol + 6 pounds of flaxseed extract

Table 21. Results of Lamb Trial 5

Treatment	A.D.G. (lbs.)	Feed per pound of gain (lbs.)	Dressing per cent	Carcass grade[a]
1	0.20	14.1	49.2	5.8
2	0.25	11.8	48.2	6.5
3	0.21	12.6	50.3	6.0
4	0.29	11.0	47.3	5.0
5	0.25	11.5	49.3	6.0
6	0.25	12.0	49.0	5.8
7	0.21	14.3	47.7	3.8
8	0.36	9.6	48.5	7.0

[a]Utility = 3, good = 6, choice = 9.

effect upon carcass grade and dressing per cent, but did increase average daily gains 12.5 per cent and decreased the feed required per pound of gain 4 per cent. The feeding of flaxseed extract increased gains 12.5 per cent, decreased the feed required per pound of gain 15 per cent, increased carcass grade by 7.4 per cent, but decreased dressing per cent 1.8 per cent. There was a significant ($P<0.05$) interaction between protein, stilbestrol and flaxseed extract on dressing per cent, decreasing this value 1.3 per cent. There was also a significant ($P<0.05$) interaction between protein and flaxseed extract and a significant ($P<0.01$) interaction between protein, stilbestrol and flaxseed extract on carcass grade, increasing this value 5.1 per cent and 11.3 per cent, respectively. Flaxseed extract in this trial performed equally as well as stilbestrol or increasing the protein content of the ration from nine to 12 per cent.

Discussion

The liveweight gains of lambs were increased by the feeding of flaxseed extract when incorporated into a ration containing nine per cent total protein. This did not occur when only three pounds of flaxseed extract was fed daily nor did it occur when either level of flaxseed extract was

fed in a 12 per cent protein ration. The feed required per pound of gain followed a pattern similar to liveweight gains when flaxseed extract was fed. The feeding of flaxseed extract tended to lower carcass quality which was measured by dressing per cent and carcass grade. The feeding of flaxseed extract increased the carcass quality of lambs as evidenced by an increase in dressing per cent and carcass grade when fed in a 12 per cent protein ration, however carcass grade and dressing per cent were lowered when flaxseed extract was fed in a nine per cent protein ration.

Although the feeding of two milligrams of stilbestrol daily consistently increased average daily gains, a depressing effect was observed upon dressing per cent and carcass grade. The feeding of stilbestrol resulted in 30 per cent greater gains on a high protein ration (12 per cent protein) than on a low protein ration (nine per cent protein). This was not in complete agreement with the results of Preston (88) in which stilbestrol was found to stimulate liveweight gains to a greater extent when fed in rations containing a low, but adequate level of protein.

Average daily gains were satisfactory in all trials, however, they were considerably lower than those normally obtained on a standard lamb-fattening ration. These lower gains

were probably due to a lower consumption of feed due to feeding a wet ration.

The increased gains obtained by the feeding of flaxseed extract could not be explained through the additional nitrogen added by the flaxseed extract. This was supported by the fact that rations containing no flaxseed extract contained urea in amounts ample enough to make the rations isonitrogenous. Flaxseed extract would seem to afford a slight protein-sparing action because of the increased gains on the low protein (nine per cent protein) ration. This was not supported however by a significant ($P<0.05$) interaction between the high level of protein and flaxseed extract which resulted in a decrease in average daily gain. There was also a significant ($P<0.01$) interaction between protein and flaxseed extract decreasing the efficiency of gains and significantly ($P<0.05$) lowering carcass grade and dressing per cent. This was not completely repeated in a later trial in which there were significant protein-flaxseed extract and protein-flaxseed extract-stilbestrol interactions increasing carcass grade and decreasing dressing per cent. The results of these interactions were inconclusive and could not be explained.

Perhaps the increased gains and feed efficiency obtained by the feeding of flaxseed extract could be explained as being due to the factor or factors studied by Burroughs *et al.* (25,

26, 27), Bentley *et al.* (13), and Ruf *et al.* (91) in which they found that water extracts of various plant feeds would improve *in vitro* cellulose digestion. The effect of flaxseed extract upon the liveweight gains of lambs at this time can be attributed to an unidentified factor or factors other than additional nitrogen in the ration contributed by flaxseed extract.

Summary

The results of five lamb feeding trials indicated that the feeding of six pounds of flaxseed extract would result in a 12-18 per cent increase in the liveweight gains of lambs fed a relatively low protein (nine per cent protein) ration. The feeding of flaxseed extract in a 12 per cent protein ration had no effect upon gains or feed efficiency. The incorporation of flaxseed extract in a nine per cent protein ration resulted in lower carcass quality as measured by dressing per cent and carcass grade. Carcass quality was seemingly increased when flaxseed extract was fed in a 12 per cent protein ration. The feeding of two milligrams of stilbestrol daily consistently increased average daily gains 3-12 per cent, but had an adverse effect upon dressing per cent and carcass grade. Thirty per cent greater gains resulted when stilbestrol was fed in a 12 per cent protein

ration than when fed in a nine per cent protein ration. Increasing the protein content of lamb rations from nine to 12 per cent resulted in 12.5 per cent faster gains and four per cent more efficient gains. The factor or factors present in flaxseed extract that increased liveweight gains of lambs are at this time unidentified, however it is quite certain that the additional nitrogen contributed by flaxseed extract had no effect.

Technique for Measuring Haircoat "Bloom"

Several workers (Watson, 101; Hunt, 62; Morrison, 80; Robbins, 90; Hayward, 53; Culbertson*) have stated that the feeding of linseed oil meal imparts a certain gloss or "bloom" to the hair coat of cattle. This has also been reported many times from cattle feeders in the field, especially from feeders who groom show cattle. Previously, this measurement of "bloom" was done by visual comparison which resulted in very erratic observations and differences. A device or method was needed to quantitatively measure the degree of "bloom" imparted by linseed oil meal to the haircoat of animals, particularly cattle.

The term "bloom" was thought to describe only the glossi-

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*C. C. Culbertson, Animal Husbandry Department, Iowa State College, Ames, Iowa. Feeding linseed oil meal to cattle. Private communication. 1958.

ness, or in essence, the amount of light reflected from the haircoat. To overcome this, an extremely sensitive light meter was developed to accurately measure this condition known as "bloom".

The light meter was housed in a rectangular 4 1/2 x 6 inch metal box with a one square inch opening in one end. This opening was closed or opened by an attached door as shown in Figures 2 and 3. A sensitive cadmium-coated semi-conductor was located within the box about 1 1/2 inches back of the opening to the outside. Placed approximately 1/2 inch back of the opening and in front of the photoelectric cell were two 2.33 volt bulbs which were focused on the opening. A microammeter with a scale of 0-500 was used as the recording device and was powered by two 67 1/2 volt dry cell batteries located within the box. The internal light source was powered by two 1 1/2 volt batteries within the box and a booster six volt dry cell battery which was plugged into receptacles located on the side of the box. Separate switches for the power to the meter and to the light source were attached. A powerstat was located beneath the meter to control the voltage to the light source. Around 300 microamperes was determined to be the most sensitive part of the microampere scale. A

Figure 2. Outside view of "bloom" meter

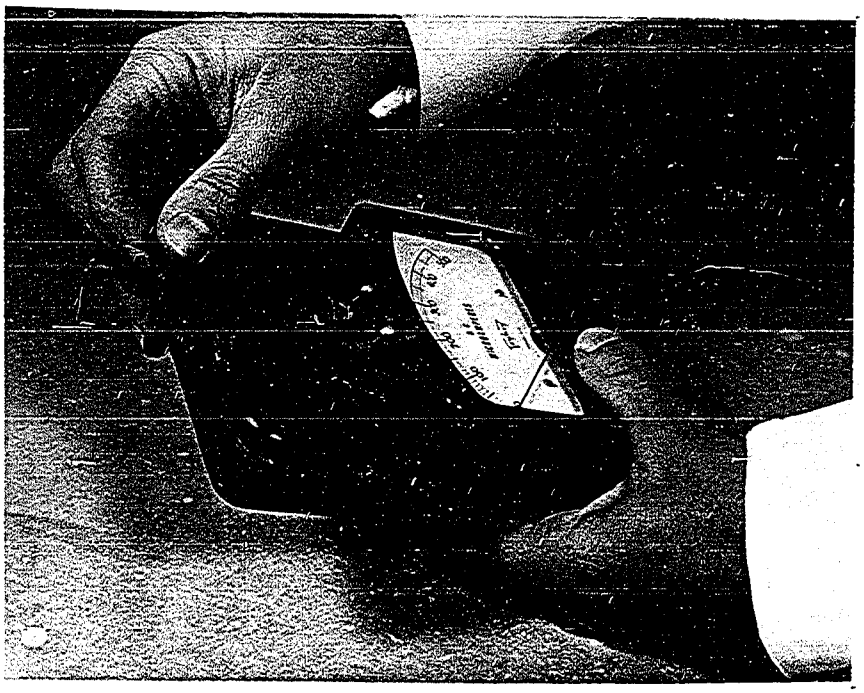
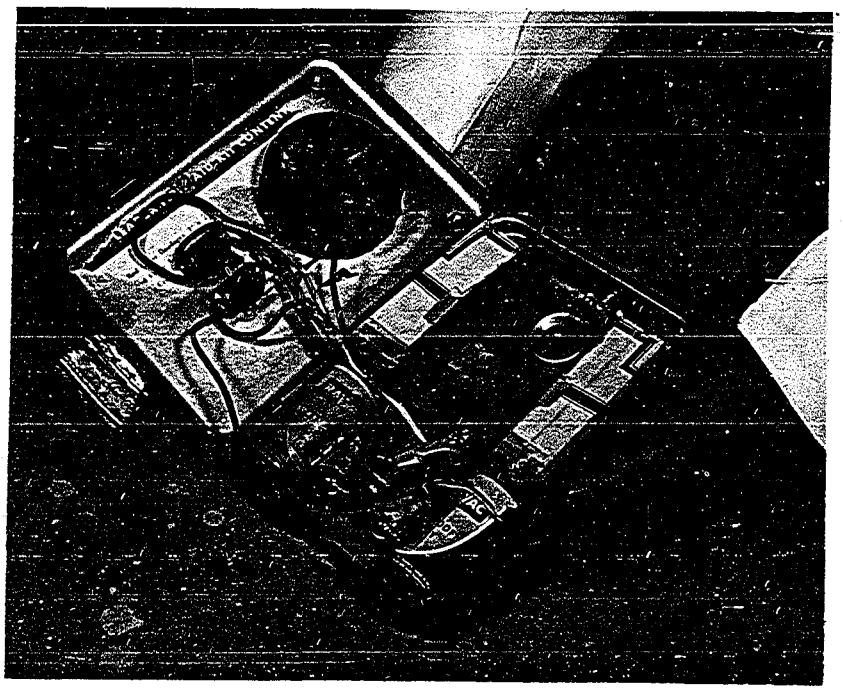


Figure 3. Inside view of "bloom" meter



schematic circuit diagram of the meter and light source is illustrated in Figure 4.

Haircoat "bloom" in the following experiments was measured on cattle, guinea pigs and rats. The following procedure was used in recording these measurements:

1. Turn power on to both the meter and the light source.
2. Close door to opening to meter box.
3. Adjust powerstat control until a reading of 300 microamperes is obtained.
4. After base reading of 300 microamperes is recorded, open door to meter box and place against the haircoat of the animal making sure the hair makes a light-tight seal.
5. Record the reading on the scale.

Three readings were taken at various positions on the haircoat of guinea pigs or rats and six readings were taken at various positions on the haircoat of cattle at any one time. Measurements on the guinea pigs were made every seven days and were made every 28 days on cattle. Readings being made on a guinea pig and on a steer are illustrated in Figures 5 and 6, respectively.

