THE INFLUENCE OF METHOD OF PREPARATION ON THE NUTRITIVE VALUE OF COTTONSEED AND SOYBEAN MEALS WHEN USED IN MAINTENANCE AND FATTENING RATIONS FOR LAMBS.

THE INFLUENCE OF METHOD OF PREPARATION ON THE NUTRITIVE VALUE OF COTTONSEED AND SOYBEAN MEALS WHEN USED IN MAINTENANCE AND FATTENING RATIONS FOR LAMBS.

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TABLE OF CONTENTS

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INTRODUCTION

Until recent years, cottonseed meal was the most important vegetable protein supplement used in livestock feeding. During the last two decades soybean products have become more and more important for this purpose until today they seriously rival the cottonseed products and even some of the well-known protein supplements of animal origin.

The first cottonseed oil produced in America was experimentally extracted in 1768 (Macy, 1921). The British Government offered prizes for oil and cake production in the British West Indies in 1783 and the South Carolina Agricultural Society offered similar prizes in 1785. A patent for a cottonseed oil extracting process was granted to C. Whiting in 1799 and a small amount of cottonseed was crushed by Benjamin Waring of Columbia, South Carolina in 1802. A patent was issued in 1819 covering the use of cottonseed cake as cattle feed (Macy, 1921). A small amount of cake was evidently being fed to cattle by 1829, but Bailey (1948) quotes figures that show that as late as 1890 a very large part of the cottonseed cake produced was used as fertilizer. It was well established as a livestock feed by World War I and has continued to the present to be a source of income to the cotton producer as well as a good source of protein for the livestock feeder.

The soybean is one of the oldest crops known to man but is relatively new to American agriculture. Markley (1944) quotes Morse and Cartter as stating that a reference to soybean is found in a Chinese manuscript written in 2838 B.C. Evidently China is the original home of the soybean but it has migrated to practically every country in the world. There has been much interest in its production in Europe and the Orient for human food but in the United States most of the soybean products have been used industrially and as livestock feed.

The first soybeans to be processed for the oil and meal were imported from Manchuria and crushed at Seattle, Washington in 1911. Oil meal from American grown beans was first produced in North Carolina in 1915. In 1918 the Chicago Heights Oil Manufacturing Company produced a small amount of oil by the expeller process and in 1922 the A. E. Staley Manufacturing Company started producing oil by the expeller process. By 1930 there were several companies processing soybeans in the United States and a permanent soybean industry had been established.

Most of the oil extraction in the United States has been by pressure methods (hydraulic press and expellers). Foreign countries have always favored the solvent extraction method. This method is growing in importance in this country and meals produced by it are already commercially available. Markley (1944) states that in 1940, 74.2 per cent of the soybean crop was expeller processed, 23.1 per cent solvent processed and only 2.7 per cent of the crop was crushed by the hydraulic process. In 1946 the solvent processing capacity comprised 30 - 35 per cent of the total soybean processing capacity (Bailey 1948). The same author estimated that 90 per cent of all cottonseed meal is produced by the hydraulic process with each of the other processes accounting for about 5 per cent of the total production.

Solvent meals are produced at a much lower temperature than are pressure process meals and contain only from 25 to 50 per cent as much fat as pressure meals. The vitamin content of the two meals may differ also due to the amount of fat-soluble vitamins that may be removed by the fat solvents in solvent processing. Since solvent process meals have become more available, livestock feeders have become interested in the relative values of the pressure process meals and the solvent process meals as protein supplements in livestock feeding.

LITERATURE REVIEW

Some trouble was experienced when cottonseed products were first used as livestock feeds. Macy (1921) quotes Voelker as observing injurious effects from cottonseed meal in 1859 and the same author gives Kuhlman credit for the discovery of a toxic yellow dye in cottonseed. This dye was crystallized by Marcklowski in 1899 and was named "gossypol" by him.

Osborne and Mendel (1917) found cottonseed kernels to be toxic to rats. The toxic substance could be extracted by ether. Steam treatment of kernels destroyed the toxic effects. Wide variations in the value of the product due to variations in the length of the heating period were noted. Gallup (1928) reported that 1 per cent of gossypol in the ration was fatal to rats. Cooking destroyed the toxic properties of the meals but autoclaving either seeds or meals lowered the digestibility. Robison, at the Ohio station destroyed the toxic factor in cottonseed meal by cooking with steam under 14 pounds pressure for one hour. Feeding the meal with 2 per cent of iron sulfate or feeding the meal with tankage would prevent death losses in swine (1939, 1948). At the same station Gerlaugh (1940) found no differences in gain of steer calves fed cottonseed meal with iron salts in contrast to similar animals fed the meal without the salts.

Lyman, et al (1944) developed a heat processing method that produced cottonseed meal containing only 0.02 per cent free gossypol, as determined by a colorimetric test. This meal was non-toxic to guinea pigs and gave good results when fed in a fattening ration to hogs for 90 days.

Heat Treatment

The effect of heat treatment on soybean meals has stimulated research in several laboratories. This work became especially important as soon as solvent extracted meal appeared on the market in large quantities. Studies were made on solvent process meals and on hydraulic and expeller process meals, and the effect of various heat treatments on each of these meals was noted.

Osborne and Mendel (1917) found that when raw soybeans were fed to rats they were unpalatable and would not support normal growth. The meal was not improved by cooking in dry heat but cooking in a steam bath for four hours produced a meal that supported good growth. A sample of commercially processed meal produced results that were practically identical to those of the autoclaved meal.

