COMPOSITION AND DIGESTIBILITY OF UNTREATED AND SODIUM HYDROXIDE TREATED FECAL WASTE FROM CATTLE FED HIGH OR LOW ROUGHAGE RATIONS

by

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INTRODUCTION

Very large quantities of livestock wastes are produced annually in the United States. It has been estimated that cattle in the United States produce over 1.0 billion tons of manure annually. Furthermore, since a large portion of the waste is from concentrated operations, the waste poses a potential pollution problem for municipalities, lakes and streams. However, since this waste is collectable, it represents a potentially valuable source of nutrients for plants and animals.

Until recently, most of these animal manures have been spread on the soil. The plant nutrient value of the waste may not be sufficient to cover the cost of hauling and spreading, at least under certain economic situations. Also, it is frequently not feasible for large concentrated production units to use the waste as fertilizer.

Recent research has indicated that some of the nutrients contained in animal manures can be utilized by livestock, particularly ruminants, when incorporated into their diets. This appears to be an attractive means of alleviating the animal waste problem. Based on the nutrient composition of typical feedlot manure, the value of it for refeeding appears to be considerably greater than for fertilizer.

Limited data exist concerning the extent to which the nutrients in cattle waste are utilized when refed to ruminants. Since cattle wastes account for approximately 85% of the total livestock wastes produced, it appears that more information is needed on the nutritive value of this potential feedstuff.

Previous research at this University has indicated that the protein and energy in dried fecal waste from steers fed a 50% roughage ration are poorly utilized when fed to steers. Further research is needed to determine the extent to which nutrients in animal wastes are utilized when refed. Research is also needed on potential methods of improving utilization of nutrients in animal wastes, since low quality feedstuffs will probably become an increasingly important part of diets for ruminants.

The present study was conducted to investigate the effect of roughage level in the diet and treatment of the wastes with sodium hydroxide on utilization of nutrients in cattle fecal wastes.

REVIEW OF LITERATURE

Nutritive Value of Cattle Wastes

Composition of Cattle Wastes

According to Church (1969) fecal material excreted by animals is composed of: (1) undigested residues of food material; (2) bile and residues of gastric, pancreatic and enteric juices; (3) cellular debris from the mucosa of the gut; (4) products excreted into the gut; and (5) cellular debris and metabolites of micro-organisms that grow in the large intestine and some coming from the forestomach in ruminants. Since numerous factors can affect the composition of fecal wastes, it is difficult to characterize the chemical composition of cattle wastes.

The effect of ration on composition of feces produced is illustrated by data from a study by Dowe *et al*. (1955) in which they chemically analyzed feces from steers fed rations with corn to alfalfa hay ratios of 1:1, 2:1, 3:1, 4:1 and 5:1. Average dry matter content of the feces ranged from 23.3 to 26.9% for steers fed the rations comprised of 1:1 and 5:1 corn to alfalfa hay, respectively. The average fecal composition, expressed as a percentage of the dry matter, was 14.6, 14.4, 15.3, 16.5 and 16.7% crude protein; 3.8, 3.4, 3.9, 4.6 and 3.4% ether extract; 36.9, 31.8, 25.5, 22.3 and 21.2% crude fiber; 6.0, 6.4, 5.5, 5.0 and 5.2% ash and 36.1, 44.1, 50.6; 51.2 and 54.7% NFE for rations composed of a 1:1, 2:1, 3:1, 4:1 or 5:1 ratio of corn to alfalfa hay, respectively.

These data indicate that the percentage of dry matter, crude protein and NFE in the feces increased as the concentrate in the ration increased, while the percentage of crude fiber in the feces increased as roughage in the ration increased. In general, any factor which affects digestibility of any ration component will affect the composition of the feces produced.

Uncontaminated fecal waste was collected from steers fed a 50% roughage ration by Lucas _et al_. (1975). The fecal waste, dried at 120 C, contained 13.2% crude protein, 31.4% crude fiber, 5.4% ash, 38.8% NFE, 70.9% cell walls, 9.4% lignin and 13.5% TDN, dry basis.

Smith _et al_. (1971) reported that dried manure from dairy cattle fed equal proportions of dry matter from alfalfa hay, corn silage and concentrates contained 12.5% crude protein and 63% cell walls, dry basis. They reported that uncontaminated dairy cattle manure contained 71% cell walls, 37% cellulose, 21% hemicellulose and 11% lignin, dry basis. The diet fed to cattle producing this manure was not stated.

Fisher (1974) summarized results of 400 digestion trials with lactating cows in considering the effects of dry matter digestibility and proportion of grain in hay-concentrate and silage-concentrate rations on characteristics and quantity of feces excreted. Of course, fecal dry matter excretion per unit of intake decreased as dry matter digestibility increased. Nitrogen content of the feces tended to increase as dry matter digestibility and the proportion of grain in the ration increased.

The average composition of dried cattle manure used by Lipstein and Bornstein (1973) was 13.1% crude protein, 2.0% crude fat, 24.2% crude fiber, 31.3% ash and 29.5% NFE, dry basis. The authors indicated that the very high ash content of the dried cattle manure was not necessarily due to contamination with large amounts of soil as most of the manure was collected from pens with concrete floors. They reported that the average gross energy content of the dried cattle manure was 3.27 kcal per gram of dry matter.

Johnson (1972) reported composition data for three samples of typical Oklahoma cattle feedlot waste. The samples were taken from a manure stockpile, a lot in which cattle were fed a growing ration and a lot in which cattle were fed a finishing ration. On a dry matter basis, samples contained 14.8, 15.0 and 19.2% crude protein; 2.9% ether extract (value for only one sample); 24.4, 22.1 and 17.3% acid-detergent fiber and 43.5, 36.4 and 35.2% ash, respectively. The low solubility and digestibility of the ash component determined in subsequent tests indicated that the high ash content was probably due to soil contamination. Mathers et al. (1973) reported that the average nitrogen content of manure from 23 Texas feedlots was 2.05% (12.8% crude protein), dry basis. They concluded that the composition of cattle wastes varies with the ration fed as well as the manner in which the waste is handled.

Braman (1975) conducted proximate and Van Soest analyses on feedlot waste collected from cattle fed either high or low roughage rations in concrete floored pens. Dry matter, crude protein, ether extract and NFE content tended to be higher in feedlot waste from cattle fed low-roughage rations than in waste from cattle fed high-roughage rations. Ash, crude fiber, neutral-detergent fiber and acid-detergent fiber content tended to be higher in waste from cattle fed high-roughage rations.

Anthony (1971b) reported that wastelage, an ensiled mixture of 57 parts wet manure and 43 parts hay, contained 52.9% dry matter and 10.6% crude protein, dry basis. According to Gonzalez (1973), manurage, consisting of 60% wilted barley forage and 40% fresh dairy manure, 80% corn forage and 20% fresh manure or 60% corn forage and 40% fresh manure contained 27.30, 33.95 and 29.25% dry matter and 9.84, 7.76 and 8.87% crude protein, dry basis, respectively.

Methods of Processing Cattle Wastes

Several processing methods have been employed in the preparation of cattle waste for refeeding. An obvious and simple processing method is drying, which has been used by a number of workers (Thomas *et al.*, 1970; Smith and Gordon, 1971; McClure *et al.*, 1971; Bucholtz *et al.*, 1971; Tinnimit *et al.*, 1972; and Lipstein and Bornstein, 1973).

Washed (Anthony and Nix, 1962), untreated and autoclaved wet cattle manure (Anthony, 1970) were mixed with concentrates and fed in early work at Auburn. However, data from feeding trials indicated that neither washing nor autoclaving manure improved its feeding value (Anthony, 1970).

A mixture of 57 parts wet manure and 43 parts hay has been ensiled, with the product named "wastelage" (Anthony, 1967, 1968; Bandel and Anthony, 1969). On a dry basis, wastelage is composed of about 20% manure and 80% hay. A major reason for investigating this process was to circumvent daily collection and mixing of manure with concentrates (Anthony, 1971a). Harpster *et al.* (1975) investigated a similar ensiled product composed of 60% fresh manure plus 40% chopped grass hay.

A product called "manurage" has been investigated by Gonzalez (1973). It consists of an ensiled mixture of fresh cattle manure and forage. In this study 20 or 40% wet manure was mixed with barley or corn forage. According to Gonzalez addition of up to 40% cattle manure to barley or corn forage did not significantly alter the ensiling process, as evaluated by silage temperature and pH.

Newton *et al*. (1975) ensiled a mixture composed of 47.4% ground shelled corn, 12% bermudagrass pellets, .6% urea and 40% cattle manure, wet basis. Wet manure contributed 13% of the ensiled dry matter.