After recording the readings, they were then compared to the base reading of 300 microamperes as a percentage. The following is an example of this procedure for a guinea pig:

Figure 4. Schematic circuit diagram of "bloom" meter and light source

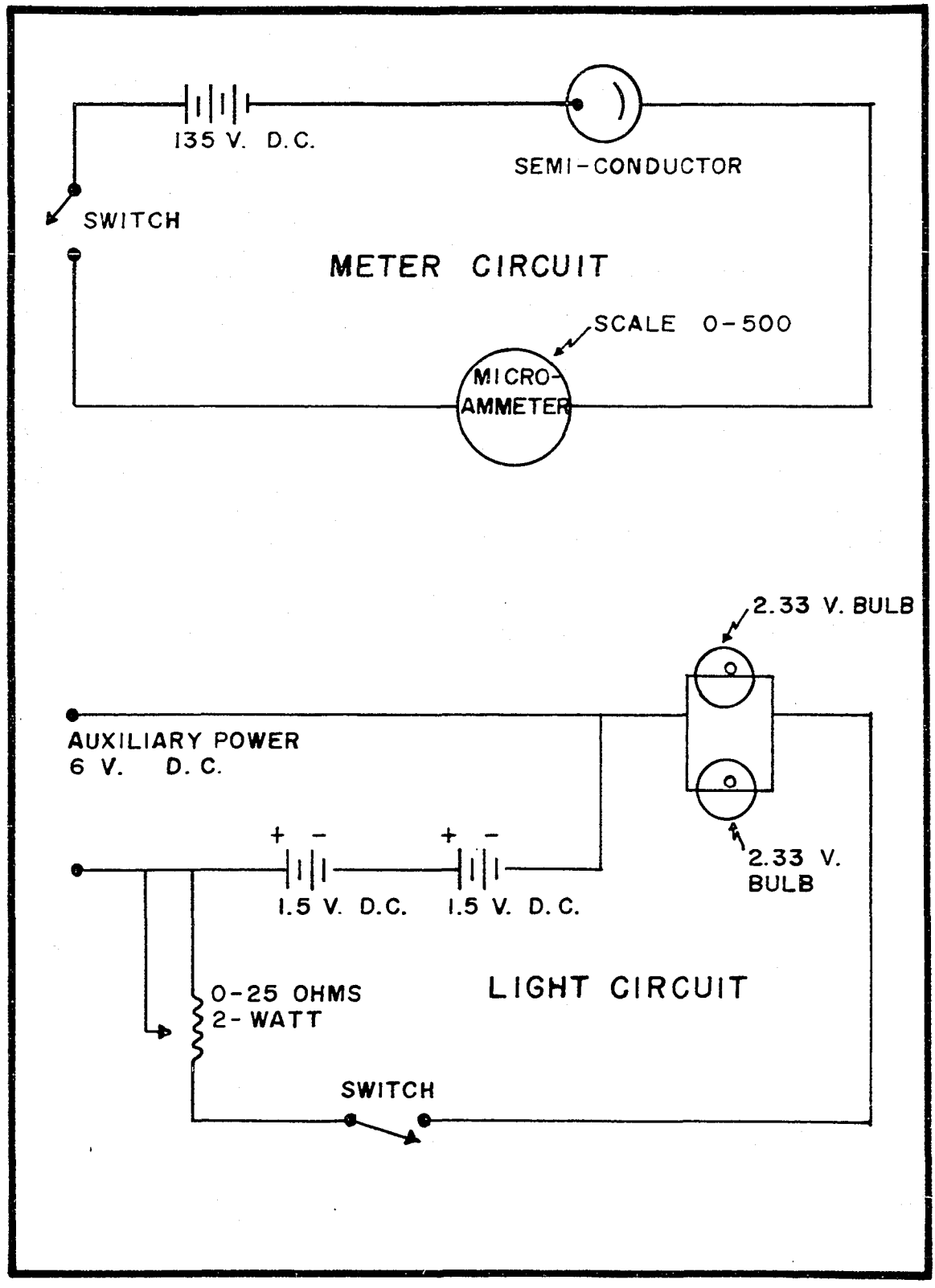

135 V. D.C.
SEMI-CONDUCTOR
SWITCH
METER CIRCUIT
SCALE 0-500
MICRO-AMMETER
2.33 V. BULB
AUXILIARY POWER
6 V. D. C.
+ −
+ −
1.5 V. D.C.
1.5 V. D. C.
2.33 V. BULB
0-25 OHMS
2-WATT
LIGHT CIRCUIT
SWITCH

Figure 5. Technique for recording "bloom" readings on guinea pigs

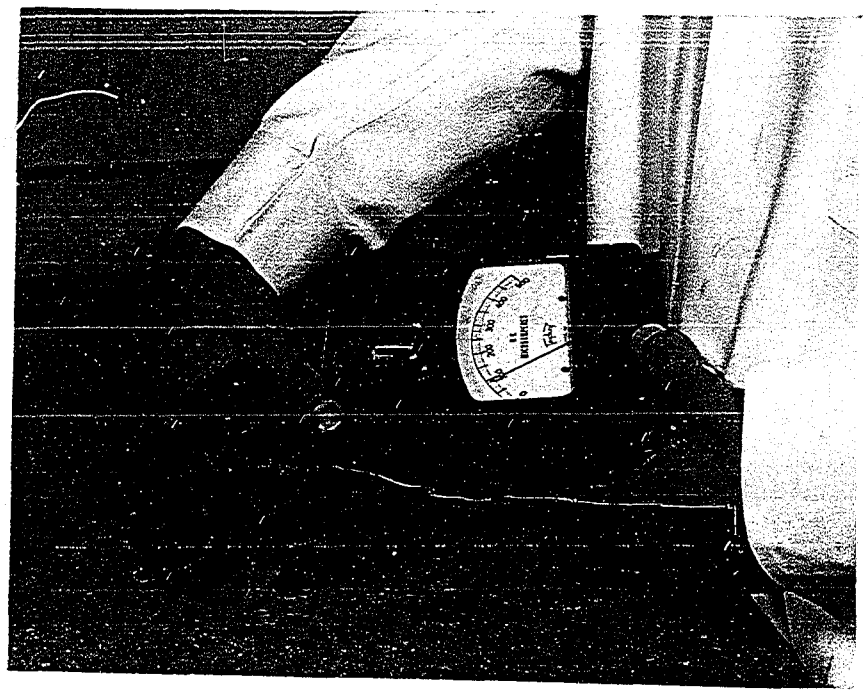


Figure 6. Technique for recording "bloom" readings on cattle

Base reading = 300 microamperes

Reading 1 = 110 microamperes divided by 300 x 100 = 36.7
Reading 2 = 112 microamperes divided by 300 x 100 = 37.3
Reading 3 = 109 microamperes divided by 300 x 100 = 36.3

Average = 36.8

Thus, the "bloom" value for the above example would be 36.8.

In utilizing the "bloom" measurements just described, it was decided that the units of change from the start of an experiment to the end described "bloom" better than the actual readings taken. This was primarily due to the difference in shades of color observed on the animals. Many times a light-colored animal would reflect more light, giving a higher "bloom" reading than a dark colored animal, even though possessing no more "bloom". Using the units of change in "bloom" over a given length of time seemed to cancel out this difference in shade of color. The light meter just described will hereafter be referred to in the text as the "bloom" meter.

Laboratory Animal Experiments

Methods and results

The effect of linseed oil meal upon the growth rate, feed efficiency and haircoat "bloom" of rats (Rat Trial 1). Quantitative data had not been taken at this time to substantiate earlier reports that linseed oil meal would increase the

haircoat "bloom" of animals. A trial was designed to test several levels of linseed oil meal to determine their relative "bloom" producing effects.

Thirty-two grey-black rats of mixed breeding weighing around 225 grams were randomly divided into four groups of eight animals each. Each group of eight animals was randomly assigned to four cages, giving two animals per cage. The 16 cages were housed in an air conditioned room maintained at a temperature of around 70°F. Feed and water was given free choice. Feed consumption, liveweight gains and feed efficiency were measured throughout the trial. Haircoat "bloom" data were taken at the beginning and at the end of the trial. The animals were weighed at 7-day intervals at which time feed refusals were weighed and discarded. Approximately seven days were allowed for the animals to become adjusted to their cages and diets before the trial was initiated. The animals remained on trial for a period of 28 days.

The treatments and diets received by the animals are presented in Table 22. The three levels of linseed oil meal used in the diets supplied approximately one-eighth, one-fourth and one-half of the total protein in the diets. The results of the trial are presented in Table 23.

The results of the trial reveal that the addition of 10 per cent linseed oil meal increased gains over the control group 36 per cent, while the addition of higher levels of

Table 22. Composition of diets used in Rat Trial 1

Ingredient	Treatment 1 lbs.	2 lbs.	3 lbs.	4 lbs.
Casein	27.00	23.25	19.48	11.95
Vegetable oil (Crisco)	14.00	14.00	14.00	14.00
Salt mix[a]	3.00	3.00	3.00	3.00
Soybean oil meal	6.75	6.75	6.75	6.75
Sucrose	49.25	43.00	36.77	24.30
Linseed oil meal	--	10.00	20.00	40.00
Total	100.00	100.00	100.00	100.00

[a]Salt mix was USP XIV from General Biochemicals, Inc. The vitamins added in grams per pound of diet are as follows: alpha tocopherol, 0.102; calcium pantothenate, 0.020; vitamin A, 28,800,000 I.U.; choline chloride, 2.724; Inositol, 0.136; menadione, 0.001; niacin, 0.272; pryidoxine, 0.010; riboflavin 0.010; thiamin, 0.010; vitamin D, 12,000 I.U.

Table 23. Results of Rat Trial 1

Treatment	Gain[a] (gms.)	"Bloom" change	Feed per 100 grams of gain
1	158.2	0.10	563.9
2	214.5	0.90	550.0
3	144.7	0.37	579.7
4	120.7	0.85	953.0

[a]Represents gain of one cage containing two animals over the entire experimental period.

linseed oil meal (20 and 40 per cent) failed to stimulate gains. Feed efficiency followed a similar pattern in that the addition of 10 per cent linseed oil meal significantly ($P < 0.05$) reduced the feed required per 100 grams of gain six per cent.

The addition of linseed oil meal, as measured by the "bloom" meter, increased the haircoat "bloom" of rats. The addition of 10 per cent linseed oil meal increased haircoat "bloom" over the basal group by around eight-fold, while the addition of 20 and 40 per cent linseed oil meal increased haircoat "bloom" only three-fold and seven-fold, respectively. The "bloom" change value for the 20 per cent linseed oil meal treatment, which is much below the values for the 10 and 40 per cent linseed oil meal treatments, could not be explained. These data indicated that the addition of linseed oil meal in rations did increase the "bloom" of the haircoat of rats.

The effect of linseed oil meal and linseed oil meal mucin upon growth rate, feed efficiency and haircoat "bloom" of guinea pigs (Guinea Pig Trials 1 and 2). The large content of mucin in linseed oil meal made it reasonable to postulate that perhaps the mucin fraction of linseed oil meal was the factor imparting haircoat "bloom" to cattle. Large animals such as cattle were not feasible to use for experimentation with mucin, since mucin was obtained in such small quantities at great expense. Laboratory animals, such as the guinea

pigs, were chosen as the proper experimental animals. Solid black animals were chosen for all of the laboratory animal experiments because there was less difference in shades of color. This has been justified in a previous section. Rats, as used in the previous trial were very varied in shade of color as they varied from light grey to black. Guinea pigs were thought to vary very little in shade of color.

Forty solid black guinea pigs of mixed breeding weighing on the average of 700 grams were randomly divided into five groups of eight animals each. Each group of eight animals was then randomly assigned to four cages, giving two animals per cage. The battery of 20 cages of animals was housed in an environmentally controlled room in which the temperature was maintained at around 70° C. Feed and water were given free choice. Feed consumption, liveweight gains, feed efficiency and haircoat "bloom" data were taken throughout the trial. The animals were weighed and the haircoat "bloom" measured at seven-day intervals, at which time feed refusals were weighed and discarded. Approximately seven days were allowed for the animals to become adjusted to their diets and cages before the experiment was initiated. The animals remained on the experiment for a period of 42 days.

The diets and treatments for the animals are shown in Table 24. The low and high levels of mucin added to the diets were approximately equal to the mucin added by the high and

Table 24. Composition of diets fed in Guinea Pig Trial 1

Ingredient	Treatment 1 lbs.	2 lbs.	3 lbs.	4 lbs.	5 lbs.
Casein	30.00	22.00	29.80	13.90	29.60
Sucrose	47.00	33.70	46.28	20.50	45.57
Solka floc	15.00	15.00	15.00	15.00	15.00
Salt mix[a]	4.00	4.00	4.00	4.00	4.00
Soybean oil meal	4.00	4.00	4.00	4.00	4.00
Linseed oil meal	--	21.30	--	42.60	--
Linseed oil meal mucin	--	--	0.92	--	1.83
Total	100.00	100.00	100.00	100.00	100.00

[a]Salt mix recommended by Hubbell et al. (60). The vitamins added per 100 grams of diet were: thiamine HCL 1 mg; riboflavin 1 mg; pyridoxine HCl 1 mg; calcium pantothenate 3 mg; niacin 5 mg; choline chloride 100 mg; inositol 100 mg; folic acid 0.6 mg; biotin 0.02 mg; vitamin B_{12} 0.003 mg; ascorbic acid 50 mg; alpha topcopherol 2 mg; 2-methyl-1-4-naphthoquinone 1 mg; vitamin A 2000 I.U.; and vitamin D 285 I.U.

low levels of linseed oil meal. The low and high levels of linseed oil meal used in the diets supplied approximately one-fourth and one-half of the total protein in the diets. The results of the trial are presented in Table 25.

Statistical analyses of the data indicate that all treatments significantly ($P<0.05$) increased total gains over the basal or control group. Likewise, all treatments significantly ($P<0.01$) increased "bloom" as measured by the "bloom" meter. Gains, as will be noted, were extremely low in the control group. This is explained by the fact that some of

Table 25. Results of Guinea Pig Trial 1

Treatment	Gain[a] (gms.)	"Bloom" change	Visual[b] "bloom"	Feed per 100 grams of gain (gms.)
1	29.3	1.40	2.22	3863
2	210.8	2.85	1.79	815
3	115.5	3.25	1.83	755
4	157.0	2.87	1.55	1457
5	100.7	3.20	1.45	1263

[a]Represents gain of one cage containing two animals over the entire experimental period.