Wilgus, et al (1936) reported that no significant differences existed between meals produced by the three different processes but that the amount of heating each meal was subjected to affected its nutritive value. The most efficient meals were produced by heating expeller meals at 140 to 150 degrees C., and hydraulic meals at 105 degrees C. The usual commercial practice of heating solvent meals for 15 minutes at 82 degrees C., also produced a satisfactory product. Hayward and co-workers (1936) found that meals manufactured by all three processes gave good growth if treated with heat at high temperatures. Ground soybeans or low temperature meals gave poor growth when fed to rats even though they seemed palatable and were consumed in large amounts. Mitchell and Beadles (1937) heated soybeans for one hour under 15 pounds of steam pressure and raised the coefficient of digestibility of protein from 78 to 83 and the biological value from 49 to 67 when fed to rats. They concluded that heating the beans made cystine more available to the animal's digestive system. Johnson and co-workers (1939) used several solvents in extracting soybean oil meal. None of the solvents seemed to affect the nutritive value of the meal. When meals were autoclaved for 19 minutes at 150 degrees C., they gave good growth and it was noted that a greater percentage of the sulfur in the meal was retained by the rat after it was digested. Bird and Burkhardt heated meals produced by all three processes. Hydraulic meals could not be improved by heating but expeller and solvent meals showed response to various amounts of heat. All of the meals could be overheated and such overheating decreased the nutritive value. They advised heating at 20 pounds pressure for 2-1/2 minutes for poultry feeding and further stated that the nutritive value could be decreased by a temperature of 128 degrees C., but not by a temperature of 104 degrees C. In two experiments with lambs, Miller and Morrison (1944) found the protein in raw soybeans to be 91 per cent as digestible as the protein in either heated or unheated solvent processed soybean oil meal. The solvent meals had biological values of 62 and 63, the heated meal having the higher value.

Caskey and Knapp (1944) developed a method of detecting inadequately heated meals that depended on a test for the presence of urease in the meal. Bird and Burkhardt confirmed the value of the test but found it to be ineffective in detecting overheating.

Hayward and Hafner (1941) conducted a series of parallel experiments with chicks and rats, using raw and autoclaved beans. They concluded that heating the beans affected the digestibility of the sulfur-containing amino acids and that adding 0.3 per cent cystine or 0.3 per cent methionine to raw beans gave as good results as autoclaving. The effect of adding methionine was greater than that of adding cystine. Autoclaved beans were better utilized with either animo acid added than were the raw beans with both amino acids added. The conclusions were that raw soybeans contain a sub-optimal quantity of methionine and a deficiency of cystine. Evans and McGinnis (1946) advised autoclaving meals at 100, 110 or 120 degrees C. for optimum results in poultry feeding. They found the methionine and cystine in the meal less available if heated over 120 degrees C. Adding 0.2 per cent methionine to raw meal gave approximately the same results as heated meal. Similar response was observed in the chicks fed the raw meal and in those fed overheated meal. In a later test (1947) these workers confirmed their previous results and also reported a high correlation between <u>in vitro</u> digestion of the meals by a solution of trypsin and erepsin and the actual digestion of the meals by the chick. Fritz and co-workers (1947) fed turkey poults ground soybeans that had been subjected to a variety of heat treatments. They advised autoclaving the beans for 20 to 30 minutes under 15 pounds pressure. Extending the time to 90 minutes caused damage from overheating and dry heat produced this effect much quicker. Poorer growth was noted from overheated meal plus 0.2 per cent lysine and 0.3 per cent methionine than from untreated expeller meal. Clandanin and co-workers (1948, 1948a) advised autoclaving solvent flakes for 4 minutes at 15 pounds pressure or autoclaving at 4 pounds pressure for 45 minutes. They concluded that overheated flakes were lacking in available lysine and methionine. Grau and Almquist (1943) gave the methionine and cystine needs of a ration for growing chicks as a total of 1.0 per cent to 1.1 per cent for both amino acids. They stipulated that of this amount 0.5 per cent to 0.6 per cent must be in the form of methionine. McGinnis and Evans (1947) conducted a four week experiment with growing chicks using both raw and autoclaved soybean oil meal. Maximum growth resulted from meal autoclaved 30 minutes at 100 degrees C., and no better growth was obtained by adding lysine, methionine and cystine to the meal. Methionine added to raw meal increased the growth rate but did not give maximum growth. When the meal was autoclaved for one hour at 130 degrees C., poor growth resulted. This could be corrected by adding lysine, methionine and cystine. The addition of any one amino acid alone gave no increase in the growth rate. They concluded that autoclaving for 30 minutes at 130 degrees C., gave twice the growth response of adding methionine to raw meal and that nutrients other than methionine were affected by autoclaving. They gave the methionine and cystine needs of the chick ration as 0.26 per cent and 0.46 per cent respectively, or about half the figures given by Almquist and Grau.

Evans and Butts (1948) found that when soybean oil meal was autoclaved for 4 hours, 40 per cent of the lysine was destroyed. Added lysine was as readily destroyed as that already in the meal. When digested *in vitro* 60 per cent less lysine was liberated from the cooked meal than from the raw meal. Adding sucrose to the meal before autclaving gave even more complete destruction of lysine.

Evidence of additional factors being involved was presented by Patton and co-workers (1946). The addition of 1.20 per cent DL-methionine to a ration of corn and heated solvent soybean oil meal did not give as good growth in chicks as adding a small amount of fish meal to the diet. The conclusion drawn was that some other factor was needed to give good growth on a corn-soybean oil meal ration and that the need of this factor might be a peculiarity of this diet only.

Enzyme Factors

A trypsin inhibiting substance was extracted from raw soybeans by Bowman (1944) and Ham and Sandstedt (1945). It was derived from aqueous extracts of raw soybeans by a dilute acid at a pH of 4.2. It was found to be inactivated by treatment with 45 per cent alcohol, or by autoclaving either the meal of the extract. Klose, Hill and Fevold (1946) reported the extraction from raw soybeans of a substance that retarded the growth of rats. It was assumed by Ham and Sandstedt that the trypsin inhibitor was also a growth inhibitor. Ham, Sandstedt and Mussehl (1945) conducted an experiment with young chicks that extended over a 15 day period. They found the trypsin inhibiting extract retarded chick growth when added to a ration containing protein from either animal or vegetable sources, but that a ration containing soybean oil meal was affected more than a ration with protein from animal sources. These Nebraska workers suggested that the inhibitor made methionine less available to the chick.

