THE INFLUENCE OF METHOD OF PREPARATION ON THE NUTRITIVE VALUE OF COTTONSEED AND SOYBEAN MEALS FED STEERS

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INTRODUCTION

Cottonseed meals and soybean oil meals are quantitatively the most important protein supplements used in feed livestock and poultry.

Macy (1921) was one of the first to review the literature on the subject of the use of cottonseed as a food or feed. She pointed out that a patent was taken out in 1819 for the preparation of cattle feed from cottonseed. The following year another patent was taken out for the extraction of the oil from cottonseed. In addition to offering a new source of profit to the southern cotton planter, the cottonseeds and cottonseed meals offered a nitrogenous feed for livestock producers.

Although soybeans are one of the oldest crops grown, they have been grown in the United States for only a relatively short time. Burlison (1936) reports that the first written record about soybeans seems to be in a Chinese book on Materia Medica entitled "Pen Tsao Gong Mu" that was written by Emperor Shen-Nung about 2850 B. C. Soybeans according to Hayward et al (1939) were probably first utilized for the production of oil and meal in this country in 1910 when raw beans were imported from Manchuria. The first domestic soybean oil meal was produced in North Carolina in 1915 when oil was pressed from the seed by cotton oil presses. In 1920, soybean oil was produced in Chicago Heights, Illinois, with an expeller, and in 1922 the A. E. Staley Manufacturing Company of Decatur, Illinois, used such a machine to crush 90,000 bushels of soybeans.

The practice of separating the lipids from cottonseeds and soybeans by solvent extraction rather than by pressure is increasing in the commercial preparation of oil meals from these seeds. Solvent extraction increases the amount of oil that can be obtained from a given amount of seed and the oil has been worth more than could be obtained for the same weight of meal.

Solvent extracted meals usually contain only about 25 percent as much ether extract (fat or oil) as those prepared in pressure equipment and the oil is removed at a much lower temperature. Hexane is the principle solvent used. The processing industry has been expanding its extraction facilities and replacing worn out pressure equipment with solvent equipment. As the amount of solvent meal has increased, feeders have concerned themselves with the comparative value of the meals prepared by solvent processes as compared to those prepared by the pressure methods (hydraulic and expeller) heretofore used almost exclusively.

REVIEW OF PREVIOUS INVESTIGATIONS

When cottonseeds and cottonseed meals were first fed some trouble was experienced from their use. Macy (1921) credits Voelker with having observed injurious effects from cottonseed meal in 1859. He also points out that in 1861 Kuhlmann found the cotton plant and seed contained a toxic yellow dye which was later crystallized and named "gossypol" by Marchlewski in 1899.

Curtis and Carson (1892) reported that they found cottonseeds and cottonseed meals were toxic to hogs but that heat treatment would make these feeds less toxic. Emery (1894) found cottonseed meals to be unsatisfactory as a protein supplement to corn for pigs and that 4 ounces of cottonseed meal added to skimmilk would kill small calves. Withers and Brewster (1913) obtained beneficial effects from feeding iron salts with toxic cottonseed rations. Withers and Ray (1913) discovered that boiling with alcoholic alkali was the most successful method of treatment to render the cottonseed meals harmless as a feed. Osborne and Mendel (1917) reported that rats refused to eat raw cottonseed meal.

Heat treatment during extraction of the oil from cottonseed was first reported by Carruth (1918). He pointed out that very little gossypol remained in the hot-pressed meals but that nearly all of it remained in the cold-pressed meals. Dowell and Menaul (1923) fed raw and autoclaved cottonseed meals to pigs and lambs. Lambs grew equally well on both supplements but the pigs fed raw cottonseed meal died while those that were fed autoclaved cottonseed meal survived the experiment. They concluded that raw cottonseed meals were not toxic to sheep and that autoclaving destroyed the fraction of the meal that is toxic to pigs.

Gallup (1926, 1927, 1927a, 1928, 1931, 1931a) conducted a series of experiments in which he studied the feeding values and toxicity of cottonseed and cottonseed meals. He concluded that either autoclaving or dry heat made the product much more valuable and safe as a livestock feed.

Excessive amounts of calcium and liberal amounts of protein in the rations containing cottonseed products were suggested by Gallup and Reder (1935). Olcott (1948) reported that the toxic factor in cottonseed could be nullified by three apparently unrelated mechanisms and these were oxidations, combination with soluble iron salts, and destruction by steam autoclaving. Lyman et al (1944) have reported an analytical procedure for testing the toxic qualities of cottonseed or cottonseed meals by colorimetric methods.

Various workers have concerned themselves with the influence of the various methods of preparation of oil meals on their feeding value. Since the oil content of the meals varies considerably it was only natural that investigators would study the effect of fat (ether extract) content of the ration on its utilization.