[b]High = 1, medium = 2, low = 3.

the essential oils necessary for normal growth of the guinea pig was deleted through error from the diet. Several deaths resulted from this in the control group.

The addition of linseed oil meal produced 70 per cent better gains than did the addition of mucin. The low level of linseed oil meal (21 per cent) produced 34 per cent better gains than did the addition of 43 per cent linseed oil meal. The low level of linseed oil meal (21 per cent) significantly ($P < 0.05$) increased gains over the low level of mucin (0.9 per cent) by 81 per cent and over the high level of mucin (1.8 per cent) by 111 per cent.

The addition of both linseed oil meal and linseed oil meal mucin increased haircoat "bloom". The addition of linseed oil meal, as measured by the "bloom" meter, increased

"bloom" 10 per cent, while the addition of mucin increased "bloom" 13 per cent. There was essentially no difference in either the level of linseed oil meal or the level of mucin in producing "bloom". These data indicated that the mucin fraction of linseed oil meal could possibly be the factor producing or contributing to the condition of the haircoat known as "bloom".

This trial was repeated using exactly the same procedure because of the death loss and poor gains observed on the basal diet in the previous trial. The diets were changed slightly so that they contained the essential oils that were deficient in the first trial. The diets used in the second trial are shown in Table 26. The trial lasted for a period of 42 days.

Death loss was completely overcome by the modified basal diet used in this trial as were the low gains made on a similar diet in the previous trial. The results of this trial are presented in Table 27.

Statistical analyses of the data indicated that the linseed oil meal treatments significantly ($P < 0.01$) increased gains over the control group. The addition of mucin failed to stimulate gains in this trial. The addition of 21 per cent linseed oil meal increased gains over the basal group by 34 per cent while the addition of 43 per cent linseed oil meal resulted in a 22 per cent increase in gains over the basal group. Feed efficiency followed a pattern similar to

Table 26. Composition of diets used in Guinea Pig Trial 2

Ingredient	Treatment 1 lbs.	2 lbs.	3 lbs.	4 lbs.	5 lbs.
Casein	30.00	22.00	29.80	13.90	29.60
Sucrose	43.00	29.70	42.28	16.50	41.57
Solka floc	15.00	15.00	15.00	15.00	15.00
Salt mix[a]	4.00	4.00	4.00	4.00	4.00
Soybean oil meal	4.00	4.00	4.00	4.00	4.00
Linseed oil meal	--	21.30	--	42.60	--
Linseed oil meal mucin	--	--	0.92	--	1.83
Corn oil	4.00	4.00	4.00	4.00	4.00
Total	100.00	100.00	100.00	100.00	100.00

[a]Salt mix and vitamins were added as described for Guinea Pig Trial 1.

Table 27. Results of Guinea Pig Trial 2

Treatment	Gain[a] (gms.)	"Bloom" change	Visual "bloom"[b]	Feed per 100 grams of gain (gms.)
1	217.6	6.1	2.3	642.6
2	292.7	7.9	1.5	794.3
3	210.3	7.7	1.7	921.2
4	267.0	9.4	1.6	964.8
5	194.7	7.2	1.8	902.6

[a]Represents gain of one cage containing two animals over the entire experimental period.

[b]High = 1, medium = 2, low = 3.

gains.

The addition of linseed oil meal, as measured by the "bloom" meter, increased "bloom" 41 per cent while the addition of mucin resulted in a 22 per cent increase in "bloom". Linseed oil meal in this trial produced 16 per cent more "bloom" than did mucin. This is in contrast to the previous trial where mucin produced 13 per cent more "bloom" than linseed oil meal. These differences between linseed oil meal and mucin were not statistically significant.

The addition of linseed oil meal and mucin, as measured by visual comparison, likewise increased haircoat "bloom". The measurement of haircoat "bloom" by the meter and by visual comparison were in close agreement. It is concluded as in the first trial that the mucin fraction of linseed oil meal appears to be the factor responsible for haircoat "bloom".

"Bloom" change data by seven-day periods are presented in Table 28. These data indicate that the greatest change in "bloom" apparently occurred in the last week of the trial. Apparently, a longer trial would be needed for greater differences in haircoat "bloom".

The effect of the level of linseed oil meal upon growth rate, feed efficiency and haircoat "bloom" of guinea pigs (Guinea Pig Trial 3). The differences obtained between various levels of linseed oil meal in their effect upon growth and haircoat "bloom" in previous trials necessitated an

Table 28. "Bloom" change by period for Guinea Pig Trial 2

Period	Treatment 1	2	3	4	5
1st week	-0.8	-0.4	0.5	-0.2	-0.7
2nd week	1.8	2.0	2.3	1.1	1.7
3rd week	1.5	-1.4	-1.2	2.1	2.6
4th and 5th week	1.2	4.9	6.0	3.9	2.6
6th week	2.4	2.8	0.1	2.5	1.0
Total	6.1	7.9	7.7	9.4	7.2

attempt to try to repeat these effects in similar trials to see if the differences were valid.

Thirty solid-black guinea pigs of mixed breeding weighing around 650 grams were randomly divided into three groups of 10 animals each. Each group of 10 animals was randomly assigned to five cages, giving two animals per cage. The battery of 15 cages was housed in the same room used for previous trials. Feed consumption, growth and haircoat "bloom" data were measured as previously described. Seven days were allowed for the animals to become adjusted to the diets and cages. The trial lasted for a period of 42 days.

The treatments and diets used in the experiment are presented in Table 29. The two levels of linseed oil meal used in the diets supplied approximately one-fourth and one-half of the total protein in the diets. The results of this trial are presented in Table 30.

Table 29. Diets used in Guinea Pig Trial 3

Ingredient	Treatment 1 lbs.	2 lbs.	3 lbs.
Casein	30.0	22.0	9.9
Sucrose	43.0	29.7	20.5
Solka floc	15.0	15.0	15.0
Salt mix[a]	4.0	4.0	4.0
Soybean oil meal	4.0	4.0	4.0
Linseed oil meal	--	21.3	42.6
Corn oil	4.0	4.0	4.0
Total	100.0	100.0	100.0

[a]Salt mix and vitamins were added as described for Guinea Pig Trial 1.

Table 30. Results of Guinea Pig Trial 3

Treatment	Gain[a] (gms.)	"Bloom" change	Visual "bloom"[b]	Feed per 100 grams of gain (gms.)
1	125.6	8.20	2.10	1063.2
2	312.2	9.26	1.83	416.4
3	379.0	10.92	1.54	591.3

[a]Represents gain of one cage containing two animals over the entire experimental period.

[b]High = 1, medium = 2, low = 3.

Statistical analyses of the data reveal that the addition of linseed oil meal significantly ($P < 0.01$) increased gains and feed efficiency. The addition of 21 per cent linseed oil meal increased gains over the basal group by 148 per cent while the addition of 43 per cent linseed oil meal resulted in a 200 per cent increase in gains over the basal group. The addition of 43 per cent linseed oil meal produced 21 per cent better gains than the addition of 21 per cent linseed oil meal which is in contrast to previous results. The 21 per cent linseed oil meal treatment resulted in 60 per cent more efficient gains than the basal group while the 43 per cent linseed oil meal treatment resulted in only 44 per cent more efficient gains. The 21 per cent linseed oil meal treatment agreed with previous results by producing 30 per cent more efficient gains than the 43 per cent linseed oil meal treatment.

Haircoat "bloom" was increased by the addition of linseed oil meal, as measured by the "bloom" meter. "Bloom" was increased over the basal group 13 per cent by the addition of 21 per cent linseed oil meal and 33 per cent by the addition of 43 per cent linseed oil meal. The 43 per cent linseed oil meal treatment resulted in 18 per cent more "bloom" than the 21 per cent linseed oil meal treatment which was in contrast to the results obtained in previous trials. "Bloom" was also increased by the linseed oil meal treatments as measured by

visual comparison. Comparable results were obtained with the "bloom" meter and by visual comparison. The results indicated in this trial, as in previous trials, that linseed oil meal would increase the haircoat "bloom" of guinea pigs.

The effect of linseed oil meal mucin and fractions of linseed oil meal mucin upon the growth rate, feed efficiency and haircoat "bloom" of guinea pigs (Guinea Pig Trial 4). Previously it has been determined that the addition of linseed oil meal mucin would increase the haircoat "bloom" of guinea pigs from 13-22 per cent. These data made it seem desirable to determine the factor or factors in linseed oil meal mucin causing this effect. The large amounts of pentose sugars and ash present in mucin were the factors chosen to study.

Forty solid black guinea pigs of mixed breeding weighing around 650 grams were randomly divided into five groups of eight animals each. Each group of eight animals was randomly assigned to four cages, giving two animals per cage. The 20 cages were housed in the same room as the cages of the previous trials. All feed efficiency, growth and "bloom" data were measured as previously described in earlier trials. Seven days were allowed for the animals to become adjusted to the diets and cages before the trial was initiated. The treatments and diets for the trial are listed in Table 31.

The sugars used in the diets were added in amounts to equal those added by the 1.8 per cent mucin. The

Table 31. Composition of diets fed in Guinea Pig Trial 4

Ingredient	Treatment 1 lbs.	2 lbs.	3 lbs.	4 lbs.	5 lbs.
Casein	30.00	29.60	30.00	30.00	30.00
Sucrose	43.00	41.57	42.12	42.60	42.86
Solka floc	15.00	15.00	15.00	15.00	15.00
Salt mix[a]	4.00	4.00	4.00	4.00	4.00
Soybean oil meal	4.00	4.00	4.00	4.00	4.00
Linseed oil meal mucin	--	1.83	--	--	--
Corn oil	4.00	4.00	4.00	4.00	4.00
Sugars from water-soluble mucin fraction	--	--	0.88	--	--
Sugras from water-insoluble mucin fraction	--	--	--	0.40	--
Ash of mucin	--	--	--	--	0.14
Total	100.00	100.00	100.00	100.00	100.00

[a]Salt mix and vitamins were added as described for Guinea Pig Trial 1.

mucin ash was added in a similar manner. The composition of the sugar mixtures is given in Table 32.

The results of this trial are given in Table 33. Statistical analyses of the data reveal that the addition of the sugars found in the water-soluble and water-insoluble fractions of linseed oil meal mucin increased gains over the group of animals receiving mucin by 38-42 per cent. The addition of mucin or the ash of mucin failed to stimulate gains over the basal group. The addition of the sugars

Table 32. Composition of sugars used in the diets of Guinea Pig Trial 4

Sugars	Water-soluble fraction of mucin (lbs.)	Water-insoluble fraction of mucin (lbs.)
Galactose	0.13	0.06
Arabinose	0.13	0.07
Xylose	0.30	0.18
Rhamnose	0.32	0.09
Total	0.88	0.40

Table 33. Results of Guinea Pig Trial 4

Treatment	Gain[a] (gms.)	"Bloom" change	Feed per 100 grams of gain (gms.)
1	213.6	2.1	699.4
2	189.7	4.4	1068.0
3	280.1	-1.5	588.7
4	262.0	4.0	722.5
5	185.3	3.9	1056.7

[a]Represents gain of one cage containing two animals over the entire experimental period.

Slightly increased gain over the control group but not significantly. Feed efficiency values followed closely the pattern of gains.

The addition of mucin, the sugars found in the water-insoluble fraction of mucin and the ash of mucin

increased haircoat "bloom" over the basal group by 109, 91 and 85 per cent, respectively, as measured by the "bloom" meter. The sugars found in the water-soluble fraction of mucin actually lowered haircoat "bloom". There was essentially no difference between the sugars found in the water-insoluble fraction of mucin, the ash of mucin and mucin in their ability to promote haircoat "bloom". These data confirm previous results that mucin increased haircoat "bloom" and indicated that the factors responsible for this are perhaps in the ash of mucin and/or in the combination of sugars found in the water-insoluble fraction of mucin.

The effect of linseed oil meal mucin and diethylstilbestrol upon growth rate, feed efficiency and haircoat "bloom" of guinea pigs (Guinea Pig Trial 5). Observations by Culbertson* as well as reports from the field have indicated that diethylstilbestrol might add additional gloss or increase the "bloom" on the haircoat of cattle. A trial was conducted with guinea pigs to verify these reports and to further substantiate the "bloom" data previously obtained by the feeding of linseed oil meal mucin.

Eighteen solid black guinea pigs of mixed breeding weighing around 700 grams were randomly divided into three groups of six animals each. The six animals of each group were randomly

*C. C. Culbertson, Animal Husbandry Department, Iowa State College, Ames, Iowa. Stilbestrol in cattle rations. Private communication. 1958.

assigned to three cages, giving two animals per cage. Feeding, housing, measurement of data and pre-trial treatment of the animals were conducted as previously described for earlier trials. The trial lasted for a period of 21 days.

The diets and treatments are presented in Table 34. The level of diethylstilbestrol used in the diets as well as the method of mixing was similar to that reported by Preston (89). The results of this trial are presented in Table 35.