Kunitz (1945) crystallized the trypsin inhibitor and showed that it was of a protein nature. It was soluble in dilute acid, dilute alkali and in a salt solution.

McGinnis and Menzies (1946) discovered that digesting raw soybean flakes with papain for 14 hours at 37 degrees C., gave as good growth as autoclaving the flakes 30 minutes at 120 degrees C. When the flakes were both autoclaved and digested with papain chicks gained slightly faster. They concluded that either autoclaving or digesting with papain was effective in inactivating the growth inhibiting substance.

Two Indian investigators, Desikachar and De (1947) conducted an experiment comparing papain digested meal with an undigested control. They could find no significant differences between the two and concluded that all proteins in the meal were affected by the trypsin inhibitor, not just the methionine containing fractions. It was also concluded that other substances in raw soybeans besides the trypsin inhibitor affected growth. This was also suggested by Borchers (1948). He prepared a highly purified solution of the trypsin inhibitor from soybean flakes digested with papain and a similar solution was precipitated from the undigested soybean extract with acetone. The acetone solution inhibited chick growth while papain solution did not. Gerry, et al (1948) also reported a growth inhibiting substance present in unheated soybean oil meal fed to chicks. They stated that the addition of DL-methionine to the ration gave only slightly greater growth and that females were affected more by the factor than were males.

Borchers, Ackerson and Sandstedt (1948) reported that the trypsin inhibitor did not compete with trypsin for the substrate but rather that the inhibitor neutralized the trypsin. Autoclaving for 30 minutes at 15 pounds pressure destroyed the inhibitor. The urease test of Caskey and Knapp, previously mentioned, was found to be ineffective in detecting the loss of action by the inhibitor, as 45 per cent of the inhibitor remained after the meal gave a negative urease test. Borchers, Ackerson and Mussehl (1948) got adverse results from meal autoclaved 4 minutes as advised by Clandanin and stated that meal should be autoclaved at least 20 minutes at 15 pounds pressure if the trypsin inhibitor is to be inactivated. They suggested a test for the presence of the inhibitor as a means of detecting inadequately heated meal. They explained the difference in results between Clandinin's work and theirs on the ground that they used the growth of chicks over six weeks as a criterion and Clandinin's results were based on only a two week growth period.

Fat Content

The fat content of both soybean oil meal and cottonseed meal varies considerably due to the method of processing. The fat content of hydraulic cottonseed meal is given by Morrison (1948) as 6.3 per cent and that of hydraulic and expeller soybean oil meals as 5.3 per cent. This same source gives the fat content of solvent cottonseed meal as 2.6 per cent and the fat content of solvent process soybean oil meal as 1.0 per cent. It can readily be seen that a given amount of one of the pressure meals will add from 2 to 5 times as much ether extract (fat) to the diet as the same amount of solvent meal from the same source. Several workers have conducted experiments to see if this difference in fat content affected the nutrition of the animals to which the meals were fed.

Moore and Cousert (1926) reported a series of experiments wherein ground soybeans gave more efficient milk production and higher butterfat production than either soybean oil meal or cottonseed meal. Maynard and co-workers at Cornell (1932, 1934, 1939, 1941), conducted a series of experiments with dairy cows, using soybeans, soybean meal, cottonseed meal, and linseed meal as protein supplements. In every trial observed by these workers, the higher fat diets caused higher levels of milk production and in many of the trials the per cent of butterfat in the milk increased also. Forbes and co-workers (1946) reported an experiment involving 4 lots of 10 albino rats. The rats were fed rations of 2 per cent, 5 per cent, 10 per cent and 30 per cent fat. The experiment extended for 70 days. It was found that as the diet increased in fat content the rats gained more weight and digested and retained more nitrogen. There was a much greater difference between the lots at the 2 per cent level and 5 per cent level than there was between the rats on the 5 per cent diet and those on the 30 per cent diet.

Other workers have failed to find any differences in diets of varying fat content. Kammlade and Mackey (1925) conducted two three-month experiments in different years on fattening lambs comparing ground soybeans, whole soybeans, cottonseed meal, pressure process soybean oil meal and linseed meal as protein supplements. The daily gain in all lots over both years varied from 0.24 lb., to 0.26 lb. In fattening steer tests, over a three-year period, whole soybeans, soybean oil meal and cottonseed meal gave practically the same daily gains (Skinner and King, 1927). These same workers reported later that steers fed cottonseed meal slightly outgained those fed whole soybeans (1929). Monroe and Krauss (1940) fed dairy cows rations with fat varying from 2.8 per cent to 9 per cent of the ration. No differences in either milk or butterfat production were observed due to fat content in any of the rations. Schubert and Wells (1940) replaced solvent extracted soybean oil meal with ground soybeans in a dairy ration. The original ration contained 1.3 per cent fat and the experimental one 4.75 per cent fat. No change was noted in milk fat content or in the total production of milk after one month on the experimental ration. Davis and Upp (1941) conducted a series of experiments with growing chicks and laying hens on diets free from fat and the same rations with graded amounts of fat added. Slower growth resulted from the fat-free ration but at maturity all the birds were the same weight. Egg production was uniformly high on all diets, fat free as well as those with fat, but low hatchability was reported for all lots. Russell, Taylor and Walker (1941) reported lowered production and loss in body weight of hens on a low fat ration.

Calcium and Phosphorous Content

Protein supplements may be good sources of minerals in animal nutrition. Morrison (1948) gives the average calcium content of soybean oil meal as 0.29 per cent and that of cottonseed meal as 0.20 per cent. Cottonseed meals are much richer in phosphorous as they average 1.0 per cent as compared to an average of 0.66 per cent for soybean meals. As most of the phosphorous is in the form of phytin, Spitzer and Phillips (1945, 1945a) fed several rats diets high in soybean oil meal to see if the phytin phosphorous in the meal could be utilized. They reported that the phosphorous was readily available for growth and that methods of preparation or heating the meal did not affect the availability of the phosphorous.