Fairchild and Wilbur (1924) and Moore and Cowsert (1926) reported that ground soybeans were superior to the fat expelled soybean oil meal for milk production. Maynard and associates (1930, 1932, 1934) have shown that low fat intake lowers both the milk and butterfat production of the dairy cow. Maynard et al (1939, 1941) reduced the ether extract from 6.27% to 3.35% by substituting solvent extracted soybean oil meal for ground soybean in dairy rations. The higher fat ration showed an advantage in the amount of 4 percent converted milk produced and these workers attributed the increases to the higher fat content of the rations. On the other hand, Monroe and Krauss (1943) could not get significant decreases in the amount of 4 percent milk produced by lowering the fat content of the rations from 4.9 to 2.7 percent. Likewise Schulbert and Wells (1940) reported no significant decrease in milk production of cows when the fat content of the ration was reduced.

Loosli and coworkers (1944) found a significant response in lactation in the rat when linoleic acid was used to replace hydrogenated oils in the diet. Fat is a source of the essential fatty acids although very little has been reported on the fatty acid requirements of the domestic animals. Reiser (1947) reported that 23 milligrams per day appeared to give good growth and reproduction in the rat but that 100 milligrams were required daily for optimum lactation.

Davis and Upp (1941) found that low fat diets had a deleterious affect on egg production and this conclusion was substantiated by Russell, Taylor, and Walker (1941). Heywang (1941, 1943), however, reported that changing the fat content of hens diet did not influence egg production.

Forbes and Swift (1944, 1946) observed that as the fat content of the ration of rats was increased, growth was improved per unit of feed consumed. In further work, Forbes et al (1946a) found that the growing albino rat digested the ration more efficiently, retained more nitrogen, gained more weight, and retained more energy as the fat contents of the diets were increased from 2 to 30 percent. Gulleckson and coworkers (1942) reported that the inclusion of milk fat in the diet increased the growth of calves as compared to those fed skimmilk. Helser and associates (1939) reported that soybean oil meal produced a better quality pork than soybeans. They attributed the difference in quality of product to the firmness resulting from the low fat diet rather than the inability of the high fat diet to properly nourish swine.

Jones (1942) observed that small amounts of fat in the diet aids in calcium absorption and calcification by maintaining a favorable intestinal acidity. This effect is more noticeable in the rachitic animal and may be due to increased absorption of vitamin D with increase in fat. Fats are also carriers of the fat soluble vitamins. Cottonseed oil and soybean oil contain about 0.1 percent tocopherols according to Hayward et al (1939). It was suggested by Harris (1947) that the tocopherols may have been an important factor in milk production. Meulder and Kelly (1942) have shown that the level of fat in the diet affected the utilization of vitamin A. Hayward (1937) reported that soybean oil meal contains 1 to 2.8 International Unites of vitamin B_1 per gram. Hayward et al (1939) reported that soybean oil contained about 0.3 International Units of vitamin A per gram, and that it carried an abundant supply of vitamin K.

Hayward and coworkers (1939) concluded that soybean oil contained 80 to 88 percent unsaturated oils, with oleic, linoleic, and linolenic being the major acids present. Reiser (1947) reported that the ether extract content of press extracted meals is approximately 6 percent while the content of the solvent extracted meals is less than one persent. Hence the substituting of solvent extracted meals for the press extracted meals would cause a reduction up to 50 percent in the ether extract content in many of the commercial feeds. The productive energy of the press extracted soybean oil meal is reported by Fraps (1947) to be 79.7 therms per 100 lbs while that of the solvent extracted meal is 71.2 therms. This represents a 10.6 percent loss in energy in the solvent extracted meals.

Many comprehensive investigations have been conducted to determine the influence of heat treatment on the nutritive values of protein supplements. Osborne and Mendel (1917) found that there was a difference in the nitrogen utilization between raw and cooked soybean oil meal. They obtained a 5 percent greater utilization from the cooked meals. Wilgus et al (1935) found that a properly cooked soybean oil meal is superior to some of the other protein supplements commonly used in poultry rations.

Wilgus and coworkers (1936) reported that there were no consistant differences in the protein efficiencies between the soybean oil meals produced by several processes, but that within processes controlled temperature variations produced significant differences in performance. Heating the solvent extracted soybean oil meal at 98 degrees C for 15 minutes gave the highest relative protein efficiency.