Statistical analysis of the data revealed that the addition of stilbestrol at the rate of 0.01 microgram per gram of diet significantly ($P < 0.01$) increased total gains 32.6 per

Table 34. Composition of diets fed in Guinea Pig Trial 5

Ingredient	Treatment 1 lbs.	2 lbs.	3 lbs.
Casein	30.00	29.60	30.00
Sucrose	43.00	41.57	43.00
Solka floc	15.00	15.00	15.00
Salt mix[a]	4.00	4.00	4.00
Soybean oil meal	4.00	4.00	4.00
Corn oil	4.00	4.00	4.00
Linseed oil meal mucin	--	1.83	--
Stilbestrol	--	--	added[b]
Total	100.00	100.00	100.00

[a]Salt mix and vitamins were added as described for Guinea Pig Trial 1.

[b]Diethylstilbestrol added at the rate of 0.01 micrograms per gram of diet.

Table 35. Results of Guinea Pig Trial 5

Treatment	Gain[a] (gms.)	"Bloom" change	Feed per 100 grams of gain (gms.)
1	110.2	3.67	369.5
2	89.7	5.23	487.8
3	146.2	2.67	310.6

[a]Represents gain of one cage containing two animals over the entire experimental period.

cent and resulted in an 11.3 per cent feed savings over the control group. These results were comparable to those obtained by Preston (89). The feeding of linseed oil meal mucin did not stimulate gains or feed efficiency over the control group as was the case in previous trials.

The addition of 1.8 per cent linseed oil meal mucin in the diet resulted in a 42.5 per cent increase in haircoat "bloom" although this was not statistically significant. The addition of diethylstilbestrol made no improvement in haircoat "bloom". This did not confirm previous reports from the field that stilbestrol would increase haircoat "bloom". A longer experimental period, as has been pointed out previously, might have produced different results as the largest increase in "bloom" in guinea pigs seemed to occur after the 35th day of trial.

Discussion

Results from trials with laboratory animals (rats and guinea pigs) indicated that the addition of linseed oil meal to the diet increased haircoat "bloom". This increase amounted to as much as 10-40 per cent. When linseed oil meal supplied approximately one-half of the total protein in the diet, more "bloom" was added to the haircoat than when linseed oil meal supplied only one-fourth of the total protein in the diet. The data indicated that linseed oil meal contained a factor or factors that increased haircoat "bloom". This factor(s) was apparently much more effective in promoting "bloom" when supplied in large quantities of linseed oil meal.

The addition of both 0.9 and 1.8 per cent of linseed oil meal mucin to laboratory animal diets increased haircoat "bloom". This increase in "bloom" was almost equivalent to that observed when linseed oil meal was fed in amounts to supply these same levels of linseed oil meal mucin (0.9 and 1.8 per cent). The results of Guinea Pig Trial 2 reveal that there was little or no effect upon haircoat "bloom" by increasing the level of linseed oil meal mucin in the diet from 0.9 to 1.8 per cent. Apparently the factor(s) responsible for the ability of linseed oil meal to confer "bloom" to the haircoat was present in the mucin fraction of linseed oil meal.

Results from later studies (Guinea Pig Trial 4) indicated

that the addition of the sugars found in the water-insoluble fraction of linseed oil meal mucin and the ash portion of linseed oil meal mucin increased the haircoat "bloom" of guinea pigs almost equivalent to that observed when mucin was included in the diet alone. The sugars found in the water-soluble fraction of linseed oil meal mucin failed to increase "bloom". The data indicated that linseed oil meal mucin contained the factor(s) responsible for "bloom" and that this factor(s) might have been present in the ash of mucin and/or in the combination of sugars found in the water-insoluble fraction of mucin.

More quantitative data were obtained by using the "bloom" meter for measuring haircoat "bloom" as opposed to the method of visual comparison. Although the two methods compared favorably, the "bloom" meter was much more sensitive and was able to detect smaller differences. This was evident in those trials in which a direct comparison between the two methods of measuring haircoat "bloom" was made.

Summary

Results from five guinea pig trials and one rat trial indicated that the feeding of linseed oil meal at levels of 21 to 43 per cent of the diet increased haircoat "bloom" 10-40 per cent. Twenty per cent more "bloom" was added to the haircoat of guinea pigs when linseed oil meal was fed at

a level of 43 per cent of the diet than when fed at a level of 21 per cent of the diet. Likewise, the feeding of linseed oil meal mucin to guinea pigs resulted in a 13-22 per cent increase in "bloom" indicating that the factor(s) responsible for the effect of linseed oil meal upon "bloom" apparently was present in the mucin fraction. The addition of a combination of sugars found in the water-insoluble fraction of linseed oil meal mucin and the addition of the ash portion of linseed oil meal mucin increased the haircoat "bloom" of guinea pigs 109 and 91 per cent, respectively. These data indicated that the factor(s) in linseed oil meal mucin responsible for increased haircoat "bloom" might be present in the combination of sugars found in the water-insoluble fraction of mucin and/or in the ash of mucin. The feeding of linseed oil meal, linseed oil meal mucin, ash of mucin and the sugars found in the water-insoluble fraction of mucin all gave comparable results as to their effect upon the haircoat "bloom" of guinea pigs. The sugars found in the water-soluble fraction of linseed oil meal mucin had no effect upon "bloom".

The feeding of diethylstilbestrol at the rate of 0.01 microgram per gram of feed was without effect upon haircoat "bloom" for the short trial in which it was included, but did result in a 33 per cent increase in gains and an 11.3 per cent increase in feed efficiency. The feeding of linseed oil meal

to guinea pigs resulted in a 20-30 per cent increase in gains and a comparable feed savings. The feeding of linseed oil meal mucin had no effect upon gains or feed efficiency.

Cattle Experiments

Methods and results

The effect of flaxseed extract upon the growth rate, feed efficiency and haircoat "bloom" of cattle (Cattle Trial 1). The feeding of flaxseed extract to lambs had previously been shown to increase average daily gains 12-18 per cent with a comparable feed saving. A desire existed to test not only the effect of flaxseed extract upon the gains of cattle, but also to see if flaxseed extract would increase the haircoat "bloom" of cattle and to see if there was any correlation between "bloom" and finish. Linseed oil meal mucin could not be obtained in quantities large enough to feed cattle, however the flaxseed extract fed contained around 0.75 per cent mucin.

Thirty-six Hereford steers weighing around 1131 pounds were assigned by weight and previous treatment to six lots of six animals each. These animals were on a previous trial with a comparable number of lots and treatments, therefore the latin square method was used to aid in assigning these animals to treatment and lot. There were two lots of six steers each on each treatment.

All animals received a full feed of cracked shelled corn, 4 lbs. of a specially fine-ground corn cob meal, 2 1/2 pounds of alfalfa hay and 1 1/2 pounds of supplement per steer daily. The cattle were full-fed corn twice a day, receiving the supplement at the morning feed. The hay was fed at the evening feed after the animals had cleaned up their full feed of corn. The corn cobs were mixed with either water or flaxseed extract at the time of feeding, similar to the procedure previously described for the lamb trials. The cattle received this wet corn cob mix at the evening feed. The cobs were thoroughly mixed with the corn at this feeding.

The treatments, supplements and liquid additions are presented in Table 36. The composition of the Iowa 10-10-10-15 supplement used is presented in Table 37. Stilbestrol was included in all rations at levels to permit each animal to receive 10 milligrams daily. The flaxseed extract was fed to supply approximately the amount of mucin supplied by the linseed oil meal supplement.

The cattle were weighed every 21 days at which time any feed refusals were weighed and discarded. The trial lasted for a period of 74 days or until it was thought that the cattle had reached a slaughter condition of high-choice to low-prime. Live grades and estimated dressing percentages were determined at this time by a committee of three packer buyers from packing plants in the state of Iowa. The cattle

Table 36. Daily supplement and liquid additions for Cattle Trial 1

Treatment	Supplement daily per steer (lbs.)	Liquid additions to 4 pounds of corncobs (lbs.)
1	1.0 pound of Iowa 10-10-10-15 + 0.5 pound of soybean oil meal	12 pounds of water
2	1.5 pounds of linseed oil meal + 10 milligrams of stilbestrol	12 pounds of water
3	1.0 pound of Iowa 10-10-10-15 + 0.5 pound of soybean oil meal	18 pounds of flaxseed extract

Table 37. Composition of the Iowa 10-10-10-15 supplement fed in Cattle Trial 1

Ingredient	Pounds per ton
Coarse ground corn cobs	1240
Molasses	310
Urea	200
Dicalcium phosphate	110
Limestone	75
Salt	40
Stilbosol[a]	20
Trace mineral premix	5
Total	2000

[a]Contained one gram of diethylstilbestrol per pound.

were followed to the packing plant where slaughter and carcass evaluations were made similar to those described by Preston (88).

Average daily gain, feed efficiency values and haircoat "bloom" scores are presented in Table 38. The "bloom" scores

Table 38. Feedlot performance and "bloom" data from Cattle Trial 1

Treatment	A.D.G. (lbs.)	Feed per pound of gain (lbs.)	"Bloom" score[a]
1	2.17	10.9	1.5
2	2.09	11.3	1.6
3	2.28	10.5	1.6

[a]High = 1, medium = 2, low = 3.

presented in this trial were obtained by visual means by a committee of three members from the staff of Iowa State College. At this time the meter for measuring haircoat "bloom" had not been developed. There were no significant differences in gain, "bloom" or feed efficiency due to treatment, however the cattle receiving flaxseed extract gained 0.11 pounds more per day than the basal group of animals. The linseed oil meal treatment failed to stimulate gains. Feed efficiency values followed a similar pattern. There was little difference in hair coat "bloom" due to treatment

although both the addition of linseed oil meal and flaxseed extract were superior by 6.7 per cent.

The carcass data from this trial are presented in Table 39. Most all of the cattle graded average-choice in all of

Table 39. Carcass data from Cattle Trial 1

Treatment	Carcass grade[a]	Rib eye area (sq.in.)	Fat thickness over rib eye (mm.)	Dressing per cent
1	8.60	12.5	34	61.5
2	8.42	13.0	38	62.0
3	7.59	13.8	34	62.7

[a]Low-choice = 7, average-choice = 8, high-choice = 9.

the lots. There was some suggestion that the cattle receiving linseed oil meal and flaxseed extract had more finish than the cattle of the basal group because of the higher dressing percentages obtained. The cattle receiving linseed oil meal dressed one per cent higher and the cattle receiving flaxseed dressed two per cent higher than the control cattle. This suggested difference in finish was substantiated by the linseed oil meal fed cattle but not by the flaxseed extract fed cattle on the basis of thickness of fat over the rib eye muscle. Fat thickness was increased 11.8 per cent over the control group by the feeding of linseed oil meal, but no difference was observed when flaxseed extract was fed. The

area of the rib eye muscle was increased over the controls by four per cent by the feeding of linseed oil meal while the feeding of flaxseed extract significantly ($P<0.05$) increased the area of the rib eye muscle by 10.4 per cent. The feeding of flaxseed extract significantly ($P<0.05$) increased the area of the rib eye over the cattle fed linseed oil meal.

These results with respect to hair coat "bloom" differed from the results obtained with linseed oil meal in a previous trial by Burroughs (24) where the cattle were fed for a longer time. It was therefore interesting to speculate that the length of the feeding period might have been of importance in the influence of linseed oil meal upon hair coat "bloom" in fattening cattle. Gains and feed required per pound of gain were satisfactory considering the hot-weather season in which the trial was conducted and the finish on the cattle. These cattle were in approximately high-good to low-choice condition at the start of the trial.

The effect of linseed oil meal upon growth rate, feed efficiency and haircoat "bloom" of cattle (Cattle Trial 2). Even though it had been shown that linseed oil meal would improve the haircoat "bloom" of guinea pigs, this had not been determined quantitatively in cattle. Aberdeen Angus cattle were chosen for the following experiment because of the small difference in shade of color as has been previously discussed.

Eight yearling Angus steers weighing around 770 pounds

were randomly assigned by weight to two groups. One group received a supplement containing linseed oil meal as the base protein while the other group received a supplement containing soybean oil meal as the base protein. All animals were individually fed a full feed of cracked shelled corn twice a day, three pounds of alfalfa hay at the evening feed and either 1.8 pounds of soybean oil meal supplement or 2.1 pounds of linseed oil meal supplement equally divided over the morning and evening feeds. The supplements were fed at different rates so that all animals would receive an equivalent amount of nitrogen providing all the supplement was eaten. The animals were allowed to remain in their individual feeding stalls for approximately 2 1/2 hours twice a day. They received water free choice. The supplements used in the trial are shown in Table 40.

The cattle were weighed every 28 days at which time feed refusals were weighed and discarded. Haircoat "bloom" evaluations were also made at this time by the use of the "bloom" meter previously described. A committee of three Iowa State College staff members visually measured haircoat "bloom" at the beginning and at the end of the trial, to make a comparison with the results obtained by the meter. The trial lasted for a period of 139 days.

The results of the feedlot performance and "bloom" data are shown in Table 41. There was essentially no difference in

Table 40. Supplements fed in Cattle Trial 2

Ingredient	Pounds per ton	
	1	2
Soybean oil	1808	--
Linseed oil meal	--	1857
Salt	22	19
Trace mineral premix	3	2
Vitamin A[a]	11	9
Vitamin D[b]	2	2
Dicalcium phosphate	154	111
Total	2000	2000

[a]2,000,000 I.U. per pound.