Auburn workers investigated the use of manure solubles as a medium for yeast production (Singh and Anthony, 1968) and fermentation of cattle manure alone (Moore and Anthony, 1970). Both of these processes represent attempts to obtain a more concentrated nutrient supply than the original cattle waste. A similar process originated by Anthony and developed by the Cerola Corporation of Sterling, Colorado, involves washing the manure with subsequent fermentation of the solid fraction (Ward and Beede, 1973). This process was used in a pilot study to produce a product, "Cerola", from feedlot waste (Ward and Beede, 1973; Ward *et al*., 1973). Another fermented product from feedlot manure, "Cereco" silage, has been studied by Ward *et al*. (1974).

Johnson *et al*. (1974) used a vibrating-screen separator with different screen sizes (8, 20, 40 and 60-mesh per 2.54 cm) to separate solids from dairy cow manure which had been diluted 1 to 15 with water.

Smith *et al*. (1969) investigated the influence of chemical treatment on feces from cattle fed alfalfa or orchardgrass hay. They found that digestibility of fecal cell walls was greatly improved by treatment with strong alkali (sodium hydroxide or sodium peroxide). Some other chemical treatments effectively increased digestibility if treated and stored for 3 weeks prior to dehydration. Included in this report were data indicating that when sodium hydroxide was added to wet feces at graded levels (increments of one percentage unit) from 0-7% (w/w), wet basis, essentially no further increase in digestibility resulted with levels above 3% (w/w), wet basis.

Smith et al. (1970) treated dairy cattle feces with sodium hydroxide, sodium peroxide and sodium chlorite in an effort to disrupt undigested cell wall residues. They concluded that enhanced in vitro digestibility of dairy cattle feces following chemical treatment was the result of direct chemical degradation of hemicellulose, cellulose and lignin, as well as increased accessibility of the remaining wall for ruminal microbial fermentation.

Use of Cattle Wastes in Non-ruminant Rations

Cattle feces are a good source of B-vitamins (Hammond, 1942). Dried cattle manure, when supplemented with riboflavin and vitamin A, was shown by Hammond (1944) to be a highly satisfactory substitute for alfalfa leaf meal in poultry rations. The dried cattle manure was reported to be similar in composition and vitamin content to alfalfa leaf meal.

Bohstedt et al. (1943) reported that cattle manure replaced the need for dried brewers yeast or alfalfa meal in pig diets. They suggested that the nutritive value of cattle manure for pigs was not entirely the result of undigested grain.

Lipstein and Bornstein (1973) substituted dried cattle manure at levels of 0, 10, 20 or 30% for sorghum grain and inert pulverized rock in broiler and layer rations. Retention of nitrogen from the dried cattle manure, determined by regression, was zero. The dried cattle manure contributed no metabolizable energy when fed to broilers 28 to 55 days of age, but for layers the dried cattle manure supplied approximately .50 kcal of metabolizable energy per gram. There was no evidence of toxicity due to inclusion of dried cattle manure in the diet, even for very young chicks. The authors concluded that the lack of nutritional contributions from dried cattle manure makes it an unsuitable ingredient for poultry diets, unless the purpose is to lower the nutrient density.

Digestibility of Cattle Wastes by Ruminants

According to Church (1969), digestion accounts for the single largest loss in nutrient utilization by ruminant species. Numerous factors influence digestibility to some extent in ruminants. Some of these, given by Church, are (1) plane of nutrition, (2) amount of fiber and/or lignin in the feed, (3) species and possibly even breed differences, (4) nutrient deficiencies, (5) factors affecting appetite, (6) frequency of feeding, (7) feed preparation, (8) the associative effect of feedstuffs and (9) adaptation to ration changes.

In spite of the current interest in refeeding of cattle waste there appears to be a paucity of reliable information on the digestibility of this material. Anthony (1970) used a 20% roughage basal ration, containing 73.0% ground snapped corn, in two experiments to evaluate the digestibility of washed, autoclaved and untreated wet cattle manure. The manure used for each treatment was collected daily from animals fed that particular ration, making this a continuous recycling program. The respective manure was mixed with the basal ration in a 40:60 ratio of manure to basal ration. In the first experiment, two conventional digestion trials with two yearling beef steers per treatment were conducted to determine digestion coefficients for the following rations: (1) basal; (2) 40% washed manure and 60% basal; (3) 40% autoclaved manure and 60% basal and (4) a diet of corn silage, ground ear corn and a supplement containing urea, cottonseed meal, minerals and vitamin A. Apparent digestion coefficients of 62.89, 67.36, 61.02 and 68.20% for dry matter and 49.84, 56.16, 50.80 and 35.31% for crude protein were reported for rations 1, 2, 3 and 4, respectively. In the second experiment digestion coefficients for the basal ration alone and basal plus 40% wet untreated manure or autoclaved manure were determined by the nylon bag technique, using four rumen fistulated steers. Dry matter digestion coefficients of 40.36, 46.61 and 45.56% were reported for the basal ration alone, basal plus untreated manure and basal plus autoclaved manure, respectively. With this technique, dry matter digestion coefficients for both of the manure containing rations were significnatly greater than for the basal ration. Data from the two previous experiments indicate that cattle manure is very highly digestible when fed to yearling steers. In fact, the cattle manure appeared to be much more digestible than the 80% concentrate basal ration fed in these experiments.

Digestibility of dehydrated uncontaminated dairy cattle feces was reported by Thomas et al. (1970). Dehydrated feces were fed to sheep in a corn-corn cob ration containing 39% dehydrated feces and 11% crude protein. The feces were substituted for soybean meal, corn starch and corn cobs in the control ration so approximately 40% of the ration crude protein was supplied by dehydrated cattle feces or soybean meal. Dry matter digestibility of the test ration was 58%. Dry matter digestibility of the dehydrated cattle feces, calculated by difference, was 29%. In the same study a dry matter digestion coefficient of 39% was determined for dehydrated cage layer feces. Nitrogen balance and apparent digestibility of nitrogen were also lower for sheep receiving cattle feces than for those receiving cage layer feces. In a subsequent report which included data from the study of Thomas et al. (1970), Bucholtz et al. (1971) indicated that less of the absorbed nitrogen from cattle feces was retained than from other nitrogen sources tested.

Smith et al. (1971) used sheep to assess digestibility of dehydrated uncontaminated manure collected from dairy cattle consuming a ration comprised of equal dry matter from alfalfa hay, corn silage and concentrates. The four diets used were: (1) unground manure; (2) unground manure and soybean meal, 9:1; (3) ground manure; and (4) ground manure and soybean meal, 9:1. Apparent digestibilities of dry matter and nitrogen were: 26.9 and 31.2; 25.9 and 47.6; 22.0 and 32.2; and 27.2 and 52.4% for diets 1, 2, 3 and 4, respectively. Apparent digestibilities of dry matter and nitrogen were significantly higher for unground manure, alone or supplemented with soybean meal, than for comparable ground manure.

McClure *et al*. (1971) collected and dried feces from beef steers fed a supplemented finishing ration containing either whole shelled corn (WSC) or crimped corn (CC), alone and with 9.1 kg of corn silage per head per day. These feces were incorporated into the following rations for a digestion trial with sheep: (1) control (no feces), (2) 45% WSC cattle feces, (3) 45% CC cattle feces, (4) 45% WSC plus silage cattle feces, (5) 45% CC plus silage cattle feces and (6) 94% WSC-CC composited cattle feces. All rations contained 1.0% trace mineralized salt and 5.0% molasses. Rations 1 through 5 contained 20% alfalfa meal with the balance of these rations from ground shelled corn. Apparent dry matter digestibilities were 80.2, 59.8, 60.9, 53.1, 52.4 and 40.3% for rations 1 through 6, respectively. Digestion coefficients for ration crude protein showed a similar trend as those for dry matter, but were slightly lower.

Tinnimit *et al*. (1972) supplied 39.0 and 44.0% of the ration dry matter and 40.0 and 46.0% of the ration crude protein with dehydrated dairy cattle feces collected from cows on a corn silage-concentrate ration. Apparent digestibility of dry matter and nitrogen by sheep was significantly lower for rations containing dried dairy cattle feces than for control rations containing soybean meal as the protein supplement. They also used dehydrated feces from fattening beef steers fed corn silage only. The feces supplied 31.5% of the dry matter and 65.0% of the crude protein. Apparent digestibility of dry matter, organic matter, ash, nitrogen and lignin, as well as nitrogen retention, percent of absorbed nitrogen retained and TDN were significantly lower for the feces containing ration than for control rations.

Johnson (1972) collected and dried feedlot waste from three sources: (1) stockpile, (2) directly from a growing lot and (3) directly from a finishing lot. The dried feedlot wastes were substituted for cottonseed hulls in a high-roughage sheep diet at levels of 25 and 40% of the ration on an air dry basis. Theoretical digestibilities for the feedlot wastes were calculated by regression analysis. Calculated digestibilities of feedlot waste from sources 1, 2 and 3, respectively, were: dry matter, 40, 35 and 50%; organic matter, 49, 42 and 56%; and crude protein, 67, 60 and 71%. According to Johnson (1972), these feedlot wastes contained 35 to 44% highly insoluble, indigestible ash, presumably of soil origin.