Solvent Versus Pressure Process Meals

Since solvent processed soybean oil meal and solvent processed cottonseed meal have become commercially availab,e numerous workers have conducted experiments to compare the relative feeding values of solvent and pressure process meals. Other workers have compared cottonseed meals with the soybean meals.

Hale, (1930) found that cottonseed meal could be used to supply as much as 9 per cent of the protein in swine rations, but that such a ration did not give as good gains as one in which tankage was the sole protein supplement. Robison (1934) found that cottonseed meal could supply 10.5 per cent of the protein in swine rations without ill effects. This same author (1939) reported that pigs fed expeller cottonseed meal reached market weight 71 days earlier than similar animals fed hydraulic cottonseed meal. The mortality rate was also much lower in the expeller meal fed group. Robison (1948) reported good gains from swine fed on solvent process meal but stated soybean meal was superior unless iron sulfate was used to supplement the cottonseed meal. There were no deaths due to feeding the solvent meal.

Garrigus and co-workers (1946) conducted digestion trials with steers and lambs fed solvent and hydraulic cottonseed meals. No significant differences between the two meals were noted; both were palatable and gave efficient gains at the levels fed.

Robison (1930, 1941) found both expeller and hydraulic process soybean oil meals superior to either raw or heated solvent process soybean oil meals as supplements in swine fattening rations. Hydraulic processed meal gave somewhat faster gains than expeller meal. In two feeding trials, Bohstedt, Fargo and Hayward (1935) reported results with hogs that were similar to those of Robison, using meals from all three processes. Vestal and Shrewsbury (1937) did not confirm these results as they found solvent meal to give faster and more efficient gains than expeller meal when fed to hogs. The expeller meal appeared to be more palatable when fed to swine.

Rusk and Snapp (1937) reported that beef calves made more efficient gains on solvent meal but that expeller meal was more palatable. The calves made equal gains for the different meals.

Various workers have tested soybean meal against cottonseed meal in livestock rations. Ross and co-workers at the Oklahoma station found soybean pellets a more effective supplement than cottonseed cake in winter rations for steers (1947). Heywang (1947) at Arizona, compared solvent cottonseed meal, hydraulic cottonseed meal, and expeller soybean meal as the main protein supplements in poultry laying rations. The rations also contained either 3.7 per cent fish meal or 4.5 per cent meat scrap. Hydraulic cottonseed meal gave slightly higher egg production but results from all three rations were very similar. Cox (1948) at Kansas, reported an experiment with lambs using a ration of corn, alfalfa hay and Atlas silage. Three lots of 30 lambs were redivided into three groups of ten lambs each, thus making 9 groups of 10 lambs each. One group of each lot was fed one of the supplements to be tested. Cottonseed meal, solvent process soybean oil meal and expeller process soybean oil meal were the supplements used. The average daily gain for all lots was 0.33 lb., 0.35 lb., and 0.36 lb., in the order named. Cox (1949) reported some trouble in keeping the lambs on the soybean meals "on feed". Briggs, Gallup and Darlow (1946) fed soybean oil meal, cottonseed meal and peanut meal to steers and reported that the nitrogen storage from all three meals was approximately equal. The digestion coefficient for the nitrogen of the cottonseed meal was 89.2 and that for the soybean meal was 91.3. Briggs and associates (1946) fed the same supplements to eight lambs and got substantially the same results as in the steer experiment. Briggs, Gallup and Hatfield (1948, 1949) conducted digestibility experiments with steers comparing four meals, solvent and hydraulic cottonseed meals and solvent and expeller soybean oil meals. They reported that soybean meals gave higher apparent protein digestibility than cottonseed meals but that the amount of nitrogen stored from all rations was very nearly the same. All meals were palatable at the levels fed.

PURPOSE OF THE STUDY

1. To determine the relative value of hydraulic and solvent process cottonseed meal as a supplement to maintenance and fattening rations for lambs.

2. To determine the relative value of expeller and solvent process soybean oil meal as a supplement to maintenance and fattening rations for lambs.

3. To determine the relative value of soybean oil meal and cottonseed meal as the protein supplement in maintenance and fattening rations for lambs.

EXPERIMENTAL PROCEDURE

Two experiments were conducted in making this study. The same lambs were used in both experiments and the chemical analyses of feeds, urine and feces were made in the same way for both experiments. The experiments differed only in the rations fed and in the metabolism cages used. The first or maintenance experiment, was conducted in the summer of 1948 and consisted of trials 1 through 8. The second or fattening experiment was conducted along similar lines except for the addition of corn to the rations and the use of a newer type metabolism stall developed at the Oklahoma Station. This experiment included all trials from 9 through 18 and was conducted in the winter and spring of 1948-1949.

Eight crossbred wether lambs of similar type and weight were used for these experiments. The animals averaged approximately 58 pounds each at the start of the first experiment. In this experiment each lamb was put on a preliminary feeding period while confined in a small pen without access to any feed other than the experimental ration. At the end of this period each lamb was transferred to a metabolism cage. The cage used was of the false bottom type described by Forbes (1915) but was slightly modified to accommodate sheep instead of swine. The cage had a coarse wire mesh bottom with a removable screen of finer mesh directly underneath to receive the feces. The urine went through both screens into the funnel at the bottom of the cage, where it drained out into a large wide mouthed glass container of two liter capacity. The urine and feces were collected daily over the ten-day collection period. Each lamb was changed to a different ration as soon as it came off a collection period, so that each lamb would receive each of the four rations at some time during the experiment. Each lamb was weighed at the beginning and end of each trial.

