THE EFFECT OF CORN OIL AND/OR ALFALFA ASH ON THE DIGESTIBILITY OF A RATION CONTAINING COTTONSEED HULLS

By

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INTRODUCTION

The recent introduction of synthetic detergents has made considerable quantities of inedible animal fats available to the feed industry. Fat, in the form of lard and tallow, became an agricultural surplus about 1947, and since that time the feed industry has sought ways to incorporate these high energy compounds into livestock feeds in such a way that the animals consuming the feed could make economical and efficient use of the products. Since one pound of fat is equal to 2.25 lb of carbohydrates on a calorific basis, it is readily apparent that the 777 million lb of surplus fat is a potential source of a high-energy feed ingredient of great economic importance (Kraybill, 1954; and Ewell, 1953).

The value of fat in ruminant nutrition has not been given as much attention as protein, carbohydrates, vitamins and minerals. The reason for this lack of interest may be due to several factors: first, it has been known for some time that milk and body fat could be produced from carbohydrates and proteins in the animal; second, the response to feeding high levels of fat to certain farm animals was disappointing in some of the early investigations. In swine feeding experiments, for example, it was shown that high levels of dietary fat produced soft pork (Ellis, 1933). Another example is that dietary fat in excess of 1 lb per 1000 lb body weight caused digestive disturbances in cattle (Morrison, 1948); and third, the competing markets for animal fats were such that the relative price per pound of fat almost equalled that of the live animal. For example, from 1920 to 1947 the price of tallow reached a maximum of 90 per cent of the average cost of the live animal (Kraybill, 1954). Recently, tallow prices have been as low as 10 to 20 per cent of the average cost of the live animal. With the decline in the market for animal fats in soaps and other industrial uses in recent years, interest has been markedly increased for developing new uses for animal fats.

Klosterman and Moxon (1952) stated "when good-quality hay is available for dry-lot feeding, there is nothing comparable to it for satisfactory low cost gains in feeding steers." In large areas of the United States, especially the drought-stricken areas, high-quality roughage may not be available and it is in these areas that feeding practices, in which low-quality roughage may be fed to produce satisfactory low cost gains, must be adopted. In the United States there are available large quantities of low-quality roughages, such as corncobs, cottonseed hulls and wheat straw for feeding to ruminants. The problem of utilization of low-quality roughages is one of nutrition as well as of economics.

Recent experiments on improving the efficiency of utilization of low quality roughages have shown that the addition of alfalfa hay or meal, or the ash from these materials will improve the utilization of some of these roughages; however, in more recent experiments, results have indicated that the improvement of low-quality roughages by the addition of alfalfa ash is not due to an improvement in the roughage *per se*, but instead, to an improvement in the basal ration containing high levels of fat. A review of the literature shows that high fat in ruminant rations appears to increase the rumen microorganisms' requirement for an inorganic element(s) present in alfalfa ash. The investigation reported in this thesis was undertaken to determine the effect of alfalfa ash, corn oil, and a combination of alfalfa ash and corn oil on the digestibility of a steer ration containing cottonseed hulls.

REVIEW OF LITERATURE

Effect of High Dietary Fat in Ruminant Rations

The effect of added dietary fat upon the digestibility of other ration components was studied by Lucas and Loosli (1944). They found lowered digestibility of dry matter, NFE, and crude fiber in rations for dairy cattle in which the ether extract had been increased to 7 per cent by the addition of corn oil or soybean oil. Byers et al. (1949) found that a ration of alfalfa hay and ground soybeans, containing 5.2 per cent dietary fat, did not increase milk production in dairy cows; however, a ration of alfalfa hay and soybean meal, containing 2.7 per cent dietary fat, did. The absorption of dietary fat by the mammary glands was demonstrated by Allen (1934) who recovered 10 to 20 per cent of added dietary fat in milk of dairy cows. Some work has indicated that fats in the solid state produce better results than the oils. Gullickson et al. (1942) fed dairy calves butterfat at the 3.5 per cent level and found that they excelled in all respects those calves fed lard, tallow, corn oil, cottonseed oil, and soybean oil. The lard and tallow-fed calves excelled the oil-fed calves.

Horton et al. (1955) have reported an experiment in which 0.4 or 8.5 per cent stabilized animal fat was added to the grain mixtures and fed to lactating dairy cows. The animals consumed the rations readily, and the added fat had no measurable effect on either milk production, fat content of the milk, or the vitamin A content of the milk or blood. Matsushima and Dowe (1954) found that a vitamin A supplement of 30,000 units per day per steer was not adequate for the prevention of hypovitaminosis A symptoms in the animals when unstabilized tallow was added to the ration. In this experiment three lots of steers were used: Lot I, basal; Lot II, pellets containing 5.5 per cent beef tallow; and Lot III, pellets containing 5.5 per cent corn oil. The average daily gain for Lots 1, 2, and 3 was 2.11, 2.00 and 1.74 lb., respectively. No statistical analysis was given of their work and therefore the significance of the results is not known.