Gonzalez (1973) fed manurage, an ensiled mixture of wet manure and forage, to dairy heifers as the sole feed to obtain digestibility values. Apparent digestibilities of dry matter, crude protein and crude fiber for control barley and corn silages, were not significantly different from values for comparable silages containing 40% dairy cattle manure. Digestibility of these components in 20% manure-corn silage was significantly lower than in control corn silage. The author suggested that the lower digestibility of the 20% manure-corn silage was due largely to the values from one animal (four per treatment) which exhibited severe diarrhea and negative digestibility values.

Dry matter intake of an ensiled mixture of 60% wet cattle manure plus 40% chopped grass hay (essentially the same as wastelage) was greater than that for corn silage when each was fed alone to sheep

(Harpster et al., 1975). In the same study, a dry matter digestibility value of 47.2% was determined for the ensiled manure containing mixture when fed alone to sheep.

Newton et al. (1975) conducted a digestion trial with steers fed three diets: (1) basal (79% ground shelled corn, 20% bermudagrass pellets and 1% urea); (2) ensiled mixture composed of 60% basal and 40% cattle manure (wet basis) and (3) mixture of basal and dried cattle manure. Manure supplied 13% of the dry matter in diets 2 and 3. Apparent digestibilities of 76.1, 73.7 and 72.1% for dry matter; 70.8, 67.2 and 59.2% for crude protein; 42.5, 41.2 and 40.7% for crude fiber; and 82.1, 81.7 and 80.3% for nitrogen-free extract were reported for diets 1, 2 and 3, respectively. The authors did not report digestibilities for manure alone. Using their dry matter digestibility values for the three diets, dry matter digestibilities of 57.6 and 45.3% were calculated, by difference, for cattle manure in the ensiled diet and dried cattle manure, respectively.

Ward and Beede (1973) reported digestibility values for a fractionated, fermented material called "Cerola." The Cerola was produced from feedlot manure obtained from steers fed a ration containing approximately 80% whole shelled corn. When Cerola was fed alone to six crossbred lambs in a 6-day collection trial, the following apparent digestion coefficients were obtained: dry matter, 75.7; crude protein, 63.9; crude fiber, 49.7; ether extract, 85.3; nitrogen-free extract, 89.0; and ash, 45.3%. TDN content was 77%, dry basis.

A fermented feedstuff (Cereco silage) produced from manure from cattle fed a 70% dry rolled corn diet was fed to 300 kg steers in a digestibility trial reported by Ward *et al*. (1974). Steers were full-fed either Cereco silage or corn silage plus a protein and vitamin supplement. Digestibility values determined for Cereco silage were similar to those for corn silage. TDN content of Cereco and corn silage was 57.1 and 62.2%, respectively. Dry matter intake was lower for Cereco silage than corn silage, 12 *vs*. 16 kg per day, respectively, when each was fed alone.

Johnson *et al*. (1974) reported that solids removed from a slurry of dairy cattle manure by vibrating-screen separation, had *in vitro* dry matter digestibilities of 30, 26, 25 and 21% for screen sizes of 8, 20, 40 and 60-mesh per 2.54 cm, respectively.

In an *in vitro* study, Smith *et al*. (1970) reported enhanced digestibility of cattle feces from cattle fed Sudax silage following chemical treatment. They reported *in vitro* dry matter digestion coefficients of approximately 90% for feces treated with sodium hydroxide, calcium hydroxide or sodium peroxide, compared to a coefficient of only 18% for untreated feces. They attributed this large difference to direct chemical degradation, as well as an increased accessibility of the remaining cell wall for microbial digestion. In a subsequent experiment, Smith *et al*. (1971) used diets comprised of 83% dairy cattle barn waste (included some sawdust bedding), 10% corn meal and 7% soybean meal to study the effect of chemical treatment of waste on subsequent digestibility by sheep. Dry matter digestibilities were 23.0, 27.3, 34.6 and 35.3% for diets containing untreated, sodium hydroxide treated, sodium peroxide treated or sodium chlorite treated dairy cattle waste, respectively. Values for apparent digestibility of nitrogen were 47.5, 46.7, 52.3 and 58.3%, respectively. All chemical treatments significantly increased dry matter digestibility, but nitrogen digestibility was not significantly affected by treatment.

Performance of Ruminants Fed Cattle Wastes

Anthony and Nix (1962) collected and washed manure from steers fed a high concentrate ration. No palatability problems were encountered when a ration comprised of 40% wet washed manure and 60% concentrate was fed to three yearling steers. Average daily gains of 1.54 kg per day were observed for the steers during a 54-day feeding trial.

In a subsequent study at Auburn University (Anthony, 1970), rations containing 40% washed, autoclaved or untreated cattle manure were consumed at rates comparable to rations containing no manure. When manure-concentrate mixtures were fed, all mixtures were consumed at a level sufficient to support average daily gains of 1.0 kg or greater. Ration dry matter required per unit of gain was greater for all manure containing rations than for the concentrate basal ration. However, steers receiving rations containing washed, autoclaved or untreated manure required less non-manure feed per unit of gain than controls.

Smith and Gordon (1971) fed three rations containing dehydrated dairy cattle manure (including some peanut-hull bedding), cornmeal and supplemental urea to equalize crude protein. Rations 1, 2 and 3 contained dehydrated manure and cornmeal in 1:1, 2:1 and 3:1 ratios, respectively. Average daily dry matter intakes by growing heifers were approximately 3% of body weight for all treatments. They also reported rates of gain of .47, .41 and .40 kg per day and feed efficiencies of

11.5, 14.7 and 19.2 kg feed per kilogram gain for rations 1, 2 and 3, respectively. Differences were not significant.

Smith et al. (1971) reported a high average daily dry matter intake of 4.6% of body weight by sheep, when dehydrated manure was fed alone. Addition of 10% soybean meal to the dehydrated manure resulted in an even higher average intake of 5.2% of body weight.

According to Anthony (1968), when wastelage (57 parts wet manure and 43 parts hay) and corn silage were compared under identical conditions, wastelage-fed cattle outgained corn silage-fed cattle. In a subsequent study, Anthony (1971b) reported that feeding a 2:3 ratio of wastelage to whole corn was an efficient plan for feeding slaughter cattle. In a 102-day feeding trial, this mixture supported average daily gains similar to those obtained with a high concentrate steer finishing ration. A greater amount of the wastelage containing mixture than the high concentrate ration was required per unit of gain (9.42 vs. 7.37). However, less non-manure feed was required per unit of gain when the wastelage containing mixture was fed than when the high concentrate ration was fed (5.65 vs. 7.37).

An ensiled mixture (ECW) composed of 60% fresh cattle manure and 40% chopped grass hay was fed by Harpster et al. (1975) to 48 finishing steers. The source of the manure was not reported. The ECW was fed alone or with high moisture corn. Average daily dry matter intake for the ECW fed alone was similar to that for a corn silage based control ration. However, average daily gain for steers receiving ECW alone was only about one-half that of steers receiving the corn silage based diet (.75 kg vs. 1.36 kg). When combinations of ECW and high moisture corn were fed, average daily gains of 1.22 kg and 1.29 kg were reported for diets containing 70 and 40% ECW, respectively. However, feed to gain ratios indicated that gain by steers fed ECW containing diets was much less efficient than that for steers fed a corn silage based diet.

Newton et al. (1975) reported average daily gains by growing heifers of 1.34 and 1.27 kg and feed efficiencies of 5.65 and 8.71 for an 80% concentrate basal diet and an ensiled mixture of 60% basal and 40% wet cattle manure, respectively.

Westing and Brandenberg (1974) compared performance of feedlot cattle fed an experimental ration containing 14% composted beef feedlot waste (as fed basis) and a control ration containing no feedlot waste. They reported similar gains, carcass characteristics and taste panel results for cattle fed the two rations. However, cattle receiving the waste containing ration required more feed per kilogram of gain than those receiving the control ration (7.87 kg vs. 7.43 kg).

Schake et al. (1974) reconstituted sorghum grain with cattle excrement from a pit under a slotted floor confinement feedlot. They mixed wet cattle excrement (15.7% dry matter) and grain in 1:1, 1:1.6 and 1:3.1 ratios, respectively. When the reconstituted grain was fed to heifers as 80% of the diet, the 1:1 excrement reconstituted sorghum grain was refused completely, so feeding was discontinued. No values were reported, but the authors indicated that feeding the 1:1.6 and 1:3.1 excrement reconstituted grain as 80% of the diet resulted in normal dry matter intake and normal rumen fluid acetic to propionic acid ratios.

Wastelage plus vitamin A and mineral supplements has been shown to be a satisfactory maintenance diet for ewes (Anthony, 1967) and brood cows (Anthony, 1969). No ill effects on reproduction have been observed with wastelage feeding. Anthony (1969) reported that the waste from one full-fed steer was sufficient to produce enough wastelage to maintain one brood cow and supply 40% (as fed basis) of a steer finishing ration.