[b]3,000 I.U. per gram.

Table 41. Feedlot performance and "bloom" data from Cattle Trial 2

Treatment	A.D.G. (lbs.)	Feed per pound of gain (lbs.)	"Bloom" change	Visual "bloom"[a]
1	2.31	7.77	24.5	2.25
2	2.28	7.73	25.1	1.92

[a]High = 1, medium = 2, low = 3.

average daily gain or feed efficiency, however these qualities were slightly in favor of the cattle fed soybean oil meal. The feeding of linseed oil meal increased "bloom" 2.5 per cent as measured by the "bloom" meter. Comparable results were

obtained by the method of visual comparison.

The change in haircoat "bloom" by 28-day periods is presented in Table 42. Maximum haircoat "bloom" was apparently observed during the first and second 28-day period with

Table 42. "Bloom" change by period for Cattle Trial 2

Period	Treatment	
	Soybean oil meal	Linseed oil meal
First 28 days	6.00	6.13
Second 28 days	7.15	7.93
Third 28 days	1.83	1.95
Fourth 28 days	4.60	4.65
Fifth 27 days	4.92	4.43
Total	24.50	25.09

a compensating lesser "bloom" increase the following 28 days. "Bloom" was again increased after 84 days indicating that perhaps maximum increase in "bloom" may not be obtained unless cattle are on a long feed.

Carcass evaluation data are presented in Table 43. There were no significant treatment differences in carcass grade, dressing per cent, area of the rib eye or thickness of fat over the rib eye muscle. The linseed oil meal-fed cattle did grade 3.3 per cent or approximately 0.1 of a grade higher than the group fed soybean oil meal. The soybean oil meal-fed cattle appeared to be fatter based on the slightly higher

Table 43. Carcass data from Cattle Trial 2

Treatment	Carcass grade[a]	Dressing per cent	Area of rib eye (sq.in.)	Thickness of fat over rib eye (mm.)
1	7.50	61.7	13.13	31.3
2	7.75	60.6	11.79	30.9

[a]Low-choice = 7, average-choice = 8, high-choice = 9.

dressing percentage and thickness of fat over the rib eye. The area of the rib eye was also slightly larger for the cattle fed soybean meal. All of the cattle graded from low-choice to average-choice condition.

The effect of the level of linseed oil meal upon the haircoat "bloom" of cattle (Cattle Trial 3). A 2 x 2 x 3 factorial experiment being conducted with 72 head of yearling Hereford cattle by the Iowa State College Animal Husbandry Department was used to obtain haircoat "bloom" data with the aid of the "bloom" meter. Linseed oil meal was used as the protein supplement and was fed at levels ranging from 0.05 to 1.4 pounds of linseed oil meal per steer daily.

Haircoat "bloom" data were obtained on these cattle to see if a difference could be detected on different levels of linseed oil meal. "Bloom" data was taken at the same time the cattle were weighed, which was at 28-day intervals. Haircoat "bloom" data were taken for a period of 84 days. There

were 12 lots of six animals each involved in the trial. The statistical design of the trial and the pounds of supplement fed per steer daily is presented in Table 44. The composition of the supplements is presented in Table 45.

Table 44. Statistical design and pounds of supplement fed per steer daily in Cattle Trial 3

	Linseed oil meal		Linseed oil meal-urea	
	No TQ[a]	TQ	No TQ	TQ
Low protein	Lot 1 (0.5 lb.)	Lot 2 (0.5 lb.)	Lot 3 (0.25 lb.)	Lot 4 (0.25 lb.)
Medium protein	Lot 5 (1.0 lb.)	Lot 6 (1.0 lb.)	Lot 7 (0.5 lb.)	Lot 8 (0.5 lb.)
High protein	Lot 9 (2.0 lb.)	Lot 10 (2.0 lb.)	Lot 11 (1.0 lb.)	Lot 12 (1.0 lb.)

[a]TQ represents tranquilizer.

The urea in the linseed oil meal-urea supplement furnished approximately 50 per cent of the total nitrogen in the supplement. The three levels of protein fed were approximately 8.5, 9.0 and 9.5 per cent of the total ration calculated upon a constant intake of hay, grain and supplement. All cattle received three pounds of hay and a full feed of corn in addition to the supplement.

The author was only interested in the effect of the level of linseed oil meal upon haircoat "bloom", therefore

Table 45. Composition of supplements fed in Cattle Trial 3

Ingredients	Lot number											
	1	2	3	4	5	6	7	8	9	10	11	12
Linseed oil meal	33.5	32.5	9.2	7.2	277	273	11.5	10.5	280.5	278.5	99.0	95.0
Urea	--	--	7.8	7.8	--	--	7.8	7.8	--	--	62.0	62.0
Dehydrated corn cobs	--	--	--	--	57	57	14.2	14.2	86.5	86.5	173.0	173.0
Omalas	5.0	5.0	10.0	10.0	20	20	5.0	5.0	10.0	10.0	20.0	20.0
Dicalcium phosphate	5.0	5.0	10.0	10.0	20	20	5.0	5.0	10.0	10.0	20.0	20.0
Limestone	5.0	5.0	10.0	10.0	20	20	5.0	5.0	10.0	10.0	20.0	20.0
Stilbosol[a]	1.0	1.0	2.0	2.0	4	4	1.0	1.0	2.0	2.0	4.0	4.0
Trace mineral premix	0.3	0.3	0.5	0.5	1	1	0.3	0.3	0.5	0.5	1.0	1.0
Vitamin A[b]	0.2	0.2	0.5	0.5	1	1	0.2	0.2	0.5	0.5	1.0	1.0
Tranquilizer premix[c]	--	1.0	--	2.0	--	4	--	1.0	--	2.0	--	4.0
Total	50.0	50.0	50.0	50.0	400	400	50.0	50.0	400.0	400.0	400.0	400.0

[a]Contains one gram of diethylstilbestrol per pound.

[b]Contains two million I.U. per pound.

[c]Contains 500 milligrams per pound.

the trial was analyzed only as a 2 x 3 factorial. The factor, tranquilizer, was omitted from the design as it had no effect upon haircoat "bloom" and was not considered as an important objective in the author's part of the experiment.

The results of the trial are presented in Table 46.

Table 46. Haircoat "bloom" data obtained in Cattle Trial 3[a]

	Linseed oil meal	Linseed oil meal-urea
Low protein	10.6[b] 0.34 pounds	11.1 0.05 pounds
Medium protein	14.6 0.69 pounds	10.8 0.12 pounds
High protein	15.1 1.4 pounds	11.2 0.25 pounds

[a]Haircoat "bloom" is presented as units of change in "bloom".

[b]Upper figure represents haircoat "bloom" increase. Lower figure represents pounds of linseed oil meal received per steer per day.

Haircoat "bloom" was increased as the level of linseed oil meal fed daily per steer was increased. "Bloom" was increased approximately 36 per cent by the feeding of 1.4 pounds of linseed oil meal per steer daily as compared to 0.05 pounds. As the level of protein in the ration increased, haircoat "bloom" was increased, while the addition of urea

to the linseed oil meal supplement decreased haircoat "bloom". There was a significant ($P<0.01$) interaction between the supplement fed and the level of protein fed. All of these effects were primarily due to a difference in the level of linseed oil meal fed per steer daily.

Haircoat "bloom" change by 28-day periods is presented in Table 47. The largest increase in "bloom" apparently

Table 47. Haircoat "bloom" change by 28-day periods obtained in Cattle Trial 3

Lot	Period 1	Period 2	Period 3	Total
1	6.7	2.2	2.1	11.0
2	5.6	4.1	0.4	10.1
3	6.6	3.4	1.1	11.1
4	10.7	4.0	-3.7	11.0
5	10.7	2.4	2.1	15.2
6	10.1	2.4	1.5	14.0
7	7.0	3.2	0.8	11.0
8	8.3	3.7	-1.5	10.5
9	9.2	3.6	2.2	15.0
10	6.3	4.0	4.8	15.1
11	8.9	2.4	0.0	11.3
12	6.5	1.6	2.9	11.0

occurred during the first 28 days with a general slacking off during the following periods. This is in partial agreement with previous results, however maximum differences might have been obtained if a longer experimental period had

been involved. A longer experimental period has been indicated in the results obtained in Cattle Trial 2 and from the trials with laboratory animals.

Discussion

The feeding of flaxseed extract to cattle resulted in increased average daily gains, more efficient gains and a sleeker haircoat. The feeding of flaxseed extract likewise improved feed efficiency over the control cattle and the linseed oil meal treated cattle. These results are similar to those previously obtained when flaxseed extract was fed to lambs.

The feeding of a linseed oil meal supplement containing stilbestrol failed to stimulate gains over control cattle receiving a soybean oil meal supplement containing stilbestrol or over animals receiving flaxseed extract with stilbestrol added. The poorer performance of linseed oil meal in this respect did not agree with previous work by Burroughs et al. (24) in which linseed oil meal containing added stilbestrol compared favorably with other supplements containing added stilbestrol. A direct comparison of soybean oil meal and linseed oil meal, both containing no added stilbestrol, produced no significant differences in average daily gain or feed efficiency. These results are in agreement with Culbertson et al. (35), but are in contrast to the work of Hinman et al.

(57) who found that linseed oil meal would increase gains over a supplement of soybean oil meal. The poor results obtained with linseed oil meal containing stilbestrol in the first trial might be attributed to the fact that stilbestrol was omitted from the supplement through error the first 13 days of the trial. During the first 28-day period the gains were extremely low for the cattle receiving linseed oil meal, although they were comparable to the gains made on the other treatments throughout the latter weigh periods.

Both flaxseed extract and linseed oil meal seemingly increased the finish of the cattle in the first trial as was borne out by an increased fat thickness over the rib eye in the case of linseed oil meal, but not in the case of flaxseed extract. Linseed oil meal increased fat thickness over the rib eye in the first trial 11.8 per cent and increased the area of the rib eye 4 per cent.

In contrast to the above results, linseed oil meal failed to increase dressing per cent, rib eye area or thickness of fat over the rib eye in the second trial. The soybean oil meal fed cattle in this trial dressed higher, had larger rib eyes and more fat over the rib eye than the linseed oil meal fed cattle. Linseed oil meal, however, did increase carcass grade over the cattle receiving soybean oil meal.

The feeding of both flaxseed extract and linseed oil meal resulted in increased haircoat "bloom". This increase amounted to as much as 2.5 to 6.7 per cent. The smallest difference in "bloom" was obtained in the first trial where comparisons were made visually. There was no difference between flaxseed extract and linseed oil meal in their effects on "bloom". Linseed oil meal mucin has been assumed to be the factor responsible for haircoat "bloom", therefore larger differences might have been obtained if the mucin could have been fed directly rather than being fed as a part of the flaxseed extract. The effect of the mucin present in flaxseed extract could have been obscured by other factors present, however the level of mucin in the flaxseed extract was approximately equal to that fed in the linseed oil meal treatment. Perhaps larger differences could have been obtained if a longer feeding period was used and if the cattle were fed to a higher grade.

Results in the second trial illustrated that even though 1.8 pounds of soybean oil meal and 2.1 pounds of linseed oil meal were given to the animals, only 1.43 and 1.32 pounds, respectively, were actually consumed. No explanation could be given for the feed refusal of these supplements. Results obtained in the third trial indicated that an increase in the level of linseed oil meal fed per steer daily would increase haircoat "bloom". The largest increase in "bloom" in

Cattle Trial 3 was obtained in the first 28 days with a progressive decrease in "bloom" during the following 28-day periods. The maximum increase in "bloom" in Cattle Trial 2 was also obtained in the first and second 28-day periods with a subsequent decrease in "bloom" during the following 28 days, however "bloom" was again increased during the latter periods of the trial. The large increase in "bloom" during the first and second 28-day periods might have been due to stress upon the animals in shipment causing them to have a poor haircoat or very little "bloom" at the beginning of a trial. Similar observations have been made along this line in respect to gains and feed consumption which are quite high the first 28-56 days of a trial. A large increase in "bloom" at the beginning of a trial seemed to be compensated by the lesser "bloom" increase during the third and fourth 28-day period. Results in Cattle Trial 2 indicated that "bloom" was increased in the latter periods of the trial. This indicated that true maximum "bloom" may not be attained in short experimental periods other than the large increase in "bloom" observed in the first 28-56 days. Maximum haircoat "bloom" may not be attained until cattle have been fed longer than 84 days.

Summary

The results of three cattle feeding trials indicated that the feeding of either flaxseed extract or linseed oil meal would increase haircoat "bloom" as much as 2.5 to 6.7 per cent. The feeding of flaxseed extract resulted in 5.1 per cent faster gains and 3.7 per cent more efficient gains than control cattle, while the feeding of linseed oil meal failed to stimulate average daily gains or feed efficiency. The results were inconclusive as to whether the feeding of linseed oil meal would increase carcass grade, dressing per cent, area of rib eye or thickness of fat over the rib eye. The results indicated that maximum haircoat "bloom" was observed in the first or second 28-day period followed by a lesser "bloom" increase the following 28 days. "Bloom" again increased after 84 days.