Johnson *et al*. (1956) fed calves a starter mixture containing 0, 2.5, 5, and 10 per cent inedible tallow and found that calves fed tallow consumed more calculated total digestible nutrients, which resulted in a 5 to 6 per cent greater increase in growth than those fed no tallow. The pounds of dry matter consumed per pound of gain were less for the calves receiving the tallow containing ration; however, apparent digestibility of dry matter, protein and nitrogen-free extract was decreased in the ration containing tallow, whereas the digestibility of ether extract increased.

Brooks *et al*. (1954) studied the effect of two levels of corn oil and lard with and without alfalfa ash on the digestibility of cellulose and crude protein *in vivo* and *in vitro*.

The addition of 32 and 64 gm of fat lowered the apparent digestibility of cellulose. The corn oil had a greater depressing effect on digestibility of cellulose than the lard. The addition of 1.8 gm of alfalfa ash overcame the detrimental effect of 32 gm of fat and improved the digestibility of the ration containing 64 gm of fat.

Swift et al. (1947) fed lambs rations containing 9.8, 6.4 and 2.8 per cent ether extract and found dry matter digestibility to be 72.8, 76.2 and 74.7, respectively. Swift et al. (1951) and Chappel et al. (1955) found that alfalfa ash increased the crude fiber digestibility of rations containing corncobs with corn oil as a part of the ration.

Ward (1956) studied the effects of fat and alfalfa ash on low-quality roughage utilization by lambs. He found that corn oil depressed growth when added to a semi-purified diet containing cottonseed hulls. The effect of adding alfalfa ash to the basal ration was small, but there was a significant increase in gain when alfalfa ash was included in a ration containing corn oil. However, a lamb fattening ration containing 10 per cent corn oil was not significantly improved by adding 0.85 per cent alfalfa ash. Further work of his showed that corn oil, when added to rations containing low-quality roughages, lowered the apparent digestibility of nitrogen-free extract, crude fiber and dry matter. The addition of alfalfa ash overcame this reduction and the digestibility returned to normal.

Erwin et al. (1956a) found that the addition of 7 per cent tallow to a steer fattening ration containing alfalfa hay increased daily gain, but reduced it when wheat straw was fed as the roughage. In later work Erwin et al. (1956b) measured the digestibility of a ration containing alfalfa hay as the roughage and found that the addition of tallow did not reduce the digestibility of dry matter or crude fiber.

Hale and King (1955) added corn oil, prime tallow, and hydrogenated animal fat at levels of 0, 4, 8, and 12 per cent to lamb fattening rations and found that digestibility of dry matter was reduced in the rations containing the higher levels of added fat. Work by Hentges et al. (1954) indicated that waste beef fat can replace up to 5 per cent of the concentrate in steer fattening rations. Feeding trials conducted by these workers over a period of 154 days showed that rations containing 0, 5, and 10 per cent additional fat produced daily gains of 1.8, 1.9, and 1.5 lb, respectively. Gallup et al. (1950) reported there were no differences in the digestibility of rations containing hydraulic or solvent process cottonseed meal when fed to sheep.

Jones et al. (1942), experimenting with cattle, found that silage, when supplemented with 4 lb of cottonseed meal and 0.18, 0.58, and 0.98 lb per day of cottonseed oil, produced daily gains of 1.76, 1.84, and 1.97 lb, respectively. Willey et al. (1952) found no difference in the rate of gain of steers fed a fattening ration in which the fat content had been raised from 3 to 7.5 per cent by the addition of cottonseed oil; however, it was noted that the amount of feed necessary for 100 lb gain decreased from 820 to 710 lb when cottonseed oil was included in the ration.

When choice grade fats are fed with good-quality hay, excellent feed-lot performance has been obtained. Proof of this may be found in the work of Kammlade and Butler (1954). These workers fed prime tallow at the 0, 5, 10, and 15 per cent level to lambs and found a greater feed efficiency and lowered cost of gain for lambs fed rations containing 5 and 10 per cent tallow. There were no significant differences between gain and carcass weight for the lambs fed 0, 5, and 10 per cent fat. The lambs fed 15 per cent fat had a significant lower gain and carcass weight than any of the other 3 groups.