Bollar *et al*. (1974) fed breeding ewes pelleted diets composed of 100% alfalfa hay or alfalfa hay and feedlot manure in a 50:50 or 25:75 ratio, respectively. Pregnancy rates tended to be slightly higher for ewes fed the manure containing diets than for those receiving alfalfa pellets only.

Regulatory and Health Aspects of Feeding Cattle Wastes

According to Taylor (1971), the Food and Drug Administration does not sanction the feeding of poultry litter, due to the potential hazards from the possible presence of disease organisms and drug and antibiotic residues. This statement also applies to feeding of cattle wastes. There is no regulation prohibiting the feeding of the waste. In fact, some states have adopted regulations permitting this practice.

No detrimental effects on animal health from feeding of cattle waste have been reported (Fontenot and Webb, 1975).

Improving the Nutritive Value of Low Quality Roughages

Very large quantities of low quality roughages are produced annually as by-products of the agricultural industry. Materials such as straws, hulls and corn plant residues contain considerable quantities of nutrients. The unique digestive tract of the ruminant can be utilized to reclaim some of these lignocellulosic materials, much of which are presently being wasted. In fact, the economics of cattle feeding and the contributing factor of competition for grains from monogastric animals, including humans, will probably result in greater exploitation of the ability of ruminants to utilize low quality fibrous materials (CAST, 1975; Rexen and Moller, 1974). However, the nutrients contained in these low quality roughages are generally poorly utilized when used as feedstuffs. Efforts have been made to improve the utilization of nutrients in these materials by various physical and chemical treatments.

Cellulose is the most abundant organic compound on earth and is a major constituent of low quality roughages. Micro-organisms found in the rumen are able to degrade cellulose to volatile fatty acids which may be used by the ruminant for energy. In vitro digestibility of isolated cellulose has been shown to be quite high. For instance, Dehority (1961) reported almost 100% digestibility of purified wood cellulose. Kamstra et al. (1958) reported an in vitro digestibility of 86% for cellulose isolated from oat hulls, whereas in vitro digestibility of cellulose in untreated oat hulls was less than 10%. The authors suggested that "encrusting substances" such as lignin were responsible for the low cellulose digestibility in the intact oat hulls. It is known that lignin content of plant materials increases as the plant matures, and according to Church (1969) the amount of fiber and/or lignin in plant material affects its overall digestibility.

Numerous physical and chemical treatments have been studied as means of improving the utilization of nutrients in low quality roughages.

Some of these include particle size reduction, irradiation, treatment with chlorine compounds and alkali treatments. The use of alkali, specifically sodium hydroxide (NaOH), is of major interest here. Other treatments will be reviewed only briefly.

Particle Size Reduction

In general, grinding of roughages through screen sizes normally used in preparation of ruminant feeds has had little effect on dry matter digestibility. For instance, grinding roughages through a 1.27 cm screen had little effect on dry matter digestibility (Long *et al.*, 1955; Reynolds and Lindahl, 1960).

Dehority (1961) investigated the effect of ball-milling on digestibility of purified wood cellulose. He reported that almost complete digestion of the cellulose had occurred after 48 hours of incubation for samples either ground through a 100-mesh screen or ball-milled. It was noted that cellulose digestion started sooner (shorter lag phase) in the ball-milled samples. This was apparently due to the increased surface area and accessibility of the cellulose for enzyme activity.

Irradiation

Digestibility of low quality roughages has been improved by irradiation with high energy electron beams (Millett *et al.*, 1970; Yu *et al.*, 1971). Millett *et al.* (1970) ground aspen and spruce wood through a 40-mesh screen and then subjected samples to irradiation at four dosage levels. *In vitro* dry matter digestibility of the aspen and spruce wood was increased from 55 and 3% to 78 and 14%, respectively, at the 10^8 rep dosage level. Yu *et al.* (1971) reported that cell wall, acid-detergent fiber and lignin content of wheat straw decreased by a factor of one-half following irradiation of the straw. Although irradiation of low quality roughages resulted in improved nutritive value in the studies mentioned, Millett *et al.* (1970) indicated that this treatment would be too costly to be of practical importance.

Treatment with Chlorine Compounds

Chlorine compounds (sodium chlorite, sodium hypochlorite, calcium hypochlorite, potassium chlorate and chlorine gas) were used by Yu *et al.* (1975) to treat wheat straw. These were expected to improve digestibility of the straw by solubilizing lignin. Treatment of the straw with 5% sodium chlorite (dry basis) reduced lignin content (7.9 to 3.6%) and improved *in vitro* cell wall digestibility from 24 to 35%. Treatment with other chlorine compounds had little effect on composition or digestibility of cell walls of wheat straw, except for chlorine gas (Cl_2). *In vitro* digestion of cell walls in the wheat straw was severely decreased by treatment with chlorine gas (24% *vs.* 1%). The authors suggest that this decrease may have been due to a toxic effect of the residual chlorine in the treated straw on bacteria in the *in vitro* system. Very low voluntary intakes resulted when the straw treated with chlorine compounds was offered to goats. The authors concluded that materials treated with chlorine compounds were not suitable feedstuffs unless the volatile or soluble chlorine compounds were removed.

Barton *et al.* (1974) reported lowered *in vitro* digestibility of peanut hulls when treated with chlorine gas. However, calcium hypochlorite substantially increased *in vitro* dry matter digestibility of peanut hulls from 25 to 40%.

Sodium Hydroxide Treatment

Alkali treatment, specifically with sodium hydroxide (NaOH), is a method which can be used to enhance the nutritive value of materials with a high lignocellulose content. The tremendous quantities of lignocellulosic wastes produced may become increasingly important energy sources for ruminants as processes for treating this material are refined and tested.

Treatment of low quality fibrous materials such as straws, cobs and wood with alkali has long been known to improve their feeding value for ruminants (Archibald, 1924). Even so, widespread treatment of low quality fibrous materials has not occurred. An abundant supply of high quality forage and grain for feeding to ruminants has been a major reason for this condition. However, in recent years increasing attention has been focused on improving the feeding value of low quality roughages and utilization of larger amounts of these materials as ruminant feeds. Treatment of these materials with sodium hydroxide (NaOH) appears to be one of the more promising approaches to improving the feeding value of these materials.

Effect on Composition and Digestibility. Early methods of NaOH treatment usually involved soaking the fibrous materials in a dilute NaOH solution, followed by thorough washing with water. One such method was developed in Germany and patented by Beckmann (1923) for treatment of straw. With this procedure the straw is soaked in eight times its weight of 1.5% NaOH solution (equivalent to 12% NaOH, w/w) in an open vat for up to 24 hours. The NaOH solution is then pumped out of the vat and the straw is washed several times with water. This is a very slow process. More recent investigators have added NaOH on a percentage weight basis and added water to bring the straw to the desired moisture level. Some studies have included washing or neutralizing the treated material, whereas others have not.

Klopfenstein and Woods (1970) treated wheat straw with 5% alkali (NaOH and KOH to give Na:K ratio of 1:1) and determined digestibility by lambs. Rations were composed of untreated or treated straw plus supplemental protein, vitamins and minerals. They reported that alkali treatment improved organic matter digestibility of the straw by 17 percentage units, from approximately 43 to 60%.

Wheat straw was treated with 0, 3, 6 and 9% NaOH and dry matter digestibility determined by the nylon bag technique (Shin et al., 1975a). Dry matter digestibility of the straws ground through a 1.27 cm and 1.0 mm screen and left in the rumen for 72 hours was 32.0 and 36.9, 47.5 and 61.5, 59.4 and 70.6, and 65.9 and 73.5% when treated with 0, 3, 6 and 9% NaOH, respectively. In a subsequent study, Shin et al. (1975b) used mature wethers to determine digestibility of wheat straw treated with 0, 3, 6 or 9 grams of NaOH plus 30 ml of water per 100 g of straw, air dry basis. Wethers consumed rations containing 60% of the treated straws at a level equal to or above that of a control ration containing 60% untreated straw. Dry matter digestibility of the ration containing untreated straw was 53.7%. Addition of 6 g NaOH per 100 g of straw resulted in the highest ration digestibility of any treatment, 66.6%. The authors reported a depression in ruminal fluid ammonia with diets containing treated straws, particularly at the high treatment level.

Yu _et al_. (1975) treated wheat and oat straw with 2 or 6% NaOH (w/w), dry basis, plus water to get straw to 20% dry matter, followed by ensiling for 14 days. They studied the effect of treatment on composition and _in vitro_ cell wall digestibility of the straws. Treatment with 2% NaOH prior to ensiling had essentially no effect on composition or _in vitro_ digestibility of cell walls. However, treatment with 6% NaOH effectively decreased cell wall content of the straw. For wheat straw, the reduction was due almost entirely to a 42% reduction in hemicellulose content. Treatment with 6% NaOH also substantially improved _in vitro_ cell wall digestibility, 24.0% vs. 50.2%, for the untreated and treated straw, respectively. NaOH treatment had a similar effect on oat straw.