Hayward and associates (1936) conducted a number of experiments to determine the effect of heat on the nutritive values of soybean proteins. They used the "growth method" (Osborne et al 1919) and the "nitrogen balance" method (Mitchell 1924) in arriving at protein values. The rations consisted of 6 parts yeast, 4 parts salts, 2 parts cod liver oil, cooked starch, and soybeans or soybean oil meals as protein supplements at 10 or 18 percent protein levels. The soybean oil meals produced better growth than ground soybeans at both levels. The high temperature expeller meal produced faster and more efficient gains than the low temperature expeller meal and ground soybeans. High temperature hydraulic meals and high temperature expeller meals gave similar results. The nutritive value of the solvent meal was considerably greater than that of ground soybeans. The average daily food intake showed that the failure of the raw soybeans and the low temperature soybean oil meals was not due to lack of good consumption. These workers suggested that the low nutritive values of raw soybeans and low temperature soybean oil meals could be raised by proper heat treatments.

Although it had been shown that the nutritional qualities of soybean proteins were greatly improved by heat treatments, no one had given satisfactory evidence as to what "properly heated" or "correctly heated" treatments actually should be. Bird and Burkhardt (1943) carried out a number of experiments to determine factors affecting the nutritive values of soybeans and soybean oil meals. They found poultry grew most rapid when fed soybean oil meal that had been autoclaved at 20 pounds pressure for 2½ minutes. Autoclaving longer than 2½ minutes at this temperature resulted in an inferior meal. A heat treatment of 104 degrees C also improved the protein quality and there seemed to be no evidence of destruction by over-heating at this temperature. Mitchell and coworkers (1945) confirmed previous reports that overheated soybeans were of lower nutritive value and found that soybeans heated in the autoclave for one hour at 15 pounds pressure had a high nutritive value. They found that they could increase the true coefficient of digestion of the protein in soybean meal from 78.0 to 83.1 and increase the biological values from 49.1 to 67.0 percent by proper autoclaving. Wei-Kuang Cheng (1944) reported that the digestibility of heated soybeans to be higher than that of the unheated soybeans. However, he reported that the biological value of the raw soybeans to be higher than that of the heated soybeans.

Robison (1939) found significant difference in the performance of expeller and hydraulic cottonseed meals when fed to pigs. The pigs fed the expeller meal grew more rapidly and were ready for market 71 days earlier than those fed the hydraulic meals. The untreated meals resulted in a very high mortality rate. Cooking with steam, the addition of ferrous sulfate, or the addition of tankage to the ration overcame these difficulties. Robison (1941) ran experiments to determine the value of soybean oil meals for feeding pigs. Raw expeller and solvent meals gave very unsatisfactory results while the heat-treated expeller and the hydraulic meals were satisfactory. Bethke and Sweet (1939) compared the expeller with the solvent soybean oil meal in poultry rations and concluded that the toasted solvent meals were comparable to expeller meals. Overheated soybean oil meal gives less growth in the growing chick than properly heated meals according to Clandinin et al (1947), Fritz, Kramke, and Reed (1947) confirmed this conclusion and found that dry heat was not as desirable as moist heat for treating the meal.

Turk, Morrison, and Maynard (1935) conducted metabolism trails with lambs to determine the nutritive values of the protein in corn gluten meal, linseed meal, and soybean oil meal prepared by pressure methods. They reported that the average coefficients of apparent digestibility of the proteins were 67 percent for soybean oil meal, 66.3 percent for corn gluten meal, and 66.3 percent for linseed meal. The lambs were also more efficient in storing protein from the soybean oil meal ration. Rusk and Snapp (1937) compared the solvent and press soybean oil meals in a feeding experiment with fattening cattle and found no differences in the nutritive values of the meals from the different processes.

Phillips and coworkers (1920) used pigs, rats, and chicks in comparing soybean oil meals with meat scraps as a protein supplement. Rations with the soybean oil meal as supplement gave the most favorable growth curves. McCollum and associates 1921) found that soybeans gave growth that was distinctly below normal. The animals on the ration containing the soybeans remained undersized and their fertility was low.

Shrewsbury and Bratzler (1933) suggested that the low nutritive value of the protein of raw soybeans was due to a deficiency of cystine. Csonka and Jones (1934) investigated the cystine, tryptophane, and tyrosine content of soybeans and studied the effect of supplying these amino acids to rations in which the proteins were supplied solely by soybeans. They observed that the cystine content is not the same in all varieties of soybeans although it did varry parallel with the nitrogen content. Later Womack et al (1937) carried out experiments in which they concluded that methionine is indispensible and that cystine is not essential for maintenance but that cystine is effective in supplmenting low methionine diets for growth purposes. Hayward and Heftner (1941) found that the proteins of raw soybeans were effectively supplemented by the addition of 0.3 percent cystine and that the addition of 0.3 percent methionine was even more effective. Combination of the two gave no improvement over the addition of methionine alone. Autoclaving the soybeans increased the nutritive values of the proteins. This suggested that soybeans and soybean oil meals contain a sub-optimal quantity of available sulphur-containing amino acids which are made slightly more available by autoclaving. This conclusion was supported by Almquist et al (1942).