In studying the effect of a high level of animal fat on the utilization of a lamb fattening ration, and possible benefits from the addition of alfalfa ash, sodium bicarbonate, or potassium bicarbonate to the high fat ration, Brethour (1957) found that a high level of fat (15 per cent) significantly decreased rate of gain and feed consumption. Digestion trials showed organic matter decreased in digestibility when the high level of fat was added. The addition of sodium bicarbonate or potassium bicarbonate did not improve the utilization of the high-fat ration.

Rhodes <u>et al</u>. (1956) studied the possibility of alleviating dietary fat inhibition of protein and cellulose digestion in sheep. These workers found that the digestibility of protein and cellulose of rations containing from 65 to 80 per cent cottonseed hulls was significantly decreased by replacing corn syrup with 1.8, 3.0 and 4.2 per cent corn oil. The depression of cellulose digestibility was completely reversed by the addition of distillers dried solubles. With 78 per cent cottonseed hulls in the ration, the digestion coefficients for cellulose and protein, respectively, were: basal, 56.4, 68.9; 3 per cent corn oil, 53.1, 60.3; 3 per cent corn oil plus 30 gm alfalfa ash per wether daily, 59.3, 70.3; 3 per cent corn oil plus 16.8 per cent distillers dried solubles, 52.1, 70.4; 3 per cent corn oil plus 8.4 per cent distillers dried solubles, 53.4, 65.9; 3 per cent corn oil plus 10 gm distillers dried solubles per wether daily, 56.2, 62.6.

Summers et al. (1956) studied the cellulolytic interrelationship of dietary fat, carbohydrates and minerals in sheep metabolism experiments. They found that a decrease in the corncob content of a ration from 80 to 65 per cent by corn starch replacement significantly reduced the digestion of cellulose from 74.2 to 68.4 per cent. Alfalfa ash (3 gm per wether daily) completely alleviated the effect of the supplemental corn starch but had no effect on the digestibility of the 80 per cent corncob ration. Three per cent corn oil added with alfalfa ash did not affect digestibility of either the 80 or the 65 per cent corncob ration. Further work by these investigators showed that alfalfa ash also improved nitrogen retention and that distillers dried solubles reversed the corn oil effect on cellulose but failed to enhance protein digestion.

Thus, it seems that the rumen microbial requirement for an inorganic element(s) present in alfalfa ash appears to be increased by fat and/or carbohydrate supplementation of sheep rations.

Effect of Alfalfa Ash in Ruminant Rations

The degree to which low-quality roughages are utilized by ruminants is partly dependent upon the extent of lignification in the plant tissues and the activity of the rumen microflora which break down cellulose into forms which can be utilized by the host animal (Crampton and Maynard, 1938). It has been demonstrated (Forbes et al., 1943) that the digestibility of various feedstuffs is influenced by the associative effects of different feed combinations and their effect upon the activity of the rumen microflora. Phillips (1953) showed the following trace elements to be of physiological importance in the nourishment of the rumen microflora, and are therefore essential dietary nutrients: copper, iron, cobalt, manganese, iodine and zinc. Woodman and Evans (1930) concluded that malnutrition of sheep on mineral-deficient herbage was due to the failure of the diet to supply the necessary inorganic constituents for structural purposes and for the normal balance of minerals in the blood and tissues of the animal's body. Recent experiments have shown that low-quality roughages, when properly supplemented with minerals, can be used to a good advantage in feeding ruminants (Moore, 1951).

Early work on digestibility of cottonseed hulls was conducted by Emery and Kilgore (1891), Emery *et al.* (1891) and Emery and Kilgore (1892). In a series of experiments with beef cattle, Emery and associates studied the digestibility of cottonseed hulls alone, the effect upon digestibility when cottonseed meal was added to the ration, and the value of a cottonseed hull-cottonseed meal ration for beef production. They found that the addition of cottonseed meal increased the digestibility of the cottonseed hulls. Their report was substantiated by the following results: dry matter digestibility increased from 35.9 to 44.9 per cent, crude protein from 24.6 to 44.3 per cent, and crude fiber from 27.1 to 33.9 per cent. From these data it is very apparent that cottonseed hulls when fed alone do not comprise a nutritionally adequate ration and that additional protein will correct at least a portion of the nutritional inadequacy.