Treating barley straw with 6% NaOH (w/w), dry basis, plus addition of water followed by ensiling, increased its dry matter digestibility to about the same as that of corn silage (Mowat, 1971). When corn silage alone or a corn silage and NaOH treated barley straw silage mixture (75:25, respectively) was fed to yearling wethers, dry matter digestibilities, determined by difference, were 76 and 75% for corn silage and NaOH treated barley straw, respectively.

Ololade _et al_. (1973) applied 0, 2, 3 or 4% NaOH (w/w), dry basis, to reconstituted whole-plant barley (50% barley straw plus 50% barley grain) followed by steaming at atmospheric pressure for 30 minutes.

The processed material contained approximately 36% dry matter. Treatment with 2 or 3% NaOH increased ($P<.05$) digestibility of dry matter, organic matter, cell walls, acid-detergent fiber, cellulose and gross energy of the reconstituted whole plant barley. However, treatment with 4% NaOH resulted in a slight decrease in digestibility of these components. The 4% NaOH treatment also resulted in a significant decrease in nitrogen retention by wethers as compared to that for the 0, 2 or 3% NaOH treatments. In the same study, Ololade et al. (1972) reported that the molar concentration of propionic acid in the ruminal fluid and ruminal fluid osmolality increased significantly with increasing levels of sodium hydroxide.

The degree of improvement in dry matter digestibility of several kinds of straw has been shown to be directly related to the amounts of alkali and water added, as well as, the temperature and pressure at which the straw was treated (Guggolz et al., 1971). They reported that untreated straws with dry matter digestibilities of 30 to 40% were improved to 50 to 60% with addition of water and pressure treatment at 28 kg/cm^2. Dry matter digestibility was further improved to 70 to 80% by addition of 3% NaOH and water plus pressure treatment at 28 kg/cm^2. Guggolz et al. (1971) reported that in vitro dry matter digestibility of perennial rye straw was 39.7, 57.9, 62.2 and 69.5 for untreated, steam treated (28 kg/cm^2), water to 50% moisture followed by steam treatment, and water to 50% moisture plus 4% NaOH (w/w), dry basis, followed by steam treatment, respectively.

Summers and Sherrod (1975) treated a number of roughages including hays, straws, hulls and cobs with 5% NaOH at 50% moisture and stored them wet. *In vitro* dry matter digestibility was improved by treatment of most materials studied. However, there was no appreciable change in *in vitro* dry matter digestibility of alfalfa hay following treatment, and 5% NaOH treatment actually decreased *in vitro* dry matter digestibility of peanut hulls. The greatest increase in *in vitro* dry matter digestibility from sodium hydroxide treatment was for roughages which had the largest decrease in hemicellulose content and little change or a slight decrease in acid-detergent lignin content. Based on the widely varying response to NaOH treatment for different roughages, Summers and Sherrod (1975) suggested that the response to NaOH treatment is species specific.

The low digestibility of peanut hulls by ruminants, 16 to 25%, depending on variety and location grown, makes them unattractive as a feedstuff, except as a roughage source (Barton *et al*., 1974). They treated peanut hulls by adding 5% NaOH (w/w), dry basis, plus water to 40% moisture and heating at 100 C for 1 hour. *In vitro* dry matter digestibility was decreased from 25.0 to 21.2% by this treatment. Similar results were reported by Summers and Sherrod (1975) for peanut hulls treated with 5% NaOH (w/w) at 50% moisture.

Gluggolz *et al*. (1971) reported an *in vitro* dry matter digestibility of only 10% for untreated hulls from spanish type peanuts. Dry matter of this kind of hulls treated with 4% NaOH (w/w) plus pressure (28 kg/cm^2 steam) was only 15% digestible, whereas dry matter of hulls treated with pressure only was 18% digestible.

Cottonseed hulls were ground through a 12.7 or 1.0 mm screen and treated with 5% NaOH (w/w) plus water to 50% moisture (Sherrod and

Summers, 1974). In vitro cell wall digestibility of hulls ground through a 12.7 mm screen was not substantially improved by NaOH treatment. However, cell wall digestibility of cottonseed hulls ground through a 1.0 mm screen and treated with 5% NaOH was almost double that of untreated hulls ground through a 12.7 mm screen (47.2% vs. 26.9%). It is impossible to determine whether the improved cell wall digestibility was due to the fine grinding or NaOH treatment since digestibility values were not reported for untreated hulls ground through a 1.0 mm screen. In a subsequent report, Summers and Sherrod (1975) reported that in vitro dry matter digestibility of cottonseed hulls was increased slightly from 24.8 to 29.5% by treating with 5% NaOH plus water to 50% moisture. The authors did not report the screen size through which the hulls were ground.

It appears from the studies reviewed that hulls are more resistant to the action of NaOH than most other low quality roughages.

Corn silage would generally not be considered a low quality roughage. However, since corn silage has been treated with NaOH in an attempt to make it an even better feedstuff, some of these studies will be reviewed. Krause et al. (1968) chopped and mixed whole corn plant (35% dry matter) with 0 or 4% NaOH, dry basis, and ensiled it for at least 2 months. In vitro dry matter digestibility was increased from 66.0 to 75.7% by 4% NaOH treatment. The treated corn silage was consumed readily when offered to growing wethers in a digestion trial (Klopfenstein et al. 1972). In vivo digestibility of organic matter from untreated and treated corn silage by wethers was 66.6 and 69.1%, respectively.

Buchanan-Smith et al. (1972) treated chopped whole corn plant with 0, 2, 3 or 4% NaOH, dry basis, and ensiled it in evacuated Cryovac bags for 50 days. Mean pH and lactic acid (g/100 g DM) values for the four silages were 4.00 and 3.99, 4.11 and 4.81, 4.12 and 4.56, and 4.38 and 3.01 for the 0, 2, 3 and 4% NaOH treated corn silages, respectively. These data indicate that good fermentation occurred in all silages. Ammonia and soluble nitrogen content of the silages was decreased by addition of NaOH, with the amount of decrease being directly related to the level of NaOH added. Flipot et al. (1975) also reported a reduction in soluble nitrogen content of corn silage treated with 3% NaOH and ensiled for 42 days in laboratory silos. They reported that soluble nitrogen was reduced by about one-third, as compared to untreated corn silage.

Corn stover was treated with 0, 2, 3 or 4% NaOH, dry basis, and ensiled for 50 days by Buchanan-Smith et al. (1972). Ensiled corn stover treated with 0, 2, 3 and 4% NaOH had pH values of 4.65, 5.18, 5.26 and 5.25, respectively.

Krause et al. (1968) chopped and mixed corn stover with 0, 3 or 5% NaOH, dry basis, added water to 50% moisture and ensiled for at least 2 months. In vitro dry matter digestibilities of 46.6, 54.5, 67.3 and 74.0% were reported for untreated dry stover and 0, 3 and 5% NaOH treated stover silages, respectively.

Koers et al. (1972) treated corn stalks with 4% NaOH, dry basis, and added water to 50% moisture. The stalks were then ensiled in metal drums. In vitro dry matter digestibility of corn stalklage was increased from 56.4 to 61.9% by treatment with 4% NaOH.

Corn cobs were increased to 50% moisture by adding water and ensiled either untreated or treated with 4% NaOH, dry basis (Koers _et al._, 1969). HCl and NH_4Cl were added to the treated cobs at levels to neutralize 33, 66 or 100% of the added NaOH. Results of a digestion trial using lambs indicate that organic matter and crude protein digestibility were not significantly affected by treatment.

Klopfenstein _et.al._(1972) treated corn cobs with 4% NaOH plus water to 50% moisture. They reported an 11.2% increase in _in vitro_ dry matter digestibility of corn cobs following NaOH treatment. According to Klopfenstein _et al._ (1974), addition of 3% NaOH to pressure treated corn cobs did not further increase digestibility.

According to Millett _et al._ (1970), wood residues are 70 to 80% carbohydrate. Digestibility of wood is generally very low and varies among species. Millett _et al._ (1970) ground several species of wood through a 40-mesh screen and treated these by soaking 5 g of the respective woods in 100 ml of 1% NaOH solution for 1 hour. The residues were then washed to neutrality with water, air-dried and _in vitro_ dry matter digestibility determined for untreated and treated woods. _In vitro_ dry matter digestibility of the untreated wood ranged from 3 to 33%, with digestibility of most of the untreated woods being less than 10%. Hardwood species tended to have higher _in vitro_ dry matter digestibilities than softwood species. _In vitro_ dry matter digestibilities of some of the more digestible hardwoods before and after treatment were 33 and 55% for Trembling Aspen, 31 and 49% for Bigtooth Aspen, 17 and 36% for Black Ash, 20 and 41% for soft Maple, and 5 and 55% for American Basswood, respectively.