Grau and Almquist (1943) found that while addition of cystine was of little benefit to chicks that additions of methionine and choline were beneficial. Bird and Mattingly (1945) reported that the addition of 2 percent methionine resulted in increased growth over the addition of 4 percent fish meal in the starting and growing mashes that contained 25 to 35 percent soybean oil meal. Evans and McGinnis (1946) confirmed reports that autoclaving increased the nutritive values of soybean oil meals when fed alone or fed with added methionine. Patton, Marval, Pettering, and Waddell (1946) have reported on experiments to determine the extent to which methionine is able to supplement a chick ration containing only protein from corn and soybeans; such a diet appeared to be lacking in an unknown growth factor which is present in sardine fish meal. There is some evidence that the need for this factor is a peculiarity of the corn-soybean diet. Bird, Marsden, and Kellogg (1948) observed that turkeys that were fed diets in which soybean oil meals were the major source of proteins grew less rapidly than the turkeys on diets containing soybean oil meal and fish meal as a source of proteins. They reported that the turkeys on the soybean oil meal diet were inferior during the entire experiment. Synthetic methionine at the rate of 0.2 percent of the diet produced a significant stimulus to growth in two of three experiments when added to the soybean oil meal ration.

According to Heidebrecht (1947) a corn-soybean oil meal ration is inadequate to support reproduction and lactation in rats. He reported that the addition of 1:20 liver extract at a 2 percent level seemed to correct this deficiency when all of the known vitamins and minerals failed.

Since the sulphur-containing amino acids were reported to be the principle growth limiting deficiency in soybean protein for chicks, Evans, McGinnis, and St. John (1947) set up experiments to compare the digestion of these proteins in the chick as compared to their digestion by enzymes "in vitro",. Autoclaving the soybean oil meal at 100 degrees C for 20 minutes increased digestion by the chick and a trypsin-erepsin mixture "in vitro" but failed to increase digestion by a pepsin-trypsin-erepsin mixture"in vitro". Autoclaving at 130 degrees C for 60 minutes decreased digestion in all comparisons. Johnson, Parson, and Steenbock (1939) observed no difference in the sulphur retention of the raw or the cooked soybean oil meal when fed to the adult rat. In their experiment, they concluded that apparently the solvent used in extracting the oils from the soybeans did not affect the protein molecule.

Ham et al (1945) reported that a growth inhibiting substance could be extracted from raw soybeans with water. McGinnis and Manzies (1946) were able to deactivate the growth inhibitor in raw soybean oil meal by "in vitro" pre-digestion with papain.

Whitson and coworkers (1946) reported feeding experiments of forty weeks duration with poultry in which diets consisted largely of corn and soybean oil meals but with small additions of alfalfa leaf meal, vitamins, and mineral supplements. As the level of soybeam oil meal increased from zero to 40 percent, in increments of 10 percent, the hatchability decreased in spite of apparently adequate quantities of the dietary factors known to be needed for hatchability. The high levels of soybean oil meal did not have an adverse effect on egg production, body weight, or egg size.

Bird et al (1946) confirmed an earlier report that eggs from hens on a diet containing 30 percent soybean oil meal as the sole protein supplement were low in hatchability and viability of hatched chicks. Gericke (1946) reported that untreated soybeans could replace only one-third of the animal protein in the rations of poultry, but that heated soybeans could replace more than one-half of the animal protein without lowering the rate of growth.

Heidebrecht et al (1948) observed that pigs receiving soybean oil meals as the only protein supplement in a fattening ration supplemented with sufficient ground limestone to produce a 1:1 calcium-phosphorus ratio required less feed to produce 100 lbs of gain and showed more profit per pig than did pigs receiving meat and bone scraps, tankage, or tankage with bone.

Stephens and associates (1948) found that soybean pellets were superior to cottonseed cake or urea pellets as a source of protein for two and three-year-old steers as measured by weight of the steers at the end of the experiment. Ross and coworkers (1947) have reported that soybean pellets were superior to cottonseed cake as a protein supplement for wintering two-year-old steers. Briggs, Gallup, and Darlow (1946) found that the storage of nitrogen by steers was about the same when cottonseed meal, soybean oil meal, and peanut meals were used to supplement prairie hay. The digestion coefficients of the nitrogen of the soybean oil meal ration was 91.3 and that of the cottonseed meal ration was 89.2.

The nutritive value of a protein is dependent on the ratio and composite content of the essential amino acids. These have been approximated for a variety of feeds by Block and Bolling (1947), Almquist and Grau (1944) and Maynard (1947).