The lambs were handled in exactly the same manner during the second experiment except for the use of the new type metabolism stalls for collections. These stalls were of the type developed by Briggs and Gallup (1949) and were for two lambs. The stall, with stanchion at one end, was wide enough for the lamb to lie down comfortably but narrow enough to eliminate unnecessary motion. The urine was collected by means of a large (12 inch) funnel that was fastened under a coarse screen wire section of the stall floor. From the funnel the urine drained into a two liter glass container. In this new type stall the feces were collected in a metal gutter-box fastened to the rear of and flush with the floor of the stall. The gutter-box could be easily removed for cleaning. Since the stanchions in the stalls could be moved either forward or backward to accommodate lambs of different sizes, the urine and feces losses were held so low as to be considered negligible.

In both experiments the lambs were fed twice daily. One half of the daily ration was fed in the morning and one half in the evening. During the first experiment the lambs had fresh water before them in the cages at all times. In the second experiment all lambs were watered at least twice daily while in the cages and had fresh water before them at all times during the preliminary feeding period.

Before the start of each experiment, all feeds to be used were secured, thoroughly mixed and enough set aside for the entire experiment. The prairie hay used in both experiments was from the same lot. It was chopped and thoroughly mixed before the experiment started. The corn used in the second experiment was purchased locally and coarsely ground (cracked). Due to an error in calculation, the corn was consumed before the end of the second experiment but it was replaced with similar grain for the last four trials. The same protein supplements were used in both experiments and these were analyzed at the start of each experiment and were checked thereafter. A composite sample of the prairie hay was obtained for chemical analysis by taking a small sample of hay from each feeding during a trial and combining the samples at the end of the trial. All feed was stored in a dry place during the entire study.

The meals used were all from the same source[1] and all had undergone some heat treatment. The exact amount of heat treatment was unknown but the meals were considered to approximate closely the commercial meals sold through retail channels so they were secured from the regular production lines.

In trials 1 through 8, 2.1 grams of Na_2HPO_4 were added to each ration containing soybean meal. This equalized the intake of phosphorous in the soybean meal rations to the same level as that of the rations containing the cottonseed meals. These rations were also supplemented with salt. In trials 9 through 18 each lamb received daily 14 grams of iodized salt and 7 grams of $CaCO_3$. Each lamb also received 300 I.U. of vitamin D daily in the form of 0.75 gram of cod liver oil.

The urine and feces were collected daily. The urine was thoroughly mixed and measured in a large graduate cylinder. The total daily amount of feces was weighed to the nearest tenth of a gram. Ten per cent aliquots of both urine and feces were saved, sealed in glass containers and stored in a refrigerator. The composite sample of urine was made up of the ten aliquots and the feces sample was obtained in the same way. The urine sample was kept slightly acid to litmus by adding concentrated hydrochloric acid. This was to prevent volatization and the consequent nitrogen loss as ammonia. A few drops of toluene were added to the feces to prevent bacterial action.

The urine and feces were analyzed chemically immediately after the end of each collection period. This consisted of the determination of the nitrogen in the urine and the amount of nitrogen, ash, fat, fiber and NFE in the feces. The chemical determinations were made by the Agricultural Chemistry Research Depart-

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[1]The meals were furnished through the courtesy of the Proctor and Gamble Co., M.A.P. Building, Ivorydale, Cincinnati, Ohio.

ment, Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma and all determinations were made under the supervision of Dr. W. D. Gallup. Duplicate samples were used in all determinations and the proximate analyses were made as specified by the A.O.A.C. (1940). Nitrogen determinations were made by the Kjeldahl method. All data were treated statistically by the analysis of variance method described by Snedecor (1946).

EXPERIMENT NO. 1

This experiment was designed to compare the two cottonseed meals with each other and with the two soybean meals when used as the main protein supplements in maintenance rations for lambs. The experiment extended from July 18, 1948 until November 3, 1948. This period was the time from the beginning of the first collection period until the end of the last collection period in the experiment. A few days were taken at the beginning of the experiment to let the lambs become accustomed to the rations, but these were not included in the time quoted.

The prairie hay used was of good quality, a light green color and of uniformly low protein content. It had been stored in a dry, well ventilated place for at least one year and the moisture content of the hay was probably at a minimum. The hay was chopped and thoroughly mixed several times before the experiment started. It was stored as before in a well ventilated dry place.

All rations fed and all material excreted (feces and urine) were chemically analyzed. From the figures obtained, the apparent coefficient of digestibility for ether extract (fat), protein, fiber, nitrogen free extract and organic matter were determined for each lamb on each ration. Each lamb's retention of nitrogen from each ration fed was also computed. The amount of nitrogen retained and the apparent coefficient of digestibility for protein in each ration were the standards by which the nitrogen utilization of the rations were judged. The rations fed are presented in table 1 and the chemical composition of the feeds is given in table 2. Approximately 60 per cent of the nitrogen intake from each ration was furnished by the protein supplement.

TABLE 1. Daily Allowance of Feeds used in Digestion and Nitrogen Utilization Studies for Lambs in Experiment I.