Keith and Daniels (1975) reported *in vitro* dry matter digestibility values of 6.3 and 14.1% for untreated and 1% NaOH treated hardwood sawdust.

Effect on Performance. Javed and Donefer (1970) used wether lambs in a growth trial to compare diets composed of 80% dehydrated alfalfa meal or 80% NaOH treated oat straw. The oat straw was treated by adding 60 liters of a 13% NaOH solution to 100 kg of ground straw (equivalent to adding 8% NaOH, w/w). After 24 hours the treated straw was neutralized by addition of acetic acid. With *ad libitum* feeding, similar amounts of the two diets were consumed. Average daily gains of .18 and .14 kg, average daily feed intakes of 1.72 and 1.65 kg, and feed to gain ratios of 9.5 and 12.0 to 1 were reported for sheep fed the dehydrated alfalfa meal and NaOH treated straw diets, respectively.

Ryegrass straw was ensiled following addition of water or 4.5% NaOH solution in studies reported by Schultz and Ralston (1974) and Schultz *et al*. (1974). Prior to ensiling, 20% molasses, 1% urea and 0.5% limestone were added to NaOH treated and untreated wet straw (30% dry matter). Dry matter content of the resulting silages was approximately 40%, and crude protein content was 7.9 and 7.0%, dry basis, for the untreated and NaOH treated ryegrass straw silages, respectively. After a 60-day ensiling period the pH of the untreated and treated silage was 4.0 and 5.2, respectively. The NaOH treated silage had a very high butyric acid content, but this did not appear to decrease consumption of the silage by heifers. When fed to a group of 30 heifers dry matter intake was similar for the NaOH treated and untreated silage.

Average daily gain tended to be higher for the heifers fed treated straw silage than for those fed untreated straw silage.

Klopfenstein and Woods (1970) reported that feeding wheat straw treated with 5% alkali (3.75% NaOH plus 1.25% KOH) plus protein supplement to lambs resulted in gains of 90 g per day, as compared to no gain for lambs receiving untreated straw plus protein supplement.

Barley straw and corn stover treated with 6% NaOH, dry basis, plus water was ensiled by Mowat (1971). The treated silages had dry matter contents of about 35%. Diets composed of corn silage alone and with NaOH treated barley straw silage in 75 to 25 or 50 to 50 ratios were fed *ad libitum* to heifers in a growth trial. Heifers fed the 75 to 25 mixture of corn silage and treated barley straw silage gained at a similar rate with similar efficiency of gain to heifers fed corn silage alone. However, heifers fed the 50 to 50 mixture gained at a slower rate ($P < .05$) than those receiving corn silage alone. The author pointed out that the slower rate of gain was due in part to a slightly reduced dry matter intake. Similar results were obtained when NaOH treated corn stover silage was fed to bull calves (Mowat, 1971).

Koers *et al*. (1969) reported that average daily gain and dry matter intake was greater ($P < .05$) for lambs fed NaOH treated ensiled corn cobs in which 33 and 66% of the NaOH had been neutralized than for those fed untreated ensiled corn cobs. However, average daily gain for lambs receiving treated ensiled corn cobs in which 100% of the NaOH was neutralized was only about one-half that of the lambs fed the control silage, even though dry matter intakes were similar.

Klopfenstein _et al_. (1974) added 3% NaOH to steam pressure treated corn cobs and fed the cobs as 79% of a ration for growing lambs. Addition of 3% NaOH to pressure treated cobs resulted in no further improvement in average daily gain and feed efficiency of lambs, as compared to cobs treated with pressure only.

Waller and Klopfenstein (1975) treated corn cobs with NaOH, $Ca(OH)_2$, NH_4OH and combinations of the three. Water was added to 60% moisture followed by treatment with 4% dry chemical or mixture of chemicals (w/w), dry basis. The resulting silages were fed to steers and wethers as 75% of the diet in growth trials. Average daily gain was highest and feed to gain was lowest for animals fed a ration containing cobs treated with 3% NaOH plus 1% $Ca(OH)_2$.

In a study reported by Koers _et al_. (1972), corn cobs, grass hay, corn stalklage and milo tailings were treated with NaOH, and water added to 50% moisture, followed by ensiling. Silages were fed to lambs as 80% of the diet in a 60-day growth trial and compared to corn silage. Poor, but similar performance was observed for all groups of lambs, except the group receiving NaOH treated corn stalklage, which gained at only about one-half of the rate of the other groups.

Keith and Daniels (1975) reported that there was no significant difference in weight gain, feed intake or feed efficiency of steers fed untreated sawdust or 1.0% NaOH treated sawdust as 25% of the ration for 84 days.

Mode of Action of NaOH. Archibald (1924) quoted Magnus (1919) as suggesting that the action of dilute alkali on fibrous materials involved solubilization of silicic acid in encrusting substances of straw, splitting off of the methoxy and acetyl groups from lignin resulting in formation of acetic acid, and the "forcing or springing" of bonds which link lignin and cellulose together. The latter action was suggested to be the most important action of alkali in improving nutrient availability of fibrous materials.

Tarkow and Feist (1968, 1969) pointed out that tremendous quantities of research have been directed toward more fully understanding the improvement in nutritive value of low quality roughages resulting from alkaline treatment. The authors suggest that the most important chemical action of alkali is breaking (by saponification) of ester cross-linkages between xylan chains in fibrous materials. Breakage of these ester linkages allows increased swelling of the fiber in solution which provides for improved enzyme-substrate interactions by allowing greater penetration by microbial enzymes.

Feist et al. (1970) studied the amount of NaOH required for maximum improvement in in vitro dry matter digestibility of aspen and red oak wood. They found that 5 to 6% NaOH (w/w) gave maximum digestibility for both aspen and red oak. Feist et al. (1970) determined the quantity of uronic ester groups and acetyl groups present in aspen wood and calculated that 5.1 g of NaOH per 100 g of wood should be required for maximum improvement in digestibility. This agrees closely with the 5 to 6% NaOH (w/w) determined experimentally.

OBJECTIVES

Experiments were conducted to evaluate the nutritive value of untreated and NaOH treated dried fecal waste from cattle fed a high- or low-roughage ration.

The specific objectives were:

1. To investigate the effect of two different drying methods on *in vitro* dry matter digestibility of cattle fecal waste.
2. To study the effect of NaOH treatment of cattle fecal waste on *in vitro* dry matter digestibility.
3. To determine the effect of different roughage levels in cattle diets on the nutritive value of fecal waste when fed to sheep.
4. To investigate the effect of NaOH treatment of fecal waste from cattle fed different roughage levels on its nutritive value when fed to sheep.

EXPERIMENTAL PROCEDURE

Preliminary In Vitro Digestion Study

A preliminary *in vitro* digestion study was conducted to evaluate the effect of two drying methods and NaOH treatment on dry matter digestibility of cattle fecal waste. A 2 X 2 X 2 factorial experiment was used with two types of waste, two drying methods and two levels of NaOH treatment. Fecal waste used in this study was collected from steers fed either a 13 or 50% roughage ration. Drying methods evaluated were either heat drying in a forced-draft oven at 120 C for 24 hr, or freeze-drying in a vat-type freeze dryer for 72 hours. Cattle fecal waste was either dried fresh with no chemical treatment or dried following addition of 3% NaOH flakes (w/w), wet basis.

In vitro dry matter digestibility of the cattle fecal wastes was determined using the two-stage procedure of Tilley and Terry (1963) with modifications outlined by Pearson (1970). In the first stage, microbial digestion was accomplished in 100 ml polypropylene centrifuge tubes equipped with Bunsen valves described by Tilley and Terry (1963). Ruminal ingesta was obtained from a rumen fistulated steer which had been maintained on a 50% roughage ration for several months prior to collection. Ruminal fluid inoculum was prepared by straining ingesta through eight layers of cheesecloth. The inoculum was immediately transported to the laboratory in pre-warmed (38.5 C) thermos bottles. One part of strained ruminal fluid was then mixed with four parts buffer

(McDougall, 1948) which had previously been adjusted to an approximate pH of 7.0 by bubbling CO_2 and maintained in a water bath at 38.5 C. A total of 50 ml of the ruminal fluid-buffer solution was added to each incubation tube which contained approximately .5 g of the respective cattle fecal waste or standard ration. All samples had been ground in a micro Wiley Mill through a 40-mesh screen. Upon addition of ruminal fluid-buffer to each tube, CO_2 was directed into the top of the tube for approximately 15 sec and the tube was immediately stoppered with a Bunsen valve in an attempt to quickly attain anaerobic condition within the tube. The tube was then placed in a constant temperature water bath at 38.5 C. The water bath was covered with a sheet of aluminum foil to keep out direct light. Tubes were shaken using a "Vortex" mixer at 2, 4, 20 and 28 hr after initiation of the incubation. The tubes were incubated for 48 hr, after which each tube was acidified to a pH of approximately 1.2 by adding 20% HCl, 1 ml at a time to avoid excessive foaming. Approximately 3 to 4 ml of acid were required per tube. Acidification of the tubes stopped microbial activity and created suitable conditions for enzymatic digestion of protein by pepsin in the second stage of the procedure.