Hussain *et al.* (1951) compared cottonseed hulls to wheat straw and reported digestion coefficients to be:

	Dry Matter	Protein	Ether Extract	NFE	Crude Fiber	Ash
Cottonseed hulls	49.4	8.7	68.0	57.0	44.5	3.4
Wheat straw	48.7	---	35.6	52.5	61.5	9.4

Similar comparisons of cottonseed hulls to corncobs were made by Starkey and Godbey (1937). They supplemented a steer fattening ration, using corncobs and cottonseed hulls as the roughage, with cottonseed meal and found the cottonseed hull-fed steers to gain 0.85 lb more per head per day than the corncob-fed steers. Melton *et al.* (1950) fed steers a ration of cottonseed hulls plus alfalfa hay and found that they outgained those steers fed ground cotton stalks or ground gin trash plus alfalfa hay.

Forbes and Garrigus (1949) compared the digestibility of two lamb rations, which differed only in the type of roughage used, and found that lambs fed the ration containing cottonseed hulls as the roughage digested 91.0 per cent as much dry matter, 117 per cent as much fat, 93.0 per cent as much energy, 82 per cent as much protein and 92 per cent as much nitrogen-free extract as did those lambs fed the ration containing alfalfa as the roughage.

It has been shown by Fraps et al. (1914) that alfalfa hay or meal will improve the utilization of several low-quality roughages and that the ash of these products is apparently responsible for this improvement.

Bentley et al. (1953) found that the addition of autoclaved rumen juice to an artificial rumen increased cellulose digestibility 2 to 3 times; further investigation showed the increase in cellulose digestion could be duplicated by the addition of nine B-vitamins, adenine, uracil, xanthine and alfalfa ash or molasses ash. A combination of B-vitamins and alfalfa ash appeared to be responsible for most of the increase in digestibility. Bentley et al. (1952) added alfalfa ash to a late-cut timothy hay ration and found that steers receiving the ration with added ash made significant increases in daily gain. Bentley and Moxon (1952) reported a 43 per cent increase in daily gain for steers fed corn and late-cut timothy hay supplemented with alfalfa ash or trace minerals; however, neither of the supplements appeared to improve the digestibility of the organic matter of the ration. The improvement reported here was correlated with an increased digestion of crude fiber. Bentley and Klosterman (1953) found alfalfa ash to increase daily gains of steers from 1.31 lb daily on a corn and cob meal ration to 1.89 lb daily.

Burroughs et al. (1948) found the apparent digestion coefficient of organic matter of a corncob ration to increase from 35 to about 50 per cent when alfalfa ash or a water extract of alfalfa was added to the ration and fed to steers. Similar results were obtained by Burroughs et al. (1950). The feeding of dehydrated alfalfa meal ash, ash of molasses fermentation solubles or a trace mineral mixture significantly increased the daily gain of steers on a fattening ration in which corncobs were the only roughage (Klosterman et al., 1953).

Tillman et al. (1954a) found that neither alfalfa ash nor a complex mineral mixture would improve the apparent digestibility of a prairie hay ration for sheep. Tillman and MacVicar (1955) added alfalfa ash to a semi-purified ration, containing wheat straw as the roughage, for sheep and reported a slight but non-significant increase in the digestibility of organic matter. Tillman et al. (1954b) found that the digestibility of all the ration components increased when alfalfa ash was added to a semi-purified diet containing cottonseed hulls as the roughage for sheep.

In an attempt to show specific mineral deficiencies for sheep in cottonseed hulls, Tefft (1954) compounded a synthetic alfalfa ash from inorganic elements and fed it to sheep after individual minerals had been omitted. The results showed that the deletion of manganese or magnesium had little effect while the omission of copper or iron resulted in significantly lower daily gains. Swift et al. (1948), in calorimeter studies, showed that alfalfa ash increased the digestibility of energy of corncobs by sheep and that there was a significant increase in metabolizable energy despite an increase in the amount of methane.

Apparently low-quality roughages are deficient in a factor(s) which is required for optimum functioning of the ruminal microorganisms. Alfalfa products, when fed as supplements to low-quality roughages, partly, and in some instances completely, overcome these deficiencies. It has been found that the ash of the alfalfa products is partly responsible for this compensation.

EXPERIMENTAL

Two weeks prior to the digestion trials, twelve yearling Hereford steers, averaging 600 lbs, were allowed to adjust themselves to a low-quality, high-roughage ration by consuming cottonseed hulls and cottonseed meal at a 3:1 ratio. Following this 15-day adjustment period, the animals were allotted to metabolism stalls and randomly assigned one of the four treatments. The ingredient composition of the rations is shown in Table I. Daily allowance per animal during the 15-day preliminary and the 10-day collecting period was 3964 gm of the basal plus the additives for the individual treatments. The animals were fed twice daily receiving one-half of their ration at each feeding. The basal ration was designed to resemble a wintering-type ration according to Morrison (1948) feeding standards for 600-lb steers.