Feed	Dry matter %	Allowance in Grams Ration AA	Ration BB	Ration CC	Ration DD
Prairie hay	92.89	572	572	572	57
Hydraulic cottonseed meal	92.77	84			
Solvent cottonseed meal	91.91		87		
Expeller soybean meal	92.24			74	
Solvent soybean meal	92.29				67

TABLE 2. Chemical Analysis of Feeds Fed Lambs in Experiment No. 1

Feed	Trial	Chemical Composition of Dry Matter (Percent) Protein %	Fat	Fiber	NFE	Org. Matter
Prairie hay	1	3.91	2.55	33.04	52.53	92.03
" "	2	3.91	2.55	33.04	52.53	92.03
" "	3	4.04	2.86	31.93	53.87	92.70
" "	4	3.96	2.56	33.34	52.88	92.74
" "	5	4.00	2.47	34.51	52.00	92.98
" "	6	4.08	2.82	32.18	53.90	92.98
" "	7	4.04	2.40	35.71	50.88	93.03
" "	8	4.03	2.65	34.87	51.19	92.74
Hydraulic cottonseed meal	1-8	44.67	6.37	8.75	33.59	93.38
Solvent cottonseed meal	1-8	42.33	3.01	11.61	36.34	93.29
Expeller soybean oil meal	1-8	50.08	5.26	5.72	32.23	93.29
Solvent soybean oil meal	1-8	53.27	0.79	5.02	33.96	93.04

EXPERIMENT NO. 2

This experiment was designed to determine the relative value of the two cottonseed meals and the two soybean oil meals when used as protein supplements in a commonly used low protein fattening ration for lambs. All protein meals used in this experiment were from the same lots as the meals used in the first experiment. Differences in chemical analyses were small. The meals were added to the rations according to the protein content and enough of each meal was used in the ration to furnish approximately 28 per cent of the total nitrogen intake of the ration. This was also the case in the first or maintenance experiment except for the larger percentage of protein furnished by the meals in that experiment.

The hay fed in this experiment was from the same lot as that used in the maintenance experiment and was handled in exactly the same way before and during the experiment as the hay used in the earlier experiment.

The experiment extended from December 23, 1948 until April 9, 1949. These dates were arrived at in the same way as in the previous experiment and time taken to accustom the lambs to the rations was not included in the experimental period.

The same coefficients of digestibility were computed as in the first experiment and the same criteria of nitrogen utilization were used as before. The rations fed are given in table 3 and the chemical composition of the ration constituents is presented in table 4.

TABLE 3. Daily Allowance of Feeds Used in Digestion and Nitrogen Utilization Studies for Lambs in Experiment 2.

		Daily Allowance in Grams			
	Dry Matter %	Ration EE	Ration FF	Ration GG	Ration HH
Prairie hay	91.92	255	255	255	255
Corn (cracked)	86.56	636	636	636	636
Hydraulic cottonseed meal	91.58	67			
Solvent cottonseed meal	91.28		73		
Expeller soybean oil meal	90.48			59	
Solvent soybean oil meal	90.06				56

TABLE 4. Chemical Analysis of Feeds Fed Lambs in Experiment No. 2

		Chemical Composition of Dry Matter (Percent)				
Feed	Trial	Protein	Fat	Fiber	NFE	ODM
Prairie hay	9	5.02	2.74	34.07	51.21	93.04
" "	10	5.42	2.87	34.34	50.17	92.80
" "	11	5.10	2.47	35.53	50.33	93.43
" "	12	5.12	2.46	36.01	49.48	93.07
" "	13	5.35	2.75	31.06	54.01	93.17
" "	14	5.03	2.47	33.77	52.47	93.34
" "	15	5.30	2.84	34.58	50.51	93.23
" "	16	5.74	2.95	34.06	50.24	92.99
" "	17	5.74	2.95	34.06	50.24	92.99
" "	18	5.60	2.95	32.76	51.60	92.91
Corn	9-14	10.47	2.76	1.87	83.42	98.52
	15	9.65	5.02	2.03	81.71	98.41
	16-18	9.94	4.61	1.86	81.93	98.34
Hydraulic cottonseed meal	9-18	45.46	5.95	8.08	33.82	93.31
Solvent cottonseed meal	9-18	43.76	2.88	12.02	34.45	93.11
Expeller soybean oil meal	9-18	51.26	4.97	5.46	31.58	93.27
Solvent soybean oil meal	9-18	54.96	0.47	5.05	32.70	93.18

RESULTS AND DISCUSSION

The coefficients of digestibility for crude protein in the rations containing the soybean oil meals averaged much higher in both experiments than did the corresponding coefficients of the rations supplemented by the cottonseed meals. This is shown in table 5. The soybean oil meal rations CC and DD had coefficients of 61.0 and 61.4, while the cottonseed meal rations AA and BB had coefficients of 54.6 and 54.3 In the second experiment the coefficients for the soybean oil meal rations GG and HH were 69.2 and 68.0, while the figures for the cottonseed meal rations EE and FF were 64.4 and 63.3. This difference was highly significant (at the 1 per cent level) in the first experiment and significant (at the 5 per cent level) in the second experiment.

The digestibility coefficient for ether extract was much higher for the press extracted soybean oil meal ration than for the solvent extracted soybean oil meal ration. A difference also existed between the hydraulic process and solvent process cottonseed meals but it was much less than was the case with the soybean oil meal rations. The solvent process soybean oil meal ration had a lower coefficient than any of the other rations. This was true in both experiments. In the first experiment the coefficients of digestibility of ether extract of rations AA and BB averaged 57.9 and 50.0, while the same figures for rations CC and DD were 51.9 and 41.6. These differences were highly significant. The same coefficients for the rations fed in the second experiment were 78.5 and 75.6 for rations EE and FF respectively and 74.8 and 73.0 for rations GG and HH. These differences were not significant.

Crude fiber had a lower average digestion coefficient in the second experiment than in the first. The digestion coefficients for crude protein, ether extract, nitrogen free extract and organic matter were all higher in the second experiment (rations EE, FF, GG and HH) than in the first(rations AA, BB, CC and

TABLE 5. The Average Apparent Digestion Coefficients of Nutrients and the Total Digestible Nutrient Content of Each Ration Fed Lambs.