For the second stage, 5.0 ml of aqueous pepsin solution containing 0.12 g of 1:10,000 pepsin was added to each tube. Each tube was shaken and the Bunsen valve was loosely replaced. Tubes were shaken at 2, 4, 20 and 28 hr after initiation of the pepsin digestion stage. After 48 hr the tubes were removed from the water bath and centrifuged at 1800 G for 15 minutes. The supernatant was poured off and the tubes were placed in a forced draft oven at 80 C for 24 hours. The tubes containing the dry undigested residue were then dessicated and weighed. The undigested residue was then washed from the tubes and the tubes were placed back into the same oven for 24 hours. The tubes were again dessicated and weighed. The amount of undigested residue from each of the original samples and from the rumen fluid was determined and used in the calculation of dry matter digestibility.

Data were analyzed by analysis of variance (Snedecor and Cochran, 1967). The analysis of variance is presented in table 1 of the appendix. The multiple range test of Duncan (1955) was used to test for significant differences among mean dry matter digestion coefficients.

Collection and Treatment of Cattle Fecal Wastes

Cattle fecal waste processed for refeeding to sheep was collected from six yearling steers averaging 300 kg initially. Steers were housed in false-bottom metabolism stalls similar to those described by Nelson *et al*. (1954) during two total collection digestion trials. A switchback design was used with three steers receiving a high-roughage ration and three steers receiving a low-roughage ration in each trial. Steers were fed 2.5 kg of their respective ration twice daily at 7:00 am and 5:00 pm. Steers had access to water from automatic waterers at all times, except during the 1 hr feeding periods.

Steer rations were calculated to contain 12.5% crude protein and either 10 or 50% roughage, as fed basis. Rations were composed of shelled corn, grass hay, soybean meal, molasses, limestone and trace mineralized salt (table 1). Rations were supplemented with vitamins A

TABLE 1. COMPOSITION OF CATTLE RATIONS

Item	Ration	
	High-roughage	Low-roughage
Ingredient composition, %		
Orchardgrass, hay, S-C, cut 1, (1), IRN 1-03-433	50.0	10.0
Corn, grain, grnd, (4), IRN 4-02-879	40.2	73.8
Soybean, seeds, solv-exted, grnd, (5), IRN 5-04-604	4.0	10.0
Sugarcane, molasses, mm 48 invert sugar, mm 79.5 degree brix (4) IRN 4-04-696	5.0	5.0
Limestone, grnd, mm 33% calcium (6) IRN 6-02-632	0.3	0.7
Trace mineralized salt (6)	0.5	0.5
Vitamin A palmitate[a], (7), IRN 7-05-143	+	+
Vitamin D_3 supplement[b], (7), IRN 7-05-149	+	+
Chemical composition		
Dry matter, %	90.0	89.7
Composition of dry matter, %		
Crude protein	13.4	13.6
Crude fiber	19.6	6.7
Ether extract	3.0	4.0
Ash	6.4	4.2
NFE	57.6	71.5

[a]Supplied 4,000 IU vitamin A per kilogram of ration.
[b]Supplied 600 IU vitamin D per kilogram of ration.

and D. Both rations were ground in a hammermill through a 2.54 cm screen and mixed in a vertical mixer prior to each trial.

Each steer trial consisted of a 5-day transition period and a 10-day preliminary period followed by a 14-day collection period. Grab samples of the ration were taken at each feeding, starting 2 days prior to the beginning and ending 2 days prior to the end of collection, and added to a sealed, glass storage jar for subsequent analysis.

Urine from each steer was collected daily in a small mouth bottle under the metal funnel of each stall, and diluted to a constant weight of 15 kilograms. When daily urine weight exceeded 15 kg the urinary collection was diluted to the nearest kilogram. Daily, 1.0% aliquots of diluted urine were taken for each steer and stored in sealed jars under refrigeration. The pH of each composite sample was checked daily and a 1 to 1 solution of concentrated sulfuric acid and distilled water was added as needed to maintain a slightly acidic pH.

Feces were collected in large pans at the rear of each stall and were transferred to covered storage cans several times daily to prevent drying. Total daily collections of feces were weighed and thoroughly mixed. A 5.0% (w/w) sample of feces from each steer was taken and stored in sealed, refrigerated jars. A small amount of thymol was added to each sample to aid in preservation. The remainder of the feces was processed daily and stored. On days 1, 3, 5, 7, 9, 11 and 13 of each collection period, untreated wet steer feces were placed in screen wire trays and dried in a forced draft oven at 120 C for 24 hours. On days 2, 4, 6, 8, 10, 12 and 14 of each collection period, the feces were treated by adding 3% NaOH (w/w), wet basis, and dried as previously described. Sodium hydroxide treated feces were prepared for drying by thoroughly mixing dry NaOH flakes with wet feces. At the conclusion of each trial, the processed feces for each treatment were coarsely ground through a Fitzpatrick mill with no screen and stored for subsequent refeeding to sheep.

Data were analyzed by analysis of variance (Snedecor and Cochran, 1967). An example of the analysis of variance is presented in table 2 of the appendix.

In Vivo Digestion Experiment

Thirty wether lambs averaging 35 kg initially were used in a total collection digestion trial to determine digestibility of untreated and NaOH treated, high- and low-roughage cattle fecal waste. The wethers were housed in false-bottom metabolism stalls similar to those described by Briggs and Gallup (1949). The wethers were fed 750 g daily in two equal feedings at 7:00 am and 5:00 pm. Water was available at all times except during the 2-hr feeding periods.

A randomized block design was used with six lambs receiving each of five rations. Lambs within a block were of similar breeding and weight, and were randomly allotted to the five rations: (1) basal; (2) 75% basal and 25% untreated, dried, high-roughage fecal waste; (3) 75% basal and 25% treated, dried, high-roughage fecal waste; (4) 75% basal and 25% untreated, dried, low-roughage fecal waste; and (5) 75% basal and 25% treated, dried, low-roughage fecal waste. Ingredient composition of the five sheep rations is presented in table 2 and chemical composition of

TABLE 2. INGREDIENT COMPOSITION OF SHEEP RATIONS[a]

Item	Basal	Rations: High-roughage waste[b] Untreated	Treated[d]	Low-roughage waste[c] Untreated	Treated[d]
Ingredient composition, %					
Orchardgrass, hay, S-C, cut 1, (1), IRN 1-03-433	30.00	22.50	22.50	22.50	22.50
Corn, grain, grnd, (4), IRN 4-02-879	62.00	46.50	46.50	46.50	46.50
Soybean, seeds, solv-exted, grnd, (5), IRN 5-04-604	2.00	1.50	1.50	1.50	1.50
Cattle fecal waste	--	25.00	25.00	25.00	25.00
Sugarcane, molasses, mm 48 invert sugar, mn 79.5 degree brix (4) IRN 4-04-696	5.00	3.75	3.75	3.75	3.75
Limestone, grnd, mn 33% calcium, (6) IRN 6-02-632	.50	.37	.37	.37	.37
Trace mineralized salt, (6)	.50	.38	.38	.38	.38
Vitamin A palmitate[e], (7) IRN 7-05-143	+	+	+	+	+
Vitamin D_3 supplement[f], (7) IRN 7-05-149	+	+	+	+	+

[a]Fecal waste containing rations were composed of 75% basal and 25% cattle fecal waste, as fed.
[b]Fecal waste collected from steers fed a 50% roughage ration.
[c]Fecal waste collected from steers fed a 10% roughage ration.
[d]Treated by adding 3% NaOH (w/w), wet basis.
[e]Supplied 770 IU vitamin A per head per day.
[f]Supplied 200 IU vitamin D per head per day.

the rations is presented in table 3. The basal ration contained 30% roughage and was calculated to contain 10.7% crude protein, as fed (N.R.C., 1968). The basal ration was composed of shelled corn, grass hay, soybean meal, molasses, limestone and trace mineralized salt plus vitamins A and D. The basal ration was ground through a 1.27 cm screen and mixed in a vertical mixer. Cattle fecal waste containing rations were prepared by substituting the respective cattle fecal waste for 25% of the basal ration, as fed basis, and hand mixing just prior to feeding.

The total collection metabolism trial consisted of a 5-day transition period, 10-day preliminary period and a 10-day collection period. Grab samples of the basal ration and four types of fecal waste were taken at each feeding starting 2 days prior to beginning the collection period and ending 2 days prior to the end of the collection period. Composite samples of the basal ration and each type of fecal waste were stored in sealed jars for subsequent analysis.