The role of fat in storage of commercial feeds is always a problem. Ordinarily it is considered that fat will cause an increase in storage risk due to the possibilities of rancidity. Reiser (1947) reported that the presence of fat in soybean oil meal had a protective effect during storage. Hayward (1939) reported that the breakdown of proteins in storage of ground raw soybeans is believed to be due to an enzyme in the raw soybean that can be destroyed by proper heat treatments.

Protein supplements are often valuable sources of minerals for farm animals. Morrison (1938) reported the average phosphorus content of soybean oil meal to be 0.66 percent and of cottonseed meal to be 1.19 percent. Spitzer and Phillips (1945, 1945a) reported that the phosphorus in soybean oil meal is readily available for growth and bone formation and that apparently heat or methods of preparation of the meal had no effect on the availability.

Rusk and Snapp (1937) indicated that solvent extracted soybean oil meals were less palatable than the expeller meals, presumably due to their fat content. Vestal and Shrewbury (1947) found swine consumed five times as much expeller soybean oil meal as solvent soybean oil meal when both were used as supplements to rations of corn and minerals. However, Monroe (1948) found no difference in palatability of solvent and expeller soybean oil meals for dairy cows.

PURPOSE OF THE STUDY

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

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

3. To determine the relative value of soybean oil meal and cottonseed products in supplementing wintering and fattening rations for steers.

EXPERIMENTAL PROCEDURE

This study was divided into two experiments and the general procedure of feeding, collecting samples of urine and feces, and chemical analysis of the samples was the same in both experiments. The two experiments differed only in the kind of rations that were fed to the steers. The first experiment was conducted in the winter of 1947-48 and prairie hay supplemented by the meals studied constituted the wintering rations used in trials 1, 2, 3, and 4. The second experiment was conducted in the spring and summer of 1948 and corn, prairie hay, and the experimental meals made up the fattening rations used in trials 5, 6, 7, and 8.

Four yearling Hereford steers weighing approximately 470 pounds each were placed on false bottom metabolism stalls and fed the wintering rations and the same four steers were used for the study of the fattening rations. Each experiment consisted of four trials and during each trial each animal received a different ration. The rations were rotated after each trial so that all steers received each of the experimental rations during the experiments. Just prior to and immediately after each trial the steers were weighed.

Enough prairie hay of uniform quality was secured and stored for both experiments. A sample of the hay was taken at each feeding to make up a composite sample for each trial. Each protein supplement was thoroughly mixed before the experiments started and the same meals were used in both studies, and a "check" analyses of the chemical composition were made during the experiment.

The meals used were from the source[1] and had been heat treated although the exact temperature of the heat treatment is unknown. Block salt was kept before the steers at all times. In trials 1, 2, 3, and 4, 15 grams of $Na_2H\ PO_4$ was added daily to the rations containing the soybean oil meal to equalize the phosphorus intakes of the soybean and cottonseed meal containing rations.

The steers were placed on 10-day preliminary feeding periods before each of the 10-day collection periods. During the latter periods, the urine and feces were collected, measured or weighed and two percent aliquots were saved and stored in a refrigerator. The composite sample of urine was kept acid with HCl to prevent losses of nitrogen through volatilization. The feces were treated with a few drops of toluene to prevent bacterial action.

The urine was collected through rubber funnels into 7.5 liter bottles that were placed below the false bottoms of the metabolism stalls. A 12-inch rubber funnel was suspended below each steer by two adjustable supporting straps—one over the loin, and the other over the withers. The straps were adjusted to hold the funnel tight enough to prevent loss of urine yet loose enough to insure comfort to the animal. The funnels were connected to a hose that ran through the false bottom of the metabolism stalls to the collecting bottles. The feces were caught in individual gutter boxes and transferred to nearby covered containers at frequent intervals.

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

Immediately following the collection period of each trial chemical analysis of urine and feces were made to determine the amount of nitrogen in the urine and to determine the amount of nitrogen, fat, ash, fiber, and NFE in the feces. The chemical determinations were made by the Agriculture Chemistry Department, Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma, under the supervision of Dr. W. D. Gallup. Duplicate samples were used for all determinations. The Kjeldahl method was used for the nitrogen determinations and the proximate analysis were made as specified by the A.O.A.C. (1940). The data were treated statistically by the analysis of variance method described by Snedecor (1946).

EXPERIMENT NO. 1

The first experiment was designed to determine the comparative values of hydraulic and solvent process cottonseed meals and expeller and solvent process soybean oil meals as supplements to low protein roughage for steers. The apparent coefficients of digestibility of protein and nitrogen retained were used as criteria of the nitrogen utilization of the rations. The apparent coefficients of digestibility were determined for the fat, fiber, nitrogen-free extract, and organic dry matter of the rations. The experimental rations fed are presented in table 1, and the protein supplements furnished approximately 60 percent of the nitrogen intake. The chemical composition of the ration constituents is given in table 2.