The concentrate portion of the ration was mixed and stored in a cool place until used. The cottonseed hulls, which constituted 69 per cent, and the concentrate portion, which constituted 31 per cent of the basal ration, were weighed separately at the time of feeding. The alfalfa ash was prepared by burning good-quality alfalfa hay in an open tank followed by further ashing in a muffle furnace at 600°F. The ash and corn oil (Mazola) were weighed at the time of feeding and mixed with the concentrate portion of the respective rations.

The steers were placed in metabolism stalls, as described by Nelson et al. (1954). The feces were collected three times a day and placed in 5-gallon cans located behind each steer's stall. At the end of each 24 hr period the total volume of feces in each can was weighed, mixed with an electric mixer, and a 5 per cent aliquot was taken and placed in a gallon glass jar and stored under refrigeration. Thymol was added to prevent bacterial action.

Urine was collected in 3-gallon containers, weighed, and a 135 gm aliquot per kg of urine was acidified and stored in glass jars under refrigeration.

Feed samples were taken daily throughout the duration of the trials. Proximate chemical analyses (A.O.A.C., 1950) were made at the close of each collection period on composite samples of feed, urine, and feces. The chemical composition of the rations is given in Table II. The chemical composition of individual ration ingredients is given in Appendix Table I.

At the end of the first trial the steers were removed from the metabolism stalls and allowed a 10-day rest period. During this rest period the animals received 3 lb of alfalfa hay, 3 lb of cottonseed hulls and 2 lb of cottonseed meal. Trial two was a replicate of trial one.

Since the addition of corn oil to the basal ration would be expected to greatly increase the digestibility of ether extract, digestion coefficients for this ration component are not reported.

RESULTS

The general appearance of all animals was good. Treatments favored none of the animals in this respect. In the latter part of trial 2 one animal consuming the oil plus basal ration scoured quite severely. Apart from this incident no other digestive disturbances were apparent.

The animals did not readily eat the rations containing the corn oil; however, after 2 weeks they began to consume all of their ration and at no time during the collection period did any of the animals refuse their feed.

The combined average digestion coefficients for dry matter, organic matter, protein, crude fiber and nitrogen-free extract for the individual rations are given in Table III. The digestion coefficients for individual steers are given in Appendix Table II. It is readily apparent that the addition of corn oil to the rations greatly reduced ($P < 0.01$) the digestibility of dry matter crude fiber and nitrogen-free extract. These figures represent a reduction of 13.7, 31.6 and 16.3 per cent in the digestion coefficients of the respective ration components. The reduction in digestibility due to the addition of corn oil to the basal ration was consistently greater than the addition of corn oil to the basal plus ash ration. For example, the digestibility of crude fiber decreased from 45.0 to 29.3 per cent when corn oil was added to the basal ration. The reduction when corn oil was added to the basal plus ash ration was from 46.9 to 33.6 per cent. The interaction of oil and ash approached significance at $P < 0.05$.

The addition of ash to the basal and basal plus corn oil rations significantly increased the digestibility of dry matter and nitrogen-free extract ($P<0.01$) and crude fiber ($P<0.05$). The average digestion coefficients for dry matter, crude fiber and nitrogen-free extract of the basal ration were 55.3, 33.6 and 62.8, respectively, as compared to the average digestion coefficients for dry matter, crude fiber and nitrogen-free extract of the basal plus oil without ash: 49.5, 29.3 and 55.1, respectively. The addition of 100 gm of alfalfa ash seemingly overcame the detrimental effect of the corn oil to some extent.

The addition of oil or ash had no significant effect on the digestibility of protein (Appendix Table IV). All animals remained in positive nitrogen balance (Table III and Appendix Table III) throughout the trial. The addition of corn oil did not significantly affect nitrogen retention; however, the addition of corn oil to the basal plus ash ration increased nitrogen retention 3.71 gm as a result of decreased urinary nitrogen. The addition of corn oil to the basal ration reduced nitrogen retention 1.46 gm. In both comparisons there was an increase in fecal nitrogen excretion. This increase may have been due to an increased dry matter intake and a reduced crude fiber digestion. If we allow a fecal nitrogen excretion of 5.3 gm per kg of dry matter intake (Swanson and Herman, 1943) we can partly account for the increased fecal nitrogen excretion. This work agrees in part with that of Robinson et al. (1956).