In Vitro Studies

Methods

The effect of flaxseed extract, flaxseed extract dry matter, linseed oil meal mucin and fractions of linseed oil meal mucin upon cellulose digestion in vitro. The purpose of these studies was to evaluate the effects of a water extract of flaxseed and various fractions of this extract upon cellulose digestion by rumen microorganisms in vitro. Previously

it had been shown by Burroughs *et al*. (25, 27), Bentley *et al*. (13) and Ruf *et al*. (91) that water extracts of feed materials would increase the cellulose digestion by rumen microorganisms *in vitro*. A postulation was that perhaps the factors causing increased gains in sheep and cattle receiving flaxseed extract could be partially explained by studies in the artificial rumen.

The *in vitro* technique as described by Cheng *et al*. (28) was used in this series of studies. The procedure was as follows: the inoculum was obtained from a fistulated steer maintained on a daily ration composed of four pounds of ground corn cob, 1.5 pounds ground corn, 0.5 pounds soybean oil meal and five pounds of alfalfa hay. The ingesta was removed from the rumen and the liquid strained through four layers of cheese cloth into pre-warmed thermos bottles. The microorganisms from two liters of this rumen liquid were used to inoculate one liter of the basal medium shown in Table 48. The rumen liquid was centrifuged at 2000 RPM for two minutes in a Servall angle centrifuge to remove small feed particles. The supernatant was then centrifuged at 25,000 RPM in a Sharples centrifuge to remove the microorganisms from the rumen liquor. The microorganisms were removed from the Sharples barrel and suspended in CO_2 saturated distilled water which had been warmed to 39° C and then the suspension was re-centrifuged in the Sharples to remove the micro-

Table 48. Basal medium for *in vitro* fermentation

Constituents	Amount
Cellulose	10.0 gm.
Urea	2.0 gm.
KH_2PO	0.6 gm.
$Na_2HPO_4 \cdot 7\ H_2O$	1.2 gm.
$NaHCO_3$	3.5 gm.
KCl	4.0 gm.
NaCl	4.0 gm.
MgSO	0.15 gm.
$CuSO_4 \cdot 5\ H_2O$	0.002 gm.
$MnSO_4 \cdot 5\ H_2O$	0.0004 gm.
$ZnSO_4 \cdot 7\ H_2O$	0.00008 gm.
$FeSO_4 \cdot 7\ H_2O$	0.075 gm.
$CoCl_2 \cdot 6\ H_2O$	0.002 gm.
$CaCl_2$	0.55 gm.
Distilled water	2.0 liter

organisms. After this second centrifuging, the microorganisms were suspended in the basal medium. This suspension of microorganisms and cellulose was placed in the water bath and CO_2 was bubbled through the suspension. After 10 minutes, the pH was adjusted to 6.9 and 20 milliliter aliquots were distributed to 75 milliliter fermentation tubes.

The flaxseed extract was added to the fermentation tubes as a liquid. If there was less than one milliliter added to any of the tubes, no correction was made for this slight dilution. When more than one milliliter had to be added, the volume of the other tubes was adjusted. Flaxseed extract

dry matter was dissolved in water and added to the digestion tubes. The water was then evaporated in a forced-air oven at 70-75° C. Linseed oil meal mucin and fractions of linseed oil meal mucin were also added to the digestion tubes in a water solution and the water evaporated.

Results

The effect of various levels of flaxseed extract upon *in vitro* cellulose digestion by rumen microorganisms is shown in Table 49. The per cent cellulose digested in 24 hours was significantly ($P<0.01$) lowered in both Trial 1 and Trial 2 by the addition of flaxseed extract. There seemed to be little effect upon cellulose digestion by levels of flaxseed extract lower than one milliliter. Although levels of flax-

Table 49. Effect of various levels of flaxseed extract upon *in vitro* cellulose digestion by rumen microorganisms

Additions of flaxseed extract per 20 milliliters (milliliters)	Per cent cellulose digested in 24 hours		
	Trial 1	Trial 2	Average
0.0	42.8	41.2	42.0
0.1	43.6	41.4	42.5
0.5	43.2	40.3	41.8
1.0	39.7	38.1	38.9
2.0	40.6	38.6	39.6
3.0	41.0	38.7	40.4
4.0	41.2	38.2	39.7
5.0	39.1	37.7	38.4

seed extract above one milliliter lowered the per cent of cellulose digested, there was little difference between these higher levels in their effect upon cellulose digestion. Apparently a water extract of flaxseed contained no factor or factors that would stimulate cellulose digestion *in vitro* unless these factors were inhibited by other factors that might have been present.

The effect of various levels of flaxseed extract dry matter upon *in vitro* cellulose digestion by rumen microorganisms is shown in Table 50. The five and 10 milligram additions of flaxseed extract dry matter lowered the diges-

Table 50. Effect of various levels of flaxseed extract dry matter upon *in vitro* cellulose digestion by rumen microorganisms

Additions of flaxseed extract dry matter per 20 milliliters (milligrams)	Per cent cellulose digested in 24 hours		
	Trial 1	Trial 2	Average
0	36.9	47.1	42.0
5	17.4	47.3	32.4
10	23.1	43.8	33.5
15	18.7	16.3	17.5
20	23.5	10.5	17.0
25	19.6	6.3	13.0
30	21.5	5.7	13.6
35	13.2	10.5	11.9
40	24.2	13.5	18.9
45	12.1	3.9	8.0
50	11.4	12.5	12.0
55	6.7	8.0	7.4

tion of cellulose by 22.9 per cent and 20.2 per cent, respectively. Levels of flaxseed extract dry matter higher than 10 milligrams continued to lower the digestion of cellulose until only 7.4 per cent of the cellulose was digested in 24 hours. This occurred when 55 milligrams of flaxseed extract dry matter were present.

It was thought that perhaps an effect from any factor or factors that might have been present in flaxseed extract could have been masked or obscured by inhibitory factors that might have been present. More purified fractions of flaxseed extract were next investigated.

The effect of isolated linseed oil meal mucin upon *in vitro* cellulose digestion by rumen microorganisms is shown in Table 51. The addition of linseed oil meal mucin increased the digestion of cellulose *in vitro* which was a statistically significant ($P < 0.05$) increase only in Trial 1. There was little effect upon cellulose digestion up to approximately the 16 milligram level. Levels of linseed oil meal mucin above 60 milligrams had either no effect or a slight depressing effect upon cellulose digestion. The greatest increase in cellulose digestion occurred at the 20, 40 and 60 milligram levels of linseed oil meal mucin. These were rather high levels as compared to other substances known to increase cellulose digestion *in vitro* (Trenkle, 97), such as certain amino acids which actively increase cellulose digestion when

Table 51. Effect of linseed oil meal mucin upon *in vitro* cellulose digestion by rumen microorganisms

Additions of linseed oil meal mucin per 20 milliliters (milligrams)	Per cent cellulose digested in 24 hours			
	Trial 1	Trial 2	Trial 3	Average of Trials 1 and 2
0	30.2	35.1	38.3	32.7
1	32.0	34.1	--	33.1
2	30.4	35.8	--	33.1
4	33.9	34.2	--	34.1
8	29.3	34.8	--	32.1
16	34.8	34.8	--	34.8
20	--	--	48.5	--
32	36.6	34.4	--	35.5
40	--	--	44.9	--
60	--	--	40.5	--
64	37.8	40.2	--	39.0
80	--	--	34.9	--
100	--	--	37.1	--
120	--	--	34.8	--
140	--	--	35.4	--

added at levels of 2-4 milligrams.

An apparent stimulation in the digestion of cellulose *in vitro* by the addition of linseed oil meal mucin deemed it necessary to determine the factor or factors present in linseed oil meal mucin causing this effect. The large quantity of carbohydrate in linseed oil meal mucin indicated that it would be desirable to see if additional carbohydrate would give an effect similar to mucin itself. The effects observed in these studies are presented in Table 52. The carbohydrate

Table 52. Effect of various levels of dextrose and linseed oil meal mucin upon *in vitro* cellulose digestion by rumen microorganisms

Additions of mucin and dextrose per 20 milliliters (milligrams)	Per cent cellulose digested in 24 hours	
	Trial 1	Trial 2
0	48.9	42.8
20 mg. mucin	52.2	38.8
40 mg. mucin	51.8	32.9
60 mg. mucin	48.4	--
1 mg. dextrose	47.9	43.8
2 mg. dextrose	50.4	40.9
20 mg. mucin + 1 mg. dextrose	53.6	40.7
20 mg. mucin + 2 mg. dextrose	51.7	34.6
40 mg. mucin + 1 mg. dextrose	48.0	34.6
40 mg. mucin + 2 mg. dextrose	49.3	31.4
60 mg. mucin + 1 mg. dextrose	48.2	
60 mg. mucin + 2 mg. dextrose	44.4	

(dextrose) was added to the fermentation tubes at a level found by Cheng *et al.* (28) to increase *in vitro* cellulose digestion (one milligram). Twice this level of carbohydrate (two milligrams) was also used in part of the fermentation tubes. The levels of linseed oil meal mucin used were the ones that gave maximum cellulose digestion in previous trials, which were 20, 40 and 60 milligrams.

The addition of linseed oil meal mucin in these studies increased cellulose digestion *in vitro* only in Trial 1. The 20 and 40 milligram levels of linseed oil meal mucin in Trial 1 significantly ($P<0.01$) increased cellulose digestion 6.7

per cent and 5.9 per cent, respectively, however the 60 milligram level lowered cellulose digestion slightly. Both the one and two milligram levels of dextrose lowered cellulose digestion in both Trials 1 and 2. There was some suggestion in both trials that linseed oil meal mucin and dextrose in combination lowered the per cent of cellulose digested. This was probably due to an over supply of available carbohydrate for the rumen microorganisms. The microorganisms probably utilized the readily available carbohydrate (dextrose) in preference to cellulose, resulting in a lowering of cellulose digestion in comparison to other treatments.

The factor or factors in linseed oil meal mucin that might stimulate cellulose digestion in vitro were further studied by conducting two trials in which the water-soluble and water-insoluble fraction of linseed oil meal mucin were added to in vitro fermentation tubes. These factors were added in amounts equivalent to the amount of these fractions that would be added by 1.8 per cent mucin. The results of these studies are given in Table 53. Linseed oil meal mucin was approximately 63 per cent water-soluble and 37 per cent water-insoluble.

Linseed oil meal mucin failed to stimulate cellulose digestion in vitro in both of these trials, except at the 20 milligram level. The 20 milligram addition of mucin stimulated cellulose digestion 6.4 per cent. It should be noted

Table 53. Effect of fractions of linseed oil meal mucin upon *in vitro* cellulose digestion by rumen microorganisms

Additions of fractions of linseed oil meal mucin per 20 milliliters (milligrams)	Per cent cellulose digested in 24 hours		
	Trial 1	Trial 2	Average
0	25.5	42.8	34.2
20 mg. mucin	25.3	47.4	36.4
12 mg. water-soluble fraction	25.7	39.8	32.8
8 mg. water-insoluble fraction	24.3	44.5	34.4
40 mg. mucin	24.2	37.3	30.8
24 mg. water-soluble fraction	21.7	41.8	31.8
16 mg. water-insoluble fraction	27.7	35.3	31.5
60 mg. mucin	24.3	26.1	25.2
36 mg. water-soluble fraction	23.8	40.4	32.1
24 mg. water-insoluble fraction	28.2	44.0	36.1

that the water-insoluble fraction of linseed oil meal mucin gave results comparable to the linseed oil meal mucin additions. The water-insoluble fraction of mucin added at the high level (24 milligrams) increased cellulose digestion over the basal 5.6 per cent. One might conclude from these results that when the addition of linseed oil meal mucin increased cellulose digestion *in vitro*, the factors responsible were apparently present in the water-insoluble fraction of the mucin. The water-soluble fraction of mucin either decreased or had no effect on cellulose digestion in almost all cases.

Discussion

The per cent cellulose digested *in vitro* in 24 hours was found to be significantly ($P<0.01$) decreased by the addition of various levels of flaxseed extract above a one milliliter addition. This was not an effect similar to those observed on other plant extracts by Burroughs *et al.* (25, 27), Bentley *et al.* (13) and Ruf *et al.* (91). The addition of flaxseed extract dry matter also decreased *in vitro* cellulose digestion in a 24-hour fermentation period.

The addition of linseed oil meal mucin significantly ($P<0.05$) increased *in vitro* cellulose digestion when levels above 16 milligrams were used. Maximum cellulose digestion was obtained at 20, 40 and 60 milligram levels of linseed oil meal mucin. The results obtained by the addition of mucin varied considerably, giving a stimulation in cellulose digestion in some trials and having no effect in others. Mucin did not appear to have an effect upon cellulose digestion similar to that of dextrose, however, more promising results might have been obtained if the pentose sugars normally found in mucin were used instead of dextrose as a carbohydrate source.