Table 1. Daily Allowance of Feeds Used in Digestion and Nitrogen Utilization Studies for Steers in Experiment Number 1.

Feed	Dry Matter %	Daily allowance in pounds			
		Ration A	Ration B	Ration C	Ration D
Prairie Hay	91.75	9.00	9.00	9.00	9.00
Hydraulic cottonseed meal	93.21	1.33	--	--	--
Solvent cottonseed meal	91.42	--	1.38	--	--
Expeller soybean oil meal	91.97	--	--	1.16	--
Solvent soybean oil meal	92.21	--	--	--	1.05

Table 2. Chemical Analysis of the Feeds Fed Steers on Experiment No. 1

Feed	Trail	Chemical composition of dry matter (percent)				
		Protein	Fat	Fiber	NFE	Organic Matter
Prairie hay	1	4.47	2.48	34.38	51.54	92.87
	2	4.74	2.32	34.17	51.92	92.48
	3	4.67	2.35	35.26	50.61	92.31
	4	4.12	2.48	33.18	52.62	91.09
Hydraulic cottonseed meal	1-4	47.41	5.83	8.94	30.93	93.11
Solvent cottonseed meal	1-4	45.12	2.69	11.96	33.56	91.42
Expeller soybean oil meal	1-4	52.73	5.24	5.98	29.43	93.38
Solvent soybean oil meal	1-4	55.44	0.76	5.34	31.63	93.17

EXPERIMENT NO. 2

The second experiment was designed to determine the comparative values of hydraulic and solvent process cottonseed meals and expeller and solvent process soybean oil meals as supplements to a low protein steer fattening ration and the same criteria of utilization were used as in Experiment No. 1. The experimental rations used are given in table 3, and protein supplements supplied approximately 28 percent of the total nitrogen intake. The chemical composition of the feeds that comprised the rations are given in Table 4.

Table 3. Daily Allowance of Feeds Used in Digestion and Nitrogen Utilization Studies for Steers in Experiment No. 2.

Feed	Dry Matter %	Daily allowance in pounds			
		Ration E	Ration F	Ration G	Ration H
Prairie hay	92.51	4.00	4.00	4.00	4.00
Corn (cracked)	89.94	10.00	10.00	10.00	10.00
Hydraulic cottonseed meal	91.81	1.05	—	—	—
Solvent cottonseed meal	91.23	—	1.15	—	—
Expeller soybean oil meal	89.65	—	—	0.93	—
Solvent soybean oil meal	89.63	—	—	—	0.87

Table 4. Chemical Analysis of the Feed Fed to Steer in Experiment No. 2

Feed	Trial	Chemical composition of dry matter (percent)				
		Protein	Fat	Fiber	NFE	Organic Matter
Prairie hay	5	4.43	2.52	34.86	50.81	92.62
	6	4.38	2.44	32.51	53.36	92.69
	7*	4.38	2.44	32.51	53.36	92.69
	8	4.24	2.64	31.01	55.02	93.91
Corn	5	10.29	3.72	1.79	82.57	98.47
	6	11.07	4.22	11.97	81.10	98.36
	7	10.65	3.90	2.11	81.78	98.44
	8	10.60	3.18	1.88	82.59	98.25
Hydraulic cottonseed meal	5-8	45.55	5.52	8.10	34.15	92.32
Solvent cottonseed meal	5-8	43.84	2.48	11.23	35.71	93.26
Expeller soybean oil meal	5-8	50.79	4.80	5.98	31.51	93.08
Solvent soybean oil meal	5-8	55.26	0.46	5.40	31.80	92.92

* The prairie hay sample for trial number 7 was damaged and the analysis for trial number 6 was used.

EXPERIMENTAL RESULTS AND DISCUSSION

The average apparent digestion coefficients for each nutrient and the calculated total digestible nutrient value of each ration are given in table 5. The apparent digestion coefficients for crude protein (N x 6.25) were 63.6 and 61.4 for the rations which were supplemented with soybean oil meals, (C and D) while these values for rations which were supplemented with cottonseed meals (A and B) were 56.6 and 56.4. This difference in digestibility due to orgin of the protein was highly significant. In the second experiment the rations supplemented with soybean oil meals (G and H) had higher crude protein digestion coefficients than the rations supplemented with cottonseed meals (E and F) but the corresponding differences were not significant.