DISCUSSION

There have been several possible explanations as to how high dietary fat decreases digestibility. One hypothesis is that high dietary fat may lower the intraruminal pH. Brethour (1957) failed to confirm this. He found that fat had an insignificant effect on intraruminal pH, while the addition of alfalfa ash increased intraruminal pH. He further stated that the addition of fat caused the ingesta to become very foamy shortly after feeding. Brooks *et al*. (1954) reported a similar foaming action. Also associated with this foaming was a putrid odor and an increase in turbidity. *Aerobacter aerogenes* was isolated from the rumen contents. The total number of bacteria present was not reduced, but there was a decrease in the number of small rods and an increase in small cocci.

Another postulation is that the dietary fat may coat the ration with a film and thereby prevent, in part, the microorganisms from completely breaking down the feed. Brethour (1957) also tested this hypotheses and found that there was no advantage in mixing the fat with either the concentrate or the roughage part of the ration.

A third possible explanation is that high dietary fat ties up, physically or chemically, some of the minerals, especially the microminerals, and makes them unavailable to the rumen microflora. This supposition is based on several facts. One, the depressing effect of high dietary fat takes place in the rumen, at least partly so; this is shown by the fact that the depressing effect of high dietary fat takes place *in vitro* as well as *in vivo* which relieves the associated effect of other organs on digestion. Second, the addition of alfalfa ash or a synthetic alfalfa ash offsets the depressing effect of fat. Third, the addition of alfalfa ash to a ration containing no added fat does not consistently increase digestibility significantly. There is still much work to be done on this problem of high fat feeding before it becomes an efficient and economical practice.

While most of the work reported in the literature has been with sheep in studying the high dietary fat problem, this writer has used steers. Nevertheless, the results obtained with both species, while not agreeing in numerical value, do agree in principle. Large increases in the amount of ether extract in a ration containing low-quality roughages reduces the digestibility of some of the ration components. The addition of alfalfa ash partly overcomes this depressing effect.

SUMMARY

In a digestion and nitrogen balance trial, using a 2 X 2 factorial design, twelve yearling Hereford steers were fed a semi-purified basal ration containing cottonseed hulls. The effect of the addition of corn oil, alfalfa ash and a combination of corn oil and alfalfa ash on the digestibility of ration components and nitrogen retention was studied.

The addition of 10 per cent corn oil to the rations caused a significant ($P < 0.01$) reduction in digestibility of dry matter, crude fiber and nitrogen-free extract. The digestibility of these ration components was reduced 13.7, 31.6 and 16.3 per cent, respectively. The reduction in digestibility due to the addition of corn oil to the basal ration was consistently greater than the addition of corn oil to the basal plus ash ration. The addition of oil had no significant effect on nitrogen retention or protein digestibility.

The addition of 2.5 per cent alfalfa ash to the rations resulted in an increase in digestibility of certain ration components. These differences were significant for dry matter and nitrogen-free extract at $P < 0.01$, and for crude fiber, $P < 0.05$. The addition of ash did not significantly affect protein digestibility. The differences in nitrogen retention due to the addition of ash approached significance.

TABLE I

PERCENTAGE COMPOSITION OF RATIONS

Ingredients	Rations 1	2	3	4
	%	%	%	%
Cottonseed hulls	69.0	69.0	69.0	69.0
Drackett protein[a]	5.7	5.7	5.7	5.7
Urea[b]	1.1	1.1	1.1	1.1
Cerelose	17.3	17.3	17.3	17.3
Cottonseed meal	4.6	4.6	4.6	4.6
Dicalcium phosphate[c]	1.3	1.3	1.3	1.3
Na_2SO_4	.5	.5	.5	.5
Salt	.4	.4	.4	.4
A & D supplement[d]	.05	.05	.05	.05
Corn oil	---	10.00	---	10.00
Alfalfa ash	---	---	2.5	2.5

[a]Drackett C-1 Protein.
[b]Urea 2-6-2.
[c]Feed grade.
[d]Quadrex - supplying 10,000 I. U. of Vitamin A and 3,000 I. U. of D_2 per gram.

TABLE II

CHEMICAL COMPOSITION OF RATIONS (per cent)

Rations	Dry Matter	Organic Matter	Protein	Ether Extract	Crude Fiber	NFE
			Trial I			
Basal	91.4	87.4	12.4	0.5	26.1	48.2
Basal plus Corn Oil	92.1	88.5	11.3	9.6	23.7	43.8
Basal plus Alfalfa Ash	91.6	85.0	12.1	0.5	25.4	47.1
Basal plus Corn Oil plus Alfalfa Ash	92.3	86.5	11.1	9.6	23.2	42.8
			Trial 2*			
Basal	91.5	86.8	12.2	0.6	33.1	40.9
Basal plus Corn Oil	92.2	88.1	11.1	9.6	30.0	37.2
Basal plus Alfalfa Ash	91.7	84.7	12.0	0.6	32.2	39.9
Basal plus Corn Oil plus Alfalfa Ash	92.4	86.1	11.0	9.5	29.3	36.4

*In this trial the fiber was higher due to an increased amount of lint on the cottonseed hulls as compared to the hulls in the first trial.