The factor(s) that are responsible for the response obtained by mucin may be found in the water-insoluble fraction of mucin. All levels of the water-insoluble fraction and

especially the high level (24 milligrams) gave results comparable to the addition of mucin at a 60 milligram level. The water-soluble fraction of mucin appeared to have no effect upon cellulose digestion *in vitro*. Perhaps there were some inhibitory factor(s) present in the flaxseed extract and flaxseed extract dry matter that prevented the factor(s) in linseed oil meal mucin from stimulating cellulose digestion. One might also postulate that perhaps mucin did not stimulate cellulose digestion at all, due to the variable results obtained. It seems best to say at this time, that if a true stimulation in cellulose digestion did occur by the addition of linseed oil meal mucin, the factor(s) responsible for this effect apparently were in the water-insoluble fraction of mucin and must remain unidentified at this time.

Summary

The results of nine *in vitro* studies indicated that the addition of linseed oil meal mucin stimulates the digestion of cellulose *in vitro*. This stimulation amounted to 14-26 per cent. The factor(s) responsible for this effect apparently were in the water-insoluble fraction of mucin, however the effect of this factor(s) was somehow inhibited when either flaxseed extract or flaxseed extract dry matter was added to *in vitro* fermentation tubes. The addition of flaxseed extract

and flaxseed extract dry matter resulted in a 20-23 per cent decrease in *in vitro* cellulose digestion.

DISCUSSION

The overall results reported in this thesis demonstrate that linseed oil meal when incorporated and fed in ruminant rations possesses at least two nutritional properties in addition to the available energy and conventional protein (nitrogen per se X 6.25) it supplies. The virtues of supplying energy and sufficient nitrogen in ruminant rations, either as a part of the major feeds commonly fed (roughages and cereal grains), or as supplementary protein (oil meals, urea and mill by-product feeds) has been well established by previous investigations. By contrast, the two additional nutritional properties of linseed meal measured in this study have been suggested in one manner or another in the past (Hayward, 52), but no quantitative measurements confirming their significance in cattle and sheep have previously been reported. These two additional nutritional properties can only be described in general forms at this time. The first relates to a growth stimulatory property of linseed oil meal other than the available energy it supplies, or the ammonia nitrogen it supplies as a result of fermentation processes in the forepart of the ruminant digestive tract. The second additional nutritional property relates to a haircoat sleekness condition ("bloom") in cattle fed linseed oil meal which is pleasing to the eye of livestock producers and those engaged in the buying and selling of cattle.

The demonstration of the growth stimulating factor in linseed oil meal was evident by the improved liveweight gains in lambs fed a water extract of flaxseed added to a ration supplying a marginal amount of protein (nine per cent). The improved liveweight gains in the lambs could not be explained on the basis of the small nitrogen content per se present in the extract since this was compensated for in the basal ration by an equal amount of nitrogen supplied by urea. Neither could the available energy present in the extract be expected to appreciably influence growth rate due to the small amount of available energy in the extract and the adequacy of energy in the basal ration fed to comparable groups of lambs.

The nature of the active factor(s) in the flaxseed extract responsible for this liveweight gain stimulation in lambs cannot be predicted from the experiments conducted. Since mucin was present in the extract, this material could have exerted such an influence. On the other hand, the active factor(s) may have been constituents present other than mucin. This latter possibility seems more likely since water extracts of a number of other feeds not containing mucin have exhibited the presence of unidentified factors stimulatory to liveweight gains in ruminants (Burroughs et al., 25, 27). Also in this respect, it seems likely that similar growth responses might be obtained from water extracts of other oil meals and that this particular property is not unique with

linseed oil meal. Support for this assumption is evident from the artificial rumen experiments resulting in cellulose digestion improvement by water extracts of linseed oil meal fractions similar to the improvements noted by other (Burroughs et al. (25, 27); Bentley et al. (13); Ruf et al. (91)) when extracts of other feeds including other oil meals brought about similar improvements in cellulose digestion in artificial rumen experiments.

The results obtained in the present investigation leave little doubt that linseed oil meal improves the sleekness of haircoat not only in cattle, but also in other animals inclusing such laboratory animals as the guinea pig and the rat. This improved sleekness in haircoat in a number of experiments was readily visible by the eye and could be quantitatively measured by the light meter developed for this purpose. The present experiments further demonstrated that the active principle in linseed oil meal in producing sleekness of haircoat was associated with its mucin and/or ash constituents. More specifically, the active factor in mucin was primarily the water-insoluble portion as demonstrated in guinea pig experiments. This study further suggests that it is the particular combination of sugars present in the water-insoluble fraction of mucin which causes a large part of the "bloom" or sleekness of haircoat condition imparted by linseed oil meal feeding.

The finding later in the experimental work that the ash of the mucin fed to guinea pigs had a favorable influence upon sleekness of haircoat was interesting, but unfortunately time did not permit further studies concerning the exact minerals responsible for this influence. The ash principle in the mucin preparation fed, appeared to be much less influential on haircoat sleekness than the combination of pentose sugars present.

The development of an apparatus and technique sufficiently critical to quantitatively measure differences in sleekness of haircoat as caused by ration influences would appear to be an important contribution of the research reported in this thesis. The apparatus and technique, or modification of same, should allow future investigators to quantitatively measure other nutritional and non-nutritional factors responsible for producing a sleekness or a "bloom" to the haircoat of animals. This would appear to be of importance not only in fattened beef cattle sold on the open market, but in all types of livestock groomed for show purposes as well as possible application in the fur-bearing industry and in household pets (dogs and cats) where a pleasing haircoat is a desirable feature.

The light meter apparatuse used to record haircoat "bloom" in these studies gave comparable but more precise results than visual evaluation. Using the light meter resulted

in an accurate measurement of the change in haircoat "bloom" over a given period of time. The recording of haircoat "bloom" in units of change over a period of time seemed to be a more desirable technique than actual meter readings recorded at any one time since a light-colored animal would consistently give higher readings than a dark-colored animal even though there was no difference in "bloom". A constant base reading about in the center of the microampere scale (300 microamperes) was found to be essential before taking the haircoat readings. The haircoat of the animals used in this study were darker and absorbed more light than the metallic surfaces on the inside of the instrument. Therefore, a drop of 150-200 microamperes occurred when the meter opening was placed against the animal than that which occurred when the meter door was closed. When measuring haircoats reflecting more light than the inside surfaces of the instrument, a lower base reading such as zero could be used.

The identity of the physical characteristic relating to haircoat "bloom" which was measured by the "bloom" meter used in this study is uncertain. One such characteristic could have been a change in pigmentation of the haircoat, however other possibilities might also exist. Although the "bloom" meter is not properly designed to separate light reflected from the surface from that which is scattered or diffusely reflected from the material investigated, it should be noted

that in this particular set of experiments there are certain features which make it likely that there is some correlation between gloss or "bloom" and the meter readings. This correlation is supported by the close agreement of the results obtained when haircoat "bloom" was evaluated by both the "bloom" meter and by visual appraisal.

Finally, in discussing the results of this thesis, the nutritional merits of linseed oil meal as a cattle supplemental ingredient as compared with other oil meals such as cottonseed meal or soybean oil meal should be reappraised. Since feeding trials in the past have on the average shown about equal liveweight gain performance in cattle receiving linseed meal as compared to other oil meal supplements, it seems only fair to conclude that all of these oil meals are roughly equally effective in supplying nitrogen, energy and unidentified factors concerned with stimulating growth or liveweight gains in fattening beef cattle. On the other hand, since linseed oil meal contains an abundant amount of mucin in contrast to essentially no mucin being present in other oil meals and since the present research has demonstrated the significance of mucin in improving the appearance of haircoat in cattle, it seems logical to also conclude that linseed oil meal excels all other oil meals with respect to producing cattle with more attractive haircoats. This conclusion is based on the assumption that other oil meals do

not contain nutrients other than mucin which impart a similar haircoat "bloom" to fattening cattle. Evidence supporting this assumption was obtained in certain of the cattle experiments reported in which those receiving linseed oil meal had superior haircoats as compared to those receiving soybean oil meal.

That mucin in linseed oil meal and not the residual oil in linseed or other oil meals is primarily responsible for the improvement in haircoat "bloom" seems worthy of mention since the oil content of oil meals have often, without proof, been regarded in the past as the active constituents primarily responsible for haircoat "bloom" in cattle. Data from this study has indicated that the oil content of linseed oil meal has no effect upon "bloom" since linseed oil meal mucin, which contains no oil, increased "bloom" equivalent to linseed oil meal. These results agreed with those of Culbertson (33) who found that solvent linseed oil meal without added oil was as effective in promoting haircoat "bloom" of cattle as hydraulic linseed oil meal.

The economic value of producing superior haircoat "bloom" in fattening beef cattle with linseed oil meal supplements cannot be fully appraised by the results of the present research. Often in the past this superior "bloom" has been claimed to be correlated with the degree of fatness of cattle.

That is, cattle receiving a fattening ration supplemented with linseed oil meal will not only show more haircoat "bloom", but also will be fatter at market time than cattle receiving a similar ration supplemented with a different kind of oil meal. This claim, if true, has not been completely established since some experiments in the past have failed to show a clear cut superiority in fatness of cattle due to linseed meal feeding over the feeding of other oil meals. It is possible that the haircoat "bloom" advantage of feeding linseed oil meal to cattle is largely an eye appeal advantage in the live animal and not an advantage in the edible beef carcass once the hides are removed from the animals and the beef is processed for human consumption. Even though a linseed meal specific fattening influence fails to be clearly established in future cattle research, this eye appeal condition in cattle does have economic importance where cattle are bought and sold on a visual appraisal basis and not upon a carcass basis, since those cattle having superior eye appeal command a higher price on the market than cattle with a haircoat having less eye appeal.

SUMMARY

Studies involving 132 lambs, 116 cattle, 168 guinea pigs, 32 rats and a series of *in vitro* experiments were conducted to determine the merits of linseed oil meal and fractions of linseed oil meal in ruminant rations. Special emphasis was placed upon linseed oil meal mucin because of the relatively high content of mucin in linseed oil meal.

The feeding of six pounds of flaxseed extract per lamb daily increased liveweight gains of lambs when fed in a ration containing nine per cent total protein. The feeding of 18 pounds of flaxseed extract per steer daily resulted in an increase in liveweight gains of cattle and a reduction in the pounds of feed required per pound of gain. Gains were not stimulated in lambs when flaxseed extract was fed in a 12 per cent protein ration nor were they stimulated when only three pounds of flaxseed extract were fed daily in a nine per cent protein ration. These increased lamb and cattle gains could not be explained through additional nitrogen from the flaxseed extract because all the rations were calculated to be isonitrogenous, which was accomplished by the addition of urea in the rations containing no flaxseed extract. There was some indication that the feeding of flaxseed extract increased the carcass quality of lambs, but not the carcass quality of cattle based upon dressing per cent, carcass grade

and thickness of fat over the rib eye muscle. Carcass grade and dressing per cent of lambs were increased by the feeding of flaxseed extract in a 12 per cent protein ration, but not in a nine per cent protein ration. Cattle receiving flaxseed extract dressed approximately two per cent higher than control cattle, however, the fatness of the cattle as measured by the thickness of fat over the rib eye was considerably less than control cattle. The feeding of flaxseed extract did result in an increase in the area of the rib eye muscle of cattle.

The feeding of two milligrams of stilbestrol per lamb daily increased average daily gains, but lowered dressing per cent and carcass grade. Thirty per cent greater gains were made by lambs when stilbestrol was fed in a 12 per cent protein ration than when fed in a nine per cent protein ration. Increasing the protein content of lamb rations from nine to 12 per cent resulted in faster gains and more efficient gains.

Results from a series of nine *in vitro* studies to aid in determining the factor or factors responsible for increasing lamb and cattle gains when receiving flaxseed extract indicated that the addition of either flaxseed extract or flaxseed extract dry matter had no stimulating effect upon *in vitro* cellulose digestion. Further results indicated that the addition of linseed oil meal mucin would stimulate *in*

vitro cellulose digestion when added at levels from 16-60 milligrams. Maximum cellulose digestion was observed when linseed oil meal mucin was added at a level of 20 milligrams. Higher levels had no effect upon cellulose digestion. Later observations indicated that the factor(s) responsible for this stimulation in *in vitro* cellulose digestion was apparently in the water-insoluble fraction of linseed oil meal mucin.

The factor(s) in flaxseed extract responsible for increased lamb and cattle gains and the factor(s) in linseed oil meal mucin responsible for the stimulation of *in vitro* cellulose digestion must remain unidentified at this time.

The feeding of 18 pounds of flaxseed extract per steer daily or the feeding of linseed oil meal at levels from 0.05 to 1.4 pounds per steer daily increased haircoat "bloom". Studies with laboratory animals indicated that the feeding of linseed oil meal mucin at levels of 0.9 and 1.8 per cent of the diet would increase the haircoat "bloom" of guinea pigs from 13-22 per cent. This increase in "bloom" was comparable to that observed by the feeding of linseed oil meal at levels to supply these same amounts of mucin (0.9 and 1.8 per cent). The feeding of a combination of sugars found in the water-insoluble fraction of linseed oil meal mucin and the ash of mucin increased the haircoat "bloom" of

guinea pigs 85-90 per cent, giving results comparable to those observed when 1.8 per cent linseed oil meal mucin was fed in the same experiment. The feeding of diethylstilbestrol at the rate of 0.01 microgram per gram of feed had no effect upon haircoat "bloom" of guinea pigs, but did result in an increase in gain.