The average apparent digestion coefficients for crude protein, ether extract, NFE, organic matter, and total digestible nutrients had a general tendency to be higher in the second experiment (rations E, F, G, H) than in the first experiment (ration A, B, C, D) although the opposite trend was observed for crude fiber; none of these differences were significant. In the first experiment the average digestion coefficients for ether extract (fat) were 58.8 and 56.9 for rations A and C which were supplemented with cottonseed meal and soybean oil meal prepared by press extraction while the values were 52.1 and 46.5 for rations B and D which were supplemented with cottonseed meal and soybean oil meal prepared by solvent extraction processes. These differences in digestibility of fat resulting from the method of fat extraction of the meals were highly significant.

Table 6 presents data on the nitrogen utilization of mixed rations when cottonseed meals and soybean oil meals prepared by pressure and solvent methods, respectively, furnished the supplemental proteins to the rations. The average

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

Ration Number	Apparent digestibility (percent) of:					T.D.N. of. R. Ration
	Crude Protein	Ether Extract	Crude Fiber	NFE	Organic Matter	
(First Experiment)						
A--Pr. Hay, Hydr. cottonseed meal	56.6	58.8	71.2	63.3	65.1	57.5
B--Pr. Hay, Solvent cottonseed meal	56.4	52.1	71.3	61.9	63.3	58.5
C--Pr. Hay, Expeller soybeam oil meal	63.6	56.9	72.6	63.3	66.2	58.3
D--Pr. Hay, Solvent soybean oil meal	61.4	46.5	73.0	63.3	65.9	57.4
(Second Experiment)						
E--Pr. Hay, Corn, Hydr. cottonseed meal	62.7	76.1	56.5	79.7	75.0	68.7
F--Pr. Hay, Corn, Solvent cottonseed meal	60.2	72.0	57.8	78.1	73.4	67.0
G--Pr. Hay, Corn, Expeller soybean oil meal	64.4	71.6	62.6	81.2	76.8	70.0
H--Pr. Hay, Corn, Solvent soybean oil meal	65.5	71.0	65.4	81.2	77.2	70.1

Table 6. T he Average Daily Nitrogen Utilization of Experimental Ration of Steers

Ration No.	Steer No.	Dietary N Gm.	Urinary N Gm.	Fecal N Gm.	Excreted N Gm.	Retained Gm.	N %
A	1	69.2	25.0	30.0	55.0	14.2	20.5
	2	67.1	24.5	30.4	54.9	12.2	18.2
	3	70.8	24.3	31.6	55.9	14.9	21.0
	4	71.2	31.8	28.8	60.6	10.6	14.9
	A ve	69.6	26.4	30.2	56.6	13.0	18.7
B	1	70.0	26.4	27.7	54.1	15.9	22.7
	2	68.0	27.3	29.6	56.9	11.1	16.3
	3	65.9	27.7	32.0	59.7	6.2	9.4
	4	69.5	27.9	29.5	57.4	12.1	17.4
	Ave	68.3	27.3	29.7	57.0	11.3	16.5
C	1	68.8	31.7	25.1	56.8	12.0	17.4
	2	69.3	34.8	25.0	59.8	9.5	13.7
	3	67.3	27.1	25.2	52.3	15.0	22.3
	4	65.2	31.8	23.2	55.0	10.2	15.6
	Ave	67.7	31.4	24.6	56.0	11.7	17.3
D	1	63.6	29.8	23.5	53.3	10.3	16.2
	2	67.3	24.9	27.8	52.7	14.6	21.7
	3	67.7	30.3	25.7	56.0	11.7	17.3
	4	65.7	32.8	25.1	57.9	7.8	11.9
	Ave	66.1	29.5	25.5	55.0	11.1	16.8
E	1	111.4	30.8	42.1	72.9	38.5	34.6
	2	109.0	45.7	34.8	80.5	82.5	26.1
	3	110.6	37.6	41.6	79.2	31.4	28.4
	4	113.7	32.1	47.4	79.5	34.2	30.1
	Ave	111.2	36.6	41.5	78.1	33.1	29.8
F	1	117.2	27.2	49.3	76.5	40.7	34.7
	2	114.9	30.6	47.0	77.6	37.3	32.5
	3	112.6	35.3	42.6	77.9	34.7	30.8
	4	114.1	32.1	43.8	75.9	38.2	33.5
	Ave	114.7	31.3	45.7	77.0	37.7	32.9
G	1	111.5	36.6	40.4	77.0	34.5	30.9
	2	114.7	30.7	48.5	79.2	35.5	31.0
	3	112.3	40.6	37.5	78.1	34.2	30.5
	4	110.0	38.5	33.3	71.8	38.2	34.7
	Ave	112.1	36.6	39.9	76.5	35.6	31.8
H	1	110.6	42.2	28.9	71.1	39.5	35.7
	2	112.2	39.6	39.2	78.8	33.4	29.8
	3	115.3	39.8	46.4	86.2	29.1	25.2
	4	113.0	26.7	41.4	68.1	44.9	39.7
	Ave	112.8	36.6	39.9	76.5	35.6	31.8

values given were obtained in ten-day collection periods. There were some slight differences in the nitrogen intake of the steers when fed different supplements but these variations represented only a small percentage of the total nitrogen intake. There were no significant differences in the amount of nitrogen retained from the rations supplemented by the four meals studied in either experiment. The nitrogen storage values were higher in the second experiment when intake of higher protein was fed and the ration contained considerably more TDN.