Ration Number		Apparent Digestibility (Percent) of:					T.D.N. of Ration
		Crude Protein	Ether Extract	Crude Fiber	NFE	Organic Matter	
First Experiment							
AA	Hydraulic cottonseed meal	54.6	57.9	64.7	58.6	60.5	53.9
BB	Solvent cottonseed meal	54.3	50.0	64.2	59.5	60.3	53.4
CC	Expeller soybean oil meal	61.0	51.9	65.5	59.5	61.4	54.6
DD	Solvent soybean oil meal	61.4	41.6	66.9	59.9	61.9	54.5
Second Experiment							
EE	Hydraulic cottonseed meal	64.4	78.5	54.6	85.4	79.4	71.1
FF	Solvent cottonseed meal	63.3	75.6	55.0	84.6	78.3	70.1
GG	Expeller soybean oil meal	69.2	74.8	60.2	86.0	80.7	72.0
HH	Solvent soybean oil meal	68.0	73.0	60.2	86.4	80.8	72.0

DD). The computed total digestible nutrient values (TDN) of all rations in the second experiment were much higher than the corresponding values in the first experiment. Although differences among rations in both experiments existed, the only significant differences found were those that have already been stated for crude protein and ether extract.

The data on the nitrogen retention of the different rations containing each of the four meals are presented in tables 6 and 7. All data from the maintenance rations are in table 6, while table 7 contains the data computed from the results of the fattening rations. The data given for each lamb are the averages computed from the composition of the ration, urine and feces over the ten day collection period.

The nitrogen content of the different rations varied slightly but these differences were not important because of the small amount of the total intake that they represented. There were rather wide variations in the percentages of nitrogen retained from the four rations in the first experiment but these differences were not significant. There was very little variation in the percentages of nitrogen retained from the rations in the second experiment and these differences were not significant. The amount of nitrogen retained from the solvent meal rations was slightly larger in all cases than the amount from the pressure process meals.

There was no evidence of harmful effects due to feeding any of the meals in either experiment.

Only two of the lambs failed to gain weight in the maintenance experiment and all lambs made very satisfactory gains in the fattening experiment. The gains in weight in both experiments were given in table 8. All of the lambs ate all of the feed offered in the first experiment but some trouble was experienced in keeping all animals on feed during the second experiment. Some feed was refused from all of the rations but more animals refused feed from the hydraulic

TABLE 6. The Average Daily Nitrogen Retention of the Maintenance Rations for Lambs in Experiment I.

Ration No.	Lamb No.	Dietary N Gm.	Urinary N Gm.	Fecal N Gm.	Excreted N Gm.	Retained Gm.	% N Retained
AA	1354	8.9	3.5	4.1	7.6	1.3	14.6
	1355	9.0	3.7	3.8	7.5	1.5	16.7
	1356	9.1	3.5	3.8	7.3	1.8	19.8
	1357	9.0	3.7	4.3	8.0	1.0	11.1
	1358	8.9	4.0	3.9	7.9	1.0	11.2
	1359	9.0	3.1	4.2	7.3	1.7	18.9
	1360	8.9	3.2	4.3	7.5	1.4	15.7
	1400	8.9	4.5	3.7	8.2	0.7	7.8
	Average	9.0	3.7	4.0	7.7	1.3	14.4
BB	1354	8.8	3.8	4.0	7.8	1.0	11.4
	1355	8.8	4.0	4.3	8.3	0.5	5.7
	1356	8.8	3.6	3.9	7.5	1.3	14.8
	1357	8.8	3.8	4.1	7.9	0.9	10.2
	1358	8.9	3.2	3.6	6.8	2.1	23.6
	1359	8.9	3.2	4.0	7.2	1.7	19.1
	1360	8.7	2.5	4.2	6.7	2.0	23.0
	1400	8.8	4.0	3.9	7.9	0.9	10.2
	Average	8.8	3.5	4.0	7.5	1.3	14.8
CC	1354	8.9	4.7	3.1	7.8	1.1	12.4
	1355	8.9	4.4	3.5	7.9	1.0	11.2
	1356	8.8	4.6	3.1	7.7	1.1	12.5
	1357	8.9	4.8	3.4	8.2	0.7	7.9
	1358	8.9	4.3	3.2	7.5	1.4	15.7
	1359	8.8	3.3	3.8	7.1	1.7	19.3
	1360	8.8	4.4	3.6	8.0	0.8	9.1
	1400	9.0	3.7	3.5	7.2	1.8	20.0
	Average	8.9	4.3	3.4	7.7	1.2	13.5
DD	1354	8.7	3.6	3.2	6.8	1.9	21.8
	1355	8.7	4.0	3.3	7.3	1.4	16.1
	1356	8.6	4.2	3.2	7.4	1.2	14.0
	1357	8.6	4.5	3.5	8.0	0.6	6.9
	1358	8.6	4.3	3.4	7.7	0.9	10.5
	1359	8.7	3.4	3.4	6.8	1.9	21.8
	1360	8.8	3.3	3.3	6.6	2.2	25.0
	1400	8.7	3.5	3.3	6.8	1.9	21.8
	Average	8.7	3.9	3.3	7.2	1.5	17.2

TABLE 7. The Average Daily Nitrogen Retention of the Fattening Rations Fed Lambs in Experiment 2.