The length of the feeding period seemed to play a major role in the amount of haircoat "bloom" observed in both cattle and guinea pigs. Haircoat "bloom" in cattle appeared to increase greatly during the first 28-56 days with a lesser "bloom" increase being observed during the 56-84 day period. "Bloom" was again increased after 84 days and up to at least 140 days.

The factor(s) in linseed oil meal responsible for an increase in haircoat "bloom" of animals appears at the present time to be present in the mucin fraction of linseed oil meal and more specifically in the combination of pentose sugars found in the water-insoluble fraction of mucin and/or in the ash of mucin.

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APPENDIX

Table 54. Analyses of variance of the feedlot performance data obtained in Lamb Trial 1

Source of variation	Degrees of freedom	M.S.[a]	M.S.	M.S.
		Daily gains	Feed per lb. gain	Daily feed consumption
Total	19			
Treatment	1	2.25	236.67	0.40
Remainder	18	2.26	104.34	0.42

[a]Mean square.

Table 55. Analyses of variance of the feedlot performance and carcass data obtained in Lamb Trial 2

Source of variation	Degrees of freedom	M.S.[a]	M.S.	M.S.	M.S.
		Daily gains	Feed per lb. gain	Dressing per cent	Carcass grade
Total	35				
Treatments	5	0.008	34.35	1.44	0.37
Flaxseed extract	2	0.01	55.70	3.39[b]	0.10
Stilbestrol	1	0.02	18.73	0.01	1.14
FE X S	2	0.0	20.81	0.20	0.46
Error	30	0.01	82.57	0.95	0.95

[a]Mean square.

[b]Significant at the $P < 0.05$ level.

Table 56. Analyses of variance of the feedlot performance and carcass data obtained in Lamb Trial 3

Source of variation	Degrees of freedom	M.S.[a] Daily gains	M.S. Feed per lb. gain	M.S. Dressing per cent	M.S. Carcass grade
Total	23				
Treatments	3	0.01	13.37	3.77	3.83
Protein	1	0.0	5.01	0.33	0.73
Flaxseed extract	1	0.0	6.31	9.38	0.23
P X FE	1	0.03[b]	51.44[c]	1.60	11.00[b]
Error	20	0.004	4.10	4.12	1.52

[a]Mean square.

[b]Significant at the $P<0.05$ level.

[c]Significant at the $P<0.01$ level.

Table 57. Analyses of variance of the feedlot performance and carcass data obtained in Lamb Trial 4

Source of variation	Degrees of freedom	M.S.[a] Daily gains	M.S. Feed per lb. gain	M.S. Dressing per cent	M.S. Carcass grade
Total	23				
Treatments	5	0.05	5.70	5.23	0.44
Stilbestrol	1	0.01	0.15	4.11	0.38
Flaxseed extract	2	0.11[b]	12.82	7.12	0.05
S X FE	2	0.005	1.35	3.91	0.87
Error	18	0.03	7.85	2.87	2.71

[a]Mean square.

[b]Significant at the $P<0.05$ level.

Table 58. Analyses of variance of the feedlot performance and carcass data obtained in Lamb Trial 5

Source of variation	Degrees of freedom	M.S.[a] Daily gains	M.S. Feed per lb. gain	M.S. Dressing per.cent	M.S. Carcass grade
Total	31				
Treatments	7	0.0099	9.69	3.83[b]	3.89[c]
Protein	1	0.0072	2.31	0.08	0.28
Stilbestrol	1	0.0066	1.90	1.62	2.53
Flaxseed extract	1	0.0365	33.21	6.84	3.78
P X S	1	0.0001	3.78	2.92	0.04
P X FE	1	0.0001	0.07	9.90	5.28
S X FE	1	0.0119	9.47	0.45	1.54
P X S X FE	1	0.0068	17.10	4.97[b]	13.77[c]
Error	24	0.0034	6.59	1.34	0.89

[a]Mean square.

[b]Significant at the $P<0.05$ level.

[c]Significant at the $P<0.01$ level.

Table 59. Analyses of variance of gain, feed efficiency and haircoat "bloom" data obtained in Rat Trial 1

Source of variation	Degrees of freedom	M.S.[a] Total gains	M.S. Feed per 100 gms. gain	M.S. "Bloom" change
Total	15			
Treatments	3	6328	178693[b]	0.593
Error	12	2222	25004	1.02

[a]Mean square.

[b]Significant at the $P<0.05$ level.

Table 60. Analyses of variance of gain and haircoat "bloom" data obtained in Guinea Pig Trial 1

Source of variation	Degrees of freedom	M.S.[a]	M.S.	M.S.
		Total gains	"Bloom" change	Visual "bloom"
Total	19			
Treatment	4	18195.81[b]	2.30[c]	0.358
Error	15	4463.55	0.31	0.133

[a]Mean square.

[b]Significant at the $P < 0.05$ level.

[c]Significant at the $P < 0.01$ level.

Table 61. Analyses of variance of gain, feed efficiency and haircoat "bloom" data obtained in Guinea Pig Trial 2

Source of variation	Degrees of freedom	M.S.[a]	M.S.	M.S.	M.S.
		Total gains	Feed per 100 gms. gain	"Bloom" change	Visual "bloom"
Total	19				
Treatment	4	11007.93[b]	1060729	5.70	0.353
Error	15	11634.00	984631	2.88	0.139

[a]Mean square.

[b]Significant at the $P < 0.01$ level.

Table 62. Analyses of variance of gain, feed efficiency and haircoat "bloom" data obtained in Guinea Pig Trial 3

Source of variation	Degrees of freedom	M.S.[a] Total gains	M.S. Feed per 100 gms. gain	M.S. "Bloom" change	M.S. Visual "bloom"
Total	14				
Treatment	2	157379.30[b]	559617.0[b]	6.75	0.392
Error	12	6905.73	34110.07	3.09	0.130

[a]Mean square.

[b]Significant at the $P < 0.01$ level.

Table 63. Analyses of variance of gain, feed efficiency and haircoat "bloom" data obtained in Guinea Pig Trial 4

Source of variation	Degrees of freedom	M.S.[a] Total gains	M.S. Feed per 100 gms. gain	M.S. "Bloom" change
Total	19			
Treatment	4	8166.9	233701	10.61
Error	15	3048.0	85567	7.89

[a]Mean square.

Table 64. Analyses of variance of gain, feed efficiency and haircoat "bloom" data obtained in Guinea Pig Trial 5

Source of variation	Degrees of freedom	M.S.[a] Total gains	M.S. Feed per 100 gms. gain	M.S. "Bloom" change
Total	8			
Treatment	2	2656.26[b]	26020.00[b]	5.03
Error	6	51.38	39.10	3.63

[a]Mean square.

[b]Significant at the $P < 0.01$ level.

Table 65. Analyses of variance of feedlot performance and haircoat "bloom" data obtained in Cattle Trial 1

Source of variation	Degrees of freedom	M.S.[a] Daily gains	M.S. Feed per lb. gain	M.S. Visual "bloom"
Total	5			
Treatments	2	0.0192	0.3969	0.0243
Replication	1	0.0294	0.5520	0.0
Error	2	0.0110	0.2701	0.0243

[a]Mean square.

Table 66. Analyses of variance of carcass data obtained in Cattle Trial 1

Source of variation	Degrees of freedom	M.S.[a]	M.S.	M.S.	M.S.
		Carcass grade	Dressing per cent	Rib eye area	Thickness of fat over rib eye
Total	5				
Treatments	2	0.345	0.785	0.93[b]	10.28
Replication	1	0.070	1.040	0.24	0.38
Error	2	0.145	0.170	0.015	2.94

[a]Mean square.

[b]Significant at the $P < 0.05$ level.

Table 67. Analyses of variance of feedlot performance and haircoat "bloom" data obtained in Cattle Trial 2

Source of variation	Degrees of freedom	M.S.[a]	M.S.	M.S.	M.S.
		Daily gains	Feed per lb. gain	"Bloom" change	Visual "bloom"
Total	7				
Treatment	1	0.0013	0.0036	0.69	0.2244
Error	6	0.1091	0.0496	2.52	0.6565

[a]Mean square.

Table 68. Analyses of variance of carcass data obtained in Cattle Trial 2

Source of variation	Degrees of freedom	M.S.[a] Carcass grade	M.S. Dressing per cent	M.S. Rib eye area	M.S. Thickness of fat over rib eye
Total	7				
Treatment	1	0.25	1.13	3.60	0.01
Error	6	0.29	4.41	1.50	0.43

[a]Mean square.

Table 69. Analysis of variance of haircoat "bloom" data obtained in Cattle Trial 3

Source of variation	Degrees of freedom	M.S.[a]
Total	11	
Treatments	5	8.45[b]
Linseed oil meal	1	17.52
Level protein	2	5.99
LSM X LP	2	6.39[b]
Error	6	0.22

[a]Mean square.

[b]Significant at the $P < 0.01$ level.

Table 70. Analysis of variance of the effect of flaxseed extract upon *in vitro* cellulose digestion by rumen microorganisms in Trial 1

Source of variation	Degrees of freedom	M.S.[a]
		Per cent cellulose digested
Total	25	
Treatment	7	8.59[b]
Error	18	1.79

[a]Mean square.

[b]Significant at the $P < 0.01$ level.

Table 71. Analysis of variance of the effect of flaxseed extract upon *in vitro* cellulose digestion by rumen microorganisms in Trial 2

Source of variation	Degrees of freedom	M.S.[a]
		Per cent cellulose digested
Total	25	
Treatment	7	7.67[b]
Error	18	1.28

[a]Mean square.

[b]Significant at the $P < 0.01$ level.

Table 72. Analysis of variance of the effect of flaxseed extract dry matter upon *in vitro* cellulose digestion by rumen microorganisms in Trial 1

Source of variation	Degrees of freedom	M.S.[a]
		Per cent cellulose digested
Total	37	
Treatment	11	243.19
Error	26	175.29

[a]Mean square.

Table 73. Analysis of variance of the effect of flaxseed extract dry matter upon *in vitro* cellulose digestion by rumen microorganisms in Trial 2

Source of variation	Degrees of freedom	M.S.[a]
		Per cent cellulose digestion
Total	32	
Treatments	10	823.70
Error	22	474.11

[a]Mean square.

Table 74. Analysis of variance of the effect of linseed oil meal mucin upon *in vitro* cellulose digestion by rumen microorganisms in Trial 1

Source of variation	Degrees of freedom	M.S.[a]
		Per cent cellulose digested
Total	27	
Treatment	7	33.82[b]
Error	20	13.25

[a]Mean square.

[b]Significant at $P < 0.05$ level.

Table 75. Analysis of variance of the effect of linseed oil meal mucin upon *in vitro* cellulose digestion by rumen microorganisms in Trial 2

Source of variation	Degrees of freedom	M.S.[a]
		Per cent cellulose digested
Total	23	
Treatment	7	12.26
Error	16	11.64

[a]Mean square.

Table 76. Analysis of variance of the effect of linseed oil meal mucin upon *in vitro* cellulose digestion by rumen microorganisms in Trial 3

Source of variation	Degrees of freedom	M.S.[a]
		Per cent cellulose digested
Total	25	
Treatment	7	76.85[b]
Error	18	25.68

[a]Mean square.

[b]Significant at the $P<0.05$ level.

Table 77. Analysis of variance of the effect of dextrose and linseed oil meal mucin upon *in vitro* cellulose digestion by rumen microorganisms in Trial 1

Source of variation	Degrees of freedom	M.S.[a]
		Per cent cellulose digested
Total	36	
Treatment	11	18.85
Mucin	3	46.39[b]
Dextrose	2	4.88
M X D	6	9.73
Error	25	6.70

[a]Mean square.

[b]Significant at the $P<0.01$ level.

Table 78. Analysis of variance of the effect of dextrose and linseed oil meal mucin upon *in vitro* cellulose digestion by rumen microorganisms in Trial 2

Source of variation	Degrees of freedom	M.S.[a]
		Per cent cellulose digested
Total	28	
Treatments	8	67.75
Mucin	2	227.31[b]
Dextrose	2	43.71[c]
M X D	4	-0.018
Error	20	9.26

[a]Mean square.

[b]Significant at the $P < 0.01$ level.

[c]Significant at the $P < 0.05$ level.

Table 79. Analysis of variance of the effect of fractions of linseed oil meal mucin upon *in vitro* cellulose digestion by rumen microorganisms in Trial 1

Source of variation	Degrees of freedom	M.S.[a]
		Per cent cellulose digested
Total	31	
Treatment	9	142.39[b]
Error	22	6.38

[a]Mean square.

[b]Significant at the $P < 0.01$ level.

Table 80. Analysis of variance of the effect of fractions of linseed oil meal mucin upon *in vitro* cellulose digestion by rumen microorganisms in Trial 2

Source of variation	Degrees of freedom	M.S.[a]
		Per cent cellulose digested
Total	30	
Treatment	9	109.35[b]
Error	21	18.74

[a]Mean square.

[b]Significant at the $P<0.01$ level.