TABLE III

AVERAGE DIGESTION COEFFICIENT AND NITROGEN BALANCE DATA

Items	Basal	Basal + Oil	Basal + Ash	Basal + Oil + Ash
Dry Matter Intake (gm)	3623.6	4023.6	3723.6	4123.6
Digestibility (%)				
Dry Matter	59.7	49.5	61.7	55.3[1]
Organic Matter	60.2	49.7	60.8	55.5[1]
Protein	57.5	55.0	56.5	55.7
Crude Fiber	45.0	29.3	46.9	33.6[2]
NFE	70.7	55.1	71.2	62.8[1]
Nitrogen Balance (gm)				
Nitrogen Intake	78.39	78.39	78.39	78.39
Nitrogen in Feces	34.08	36.18	34.51	35.54
Nitrogen in Urine	33.02	32.38	33.67	28.93
Nitrogen Retention	11.29	9.83	10.21	13.92[3]

1. See sample analysis of variance, Table IV. Differences between corn oil and no oil and ash and no ash were significant ($P < 0.01$) for dry matter, organic matter and NFE.
2. The differences due to added oil and ash were significant at the 1 and 5 per cent level, respectively.
3. Although treatment differences (Appendix Table IV) were significant ($P < 0.05$) the addition of corn oil or ash did not significantly change nitrogen retention. The addition of ash approached significance ($P < 0.05$) and the oil times ash interaction was significant ($P < 0.05$).

TABLE IV

ANALYSIS OF VARIANCE FOR DIGESTIBILITY OF DRY MATTER

Source	df	SS	MS	F
Total	23	684.30	---	---
Trial	1	38.00	38.00	6.93*
Treatment	3	531.25	177.07	---
Oil vs No Oil	1	418.33	418.33	76.3**
Ash vs No Ash	1	91.26	91.26	16.6**
Oil X Ash	1	21.66	21.66	3.95
Trt. X Trial	3	30.33	10.11	1.84
Error	16	87.7	5.48	---

**$P < 0.01$
* $P < 0.05$

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APPENDIX

APPENDIX

TABLE I

CHEMICAL COMPOSITION OF FEEDS

(per cent)

Feeds	Dry Matter	Protein	Ether Extract	Crude Fiber	NFE	Ash
			Trial 1			
Cottonseed hulls	90.04	3.75	0.39	41.34	51.62	3.10
Concentrate mix	94.26	34.35	1.08	1.77	55.39	7.93
Corn oil	100.00	---	100.00	---	---	---
Alfalfa ash	100.00	---	---	---	---	100.00
			Trial 2			
Cottonseed hulls	90.35	3.88	0.44	52.30*	40.29	3.09
Concentrate mix	93.93	33.56	1.05	1.99	54.19	8.25
Corn oil	100.00	---	100.00	---	---	---
Alfalfa ash	100.00	---	---	---	---	100.00

*This high figure is apparently due to the large amount of lint left on the hulls.

TABLE II

DIGESTION COEFFICIENTS FOR STEERS

Steer No.	Ration[1]	Trial	Digestion Coefficients (per cent) Dry Matter	Organic Matter	Crude Protein	Crude Fiber	Nitrogen Free Extract
9	1	1	57.0	57.5	55.4	37.8	68.7
10	1	1	54.8	55.3	53.8	30.7	69.0
5	1	1	60.7	61.3	56.8	42.0	72.9
1	1	2	64.0	64.7	58.4	54.4	74.8
6	1	2	60.6	61.0	60.7	52.2	68.6
5	1	2	61.2	61.6	60.8	52.9	70.3
Ave.			59.7	60.2	57.6	45.0	70.7
12	2	1	45.0	45.1	55.2	16.7	51.5
2	2	1	46.0	46.4	57.7	24.1	49.5
8	2	1	49.3	49.4	54.3	19.2	58.2
7	2	2	48.1	49.1	50.1	41.6	58.9
11	2	2	52.2	52.2	56.9	37.6	59.3
4	2	2	55.7	56.1	55.7	36.5	67.6
Ave.			49.5	49.7	55.0	29.3	55.1
6	3	1	61.9	62.2	56.5	44.6	73.3
4	3	1	62.2	62.5	57.2	42.6	74.8
1	3	1	60.9	61.5	55.0	41.9	73.0
8	3	2	57.2	57.9	54.6	48.7	66.3
9	3	2	60.1	60.5	55.1	55.1	66.8
3	3	2	60.3	60.7	56.2	48.8	72.0
Ave.			61.7	60.8	55.7	46.9	71.2
11	4	1	56.0	56.0	55.9	25.6	64.8
7	4	1	54.2	54.4	54.5	26.0	65.9
3	4	1	54.9	54.7	55.5	24.5	63.3
12	4	2	56.9	57.2	54.6	42.7	64.4
10	4	2	53.9	54.2	54.9	38.4	62.3
2	4	2	55.7	56.3	52.5	44.3	63.4
Ave.			55.3	55.5	55.7	33.6	62.8