Ration No.	Lamb No.	Dietary N Gm.	Urinary N Gm.	Fecal N Gm.	Excreted N Gm.	Retained Gm.	% N Retained
EE	1354	15.7	6.2	5.9	12.1	3.6	22.9
	1355	13.4	6.9	6.0	12.9	0.5	3.7
	1356	16.0	6.8	5.1	11.9	4.1	25.6
	1357	13.6	6.3	5.3	11.6	2.0	14.7
	1359*	15.2	7.2	4.5	11.7	3.5	23.0
	1359	15.2	8.0	4.7	12.7	2.5	16.4
	1360	15.2	6.8	5.0	11.8	3.4	22.4
	1400	15.8	7.5	5.1	12.6	3.2	20.2
	Average	15.0	7.0	5.2	12.2	2.8	18.6
FF	1354	16.0	7.5	5.4	12.9	3.1	19.4
	1355	14.4	5.1	6.2	11.3	3.1	21.5
	1356	15.1	8.2	5.5	13.7	1.4	9.3
	1357	15.9	6.9	6.0	12.9	3.0	18.9
	1358	16.0	6.9	6.0	12.9	3.1	19.4
	1359	16.1	5.5	5.9	11.4	4.7	29.2
	1360	15.9	8.8	5.3	14.1	1.8	11.3
	1400	15.4	6.9	5.4	12.3	3.1	20.1
	Average	15.6	7.0	5.7	12.7	2.9	18.6
GG	1354	15.9	7.8	4.5	12.3	3.6	22.6
	1355	15.7	7.4	4.7	12.1	3.6	22.9
	1356	15.6	6.4	6.2	12.6	3.0	19.2
	1357	14.8	7.7	4.8	12.5	2.3	15.5
	1358	15.6	8.8	4.7	13.5	2.1	13.5
	1359	15.7	7.5	5.1	12.6	3.1	19.7
	1400*	15.1	8.5	4.3	12.8	2.3	15.2
	1400	15.1	8.7	3.8	12.5	2.6	17.2
	Average	15.4	7.8	4.8	12.6	2.8	18.2
HH	1354	14.8	8.3	4.6	12.9	1.9	12.8
	1355	15.9	7.8	5.3	13.1	2.8	17.6
	1356	15.8	6.8	5.0	11.8	4.0	25.3
	1357	12.0	5.5	4.6	10.1	1.9	15.8
	1358	15.2	7.5	4.2	11.7	3.5	23.0
	1359	15.7	8.4	4.4	12.8	2.9	18.5
	1360	15.7	7.4	5.0	12.4	3.3	21.0
	1400	15.9	7.5	5.3	12.8	3.1	19.5
	Average	15.1	7.4	4.8	12.2	2.9	19.2

*Since 1358 was off feed while on Ration EE and 1360 was off feed while on Ration GG, retrials were run and 1359 was substituted on Ration EE and 1400 on Ration GG.

TABLE 8. THE GAINS IN WEIGHT OF THE LAMBS ON EXPERIMENT.

Lamb No.	Experiment No. 1 (Maintenance) July 18 to Nov. 3*	Experiment No. 2 (Fattening) Dec. 23 to April 9*
	Pounds	Pounds
1354	2	28
1355	6	19
1356	0	21
1357	3	28
1358	2	23
1359	4	22.5
1360	2	24.5
1400	0	25

*These dates are first day of the first collection period and last day of last collection period in each experiment.

cottonseed meal ration than from any other. The data from experimental trials in which the sheep refused most of the ration or appeared sick was not used. The hydraulic cottonseed meal ration seemed to be somewhat less palatable to all animals. All of the fattening rations contained concentrates in amounts as high as the maximum recommended for animals on full feed. (Morrison, 1948).

Evidently the source of the protein did not affect the amount of nitrogen retained from the rations, even though the protein from the soybean oil meals was digested more efficiently than the protein from the cottonseed meals. This was the case in both maintenance and fattening rations. The difference in both nitrogen retention and efficiently in digesting protein was more marked on the lower protein maintenance ration.

With both cottonseed and soybean meals, the ether extract had higher coefficients of digestibility for the pressure process meals than for the corresponding solvent process meals. This difference was pronounced in the first experiment and was highly significant. Corresponding differences existed in the second experiment but they were less marked and were not significant. Evidently the fat content of the meals had very little effect on the total fat content of the ration, but this effect increased with an increase in the amount of the meal in the ration. Therefore, one may assume that a ration containing a very large amount of solvent process meal would show results differing from those obtained by feeding a similar ration containing a similar amount of the pressure process meal. The difference between pressure process soybean oil meal and solvent process soybean oil meal would probably be more striking than the difference between the two cottonseed meals, due to the very low fat content of the solvent soybean oil meal.

The fat content of the meals had no apparent effect on the total digestible nutrients of any of the rations fed in either experiment. There was less than 3 per cent variation in the average TDN values of all rations in either experiment.

SUMMARY

Soybean oil and cottonseed meals prepared by both pressure and solvent processes were compared as protein supplements to maintenance and fattening rations. The meals were hydraulic process and solvent process cottonseed meals and expeller process and solvent process soybean oil meals. Two experiments were conducted with eight crossbred wether lambs. Each of the four meals was used to supplement chopped prairie hay to form a maintenance ration in the first experiment. The same meals were used to supplement corn and prairie hay in the fattening rations fed in the second experiment. Data were obtained on the apparent digestibility of crude protein, ether extract, crude fiber, organic matter and nitrogen free extract in each ration. The amount of nitrogen retained by the lambs was determined for each ration.

The protein intake from all rations in the first experiment was held at approximately the same level. The meals used in these rations supplied approximately 60 per cent of the total protein in the ration. All rations in the second experiment were also equalized as to protein intake but the meals supplied only about 23 per cent of the total protein.

In both maintenance and fattening rations, the apparent digestion coefficients for crude protein were higher for the soybean oil meal rations than for the cottonseed meal ration. This difference was significant in the case of the fattening rations and highly significant in the case of the maintenance rations. The higher digestibility of protein in the soybean rations failed to produce a corresponding increase in nitrogen storage. Differences in nitrogen storage due to protein source were obtained in both experiments but the differences were not significant in either experiment.

In both experiments, the pressure process meals showed higher apparent digestion coefficients for ether extract than did the solvent process meals.

The difference was highly significant in the maintenance rations but not significant in the fattening rations.

The source of the meals (cottonseed or soybean) and the different methods of processing had no significant effect on apparent digestion coefficients of crude fiber, organic matter, or nitrogen free extract in either experiment. The calculated TDN values of all rations within each experiment were not significantly different.

Evidently soybean oil meals and cottonseed meals were of approximately equal value when used to maintain and fatten lambs, and the method of processing used to produce the meals seems to have little or no influence on their feeding value when used for this purpose. The results of this study indicate a lamb feeder would be justified in purchasing the meal that is least expensive and readily available.

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