The use of cottonseed meals and/or soybean oil meals as a desirable protein supplement in the rations of swine, poultry, or small laboratory animals has given questionable results in some investigations. However, the bulk of evidence seems to indicate that either, when fed separately or in combination with other supplements, is satisfactory in supplementing feeds for the maintenance, and growth and fattening of cattle. The results of these experiments further confirm these observations.

Except for some stiffness of the limbs, which was assumed to be caused from continued confinement in the metabolism stalls, no ill-effects were noted in the steers. The gains in weight of the steers during the experiment are given in table 7.

Table 7. The Gains in Weight of the Experimental Steers

Steer No.	Experiment No. 1 Dec. 13 to Feb. 27*	Experiment No. 2 May 15 to July 21*
1	Pounds	Pounds
1	78	142
2	69	144
3	62	170
4	75	159

* These were the inclusive dates of the experiments after the steers had become adjusted to the metabolism stalls and the experimental rations

There was very little difference in the amount of nitrogen retained from the four wintering rations fed in experiment No. 1 or from the four fattening rations fed in experiment no. 2. This observation indicates that although the nitrogen of soybean oil meals was digested more efficiently that the lack of storage was probably the result of feeding protein at higher levels than required by the animal for most efficient retention of nitrogen. Most investigators have found that soybean meal proteins are retained at least as efficiently as those of cottonseed meal when added to rations at levels required to supply the minimum requirements of the animal.

Since all of the steers were restricted to the same feed intake and consumed all the feed offered, no differences in the palatibility of the various rations were observed. Some investigators have reported that there are differences in the palatibility of soybean oil meal rations and cottonseed meal rations and of press process meal rations and solvent process meal rations when animals are fed free choice.

Although the ether extract of pressure treated soybean and cottonseed meals was more digestible than the ether extract from similar meals prepared by solvent methods this had little influence on the calculated total digestible nutrient values of the rations. This no doubt was due to the low total fat content of the rations fed even when the oil had been less efficiently removed from the supplement fed. The TDN values of the rations might have been more in favor of the meals with higher fat content had larger amounts of the meals been fed. In commercial feeding, large amounts of protein meals are sometimes fed when the price of meals is low as compared to that of other ration ingredients.

SUMMARY

Nitrogen balance trials were conducted on four yearling Hereford steers to compare cottonseed meals and soybean oil meals prepared by pressure and solvent processes as supplements to winter and fattening rations. These meals were used to supplement a wintering ration of prairie hay and were used to supplement a fattening ration of corn and prairie hay. Each steer received each of the four rations used in the two studies. Data on the apparent digestibility of the chemical constituents of the ration and the amount of nitrogen retained from the ration were compared.

In the study of wintering rations the meals furnished approximately 60 percent of the nitrogen intake, while in the fattening trials they furnished approximately 26 percent of the protein ingested.

The apparent digestion coefficient of the crude protein in the wintering rations supplemented by the soybean oil meals was higher than that of rations supplemented by cottonseed meals; the difference was highly significant. When the fattening rations were studied, the soybean oil meal supplemented rations had higher apparent digestion coefficients than the cottonseed meal rations; these differences were not significant. Increases in apparent digestion coefficients of protein did not result in consistent increase in nitrogen storage in these studies.

Wintering rations supplemented with a pressure treated meal had higher apparent digestion coefficients of ether extract than rations supplemented with the corresponding solvent prepared meals; these difference were highly significant. This same trend was observed when the same meals were used to supplement fattening rations but the differences were not significant. The source of the parent meal or the method of preparation did not influence apparent digestion coefficients of crude fiber, nitrogen-free extract, organic matter, or the calculated total digestible nutrients of the rations.

The steers ate all feeds with relish and made similar weight gains on the four wintering rations and on the four fattening rations. Evidence secured in these studies by apparent digestion coefficients and nitrogen balance determinations indicates that pressure processed cottonseed meal or soybean oil meal or solvent prepared meals from the same parent seeds are satisfactory protein supplements for wintering or fattening steers.

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