[1]Ration 1 = Basal
Ration 2 = Basal + Corn Oil
Ration 3 = Basal + Alfalfa Ash
Ration 4 = Basal + Corn Oil + Alfalfa Ash

TABLE III

DAILY NITROGEN BALANCE DATA (gm)

Ration	Trial No.	Steer No.	INTAKE Dry Matter	INTAKE Nitrogen	EXCRETION Fecal N.	EXCRETION Urinary N.	NITROGEN Gm Retained
1.	1	9	3621.5	78.96	35.22	30.20	13.54
	1	10	3621.5	78.96	36.46	34.80	7.70
	1	5	3621.5	78.96	34.13	33.32	11.51
	2	1	3625.8	77.82	32.32	38.49	7.01
	2	6	3625.8	77.82	31.96	33.80	12.06
	2	5	3625.8	77.82	34.40	32.40	11.02
2.	1	12	4021.5	78.96	35.38	35.80	7.78
	1	2	4021.5	78.96	33.38	38.55	7.03
	1	8	4021.5	78.96	36.34	27.72	14.90
	2	7	4025.8	77.82	40.72	34.98	2.12
	2	11	4025.8	77.82	35.16	32.50	10.16
	2	4	4025.8	77.82	36.16	33.20	8.46
3.	1	6	3721.5	78.96	34.32	30.80	13.84
	1	4	3721.5	78.96	33.78	31.80	13.38
	1	1	3721.5	78.96	35.54	36.07	7.35
	2	8	3725.8	77.82	35.98	32.13	9.71
	2	9	3725.8	77.82	35.69	33.60	8.53
	2	3	3725.8	77.82	34.80	37.62	5.40
4.	1	11	4121.5	78.96	34.85	26.66	17.44
	1	7	4121.5	78.96	35.90	27.93	15.13
	1	3	4121.5	78.96	35.15	28.58	15.23
	2	12	4125.8	77.82	35.32	28.48	14.02
	2	10	4125.8	77.82	35.13	30.90	11.79
	2	2	4125.8	77.82	36.91	31.04	9.87

TABLE IV

ANALYSIS OF VARIANCE TABLE FOR THE DIGESTION AND NITROGEN BALANCE STUDY OF THE STEERS FOR TRIAL 1 AND 2 COMBINED

Source	DF	SS	MS	F
Dry Matter				
Total	23	684.30	---	---
Trial	1	38.00	38.00	6.93*
Treat.	3	531.26	177.08	32.31**
Trt. x Tr.	3	30.33	10.11	1.84
Error	16	87.71	5.48	
Organic Matter				
Total	23	637.45	---	---
Trial	1	26.46	26.46	5.87*
Treat.	3	481.27	160.42	35.57**
Trt. x Tr.	3	57.48	19.16	4.25*
Error	16	72.24	4.51	
Crude Protein				
Total	23	104.01	---	---
Trial	1	7.48	7.48	2.48
Treat.	3	23.68	7.89	2.61
Trt. x Tr.	3	24.45	8.15	2.70
Error	16	48.40	3.02	
NFE				
Total	23	1,065.38	---	---
Trial	1	3.37	3.37	---
Treat.	3	750.82	250.27	27.20**
Trt. x Tr.	3	164.79	54.93	5.98**
Error	16	146.90	9.18	
Crude Fiber				
Total	23	2,911.17	---	---
Trial	1	1,312.7	1,312.7	130.22**
Treat.	3	1,335.64	445.2	44.21**
Trt. x Tr.	3	101.67	33.89	3.36
Error	16	161.28	10.08	
Nitrogen Retention				
Total	23	285.83	---	---
Trial	1	10.29	10.29	1.037
Treat.	3	119.61	37.87	3.817*
Tr. x Trt.	3	6.09	2.03	0.204
Error	16	149.84	9.92	

**At the 1 per cent level of significance
* At the 5 per cent level of significance

VITA

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