During the collection period, total feces and urine were collected and sampled daily. Daily fecal collections were dried in small aluminum pans in a forced-draft oven at a maximum temperature of 60 C for 24 hr, and composited by animal over the 10-day collection period. Composites were stored in metal cans with loosely fitting lids to allow for moisture equilibration between the air and the dried feces. At the end of collection, composites were weighed and sampled. Any composites which were incompletely pelleted or clumped together were ground through a Fitzpatrick mill prior to sampling to insure that the sample was representative. Urine was collected daily in glass jars to which had been added 15 ml of a 1 to 1 (w/w) sulfuric acid to water mixture. The

TABLE 3. CHEMICAL COMPOSITION OF SHEEP RATIONS[a]

	Rations				
		High-roughage waste[b]		Low-roughage waste[c]	
Item	Basal	Untreated	Treated[d]	Untreated	Treated[d]
Chemical composition					
Dry matter, %	89.2	90.5	90.1	90.8	90.5
Composition of dry matter, %					
Crude protein	11.7	13.4	12.5	14.1	13.1
Crude fiber	12.0	14.2	13.5	13.0	12.1
Ether extract	3.7	3.4	3.1	3.9	3.1
Ash	5.0	6.3	10.5	5.8	9.7
NFE	67.7	62.7	60.4	63.2	62.0
Cell solubles	71.1	63.3	70.8	65.0	72.2
Cell walls	28.9	36.7	29.2	35.0	27.8
Acid-detergent fiber	13.9	21.1	17.3	15.7	14.2
Lignin	5.0	8.5	6.6	6.1	5.1
Cellulose	8.8	12.0	10.4	9.5	8.9
Insoluble ash	.1	.6	.3	.1	.2
Hemicellulose	15.0	15.6	11.9	19.3	13.6
Gross energy, kcal/kg dry matter	4340	4439	4220	4465	4319

[a]Fecal waste containing rations were composed of 75% basal and 25% cattle fecal waste, as fed.
[b]Fecal waste collected from steers fed a 50% roughage ration.
[c]Fecal waste collected from steers fed a 10% roughage ration.
[d]Treated by adding 3% NaOH (w/w), wet basis.

acid was added in order to maintain the urine at a slightly acidic pH, preventing loss of ammonia. Daily collections of urine were diluted to a constant weight of 4000 g and a 2% sample, by volume, was taken and stored under refrigeration in sealed plastic bottles.

Samples of the basal ration, the four types of dried cattle fecal waste fed and sheep feces were prepared for analysis by grinding in a Wiley Mill through a 1.00 mm screen. Crude fiber in feeds and feces was determined by the method of Whitehouse et al. (1945). Other proximate components in feeds and feces were determined by A.O.A.C. (1970) procedures. Total nitrogen content of urine was determined by the method of A.O.A.C. (1970) on duplicate 5.0 ml samples.

Dried ration and fecal samples were also analyzed using the Van Soest analysis scheme. Total cell walls or neutral-detergent fiber (Van Soest and Wine, 1967), acid-detergent fiber (Van Soest, 1963) and lignin, cellulose and insoluble ash (Van Soest and Wine, 1968) were determined. Hemicellulose was determined by difference (neutral-detergent fiber minus acid-detergent fiber). Energy content of rations, feces and urine was determined in a Parr adiabatic oxygen bomb calorimeter, equipped with an automatic jacket temperature controller. Urine was prepared for energy determination by freeze-drying approximately 250 g urine samples in a vat type freeze dryer. Immediately prior to freeze-drying, the urine was frozen in a thin layer around the inside of a 500 ml polypropylene bottle by rotating the bottle in an ethanol-dry ice bath. The bottles were transferred to the freeze dryer and the samples were dried to a constant weight (72 hr).

At the end of the collection period, ruminal fluid was sampled _via_ stomach tube 2 hr after the feeding at which the last collection was made. Ruminal fluid was strained through four layers of cheesecloth and pH was immediately measured electrometrically. Analyses for ammonia nitrogen (Conway, 1958) and volatile fatty acids (Erwin _et al_., 1961) were performed on the strained ruminal fluid.

Jugular blood samples were taken 6 hr after the feeding at which the last collection was made. Blood samples were analyzed for urea by the method of Coulombe and Favreau (1963).

The pH of NaOH treated and untreated cattle fecal waste fed in this study was not determined. However, at a later date, pH values were determined for similarly treated cattle fecal wastes and are presented in table 3 of the appendix.

Apparent digestibility of dry matter, organic matter, crude protein, ether extract, crude fiber, nitrogen-free extract, energy, cell solubles, cell walls, acid-detergent fiber, cellulose and hemicellulose in dried cattle fecal waste was calculated by difference by the method of Crampton and Harris (1969). Methane production was calculated using the formula of Swift _et al_. (1948), and used to calculate metabolizable energy content of the basal and cattle fecal waste containing rations. Metabolizable energy content of the cattle fecal wastes was calculated by difference by the method of Crampton and Harris (1969).

Data were analyzed by analysis of variance (Snedecor and Cochran, 1967). An example of analysis of variance for sheep rations parameters is presented in table 4 of the appendix, and for cattle fecal waste parameters in table 5 of the appendix. The multiple range test of Duncan (1955) was used to test for significant differences among treatment means at the 1 and 5% levels for all the data except those that were calculated by difference.

RESULTS AND DISCUSSION

Preliminary In Vitro Study

In vitro dry matter digestibility (IVDMD) values for the eight cattle fecal waste treatment combinations are presented in table 4. IVDMD values for the four treatments of high-roughage cattle fecal waste were all different ($P<.01$). Heat dried high-roughage cattle fecal waste with no NaOH treatment had the lowest IVDMD value, 14.86%. This value is quite similar to the IVDMD value of approximately 16%, determined for comparable cattle fecal waste in a previous study (Lucas *et al.*, 1975). Addition of 3% NaOH (w/w) to high-roughage cattle fecal waste prior to heat drying resulted in an increase ($P<.01$) in IVDMD to 43.63%. This value is three times that of the untreated heat dried high-roughage waste.

IVDMD of freeze dried high-roughage cattle fecal waste with no NaOH treatment was higher ($P<.01$) than comparable heat dried waste (20.92 *vs.* 14.86%). Addition of 3% NaOH in conjunction with freeze drying of high-roughage waste resulted in an increase ($P<.01$) in IVDMD to 35.25%. However, the magnitude of the increase in IVDMD resulting from NaOH treatment was not as great for freeze dried waste as for heat dried waste.

IVDMD of heat dried low-roughage waste with no NaOH treatment was 34.05%, more than double ($P<.01$) that of high-roughage waste with the

TABLE 4. EFFECT OF DRYING METHOD AND NaOH TREATMENT ON IN VITRO DRY MATTER DIGESTIBILITY OF FECAL WASTE FROM STEERS FED A HIGH-OR LOW-ROUGHAGE RATION

Type of Waste	Drying Method	Chemical treatment[a]	IVDMD[b,c]
High-roughage[d]	Heat (120 C)	None	14.86[f]
		3% NaOH	43.63[g]
	Freeze	None	20.92[h]
		3% NaOH	35.25[i]
Low-roughage[e]	Heat (120 C)	None	34.05[j]
		3% NaOH	53.68[k]
	Freeze	None	42.90[g]
		3% NaOH	56.51[k]

[a]Addition of either 0 or 3% NaOH (w/w), wet basis.
[b]*In vitro* dry matter digestibility.
[c]Each value listed represents the mean of 12 determinations.
[d]Fecal waste collected from steers fed a 50% roughage ration.
[e]Fecal waste collected from steers fed a 13% roughage ration.
[f,g,h,i,j,k]Means in the same column with different superscripts are significantly different ($P<.01$).

same treatment. Addition of 3% NaOH to low-roughage cattle fecal waste prior to heat drying resulted in an increase ($P<.01$) in IVDMD to 53.68%.

The IVDMD value for freeze dried low-roughage waste with no NaOH treatment was 42.90%. This value was increased ($P<.01$) to 56.51% by addition of 3% NaOH prior to freeze drying. IVDMD of freeze dried low-roughage waste with no NaOH treatment was greater ($P<.01$) than that for heat dried low-roughage fecal waste with no NaOH treatment (42.90% *vs*. 34.05%). However, the IVDMD of NaOH treated, heat dried low-roughage waste was not significantly different from that of treated freeze dried low-roughage waste (53.68 *vs*. 56.51%).

The increased IVDMD of both types of fecal waste following NaOH treatment is in agreement with *in vitro* results reported by Smith *et al*. (1969) for NaOH treated dairy cattle wastes. They reported a five fold increase in *in vitro* cell wall digestibility following addition of 3% NaOH (w/w), wet basis, to waste from dairy cattle fed orchardgrass hay alone. Addition of 3% NaOH on a wet basis is a sizable addition, approximately 15% on a dry basis. It is likely that addition of a lower level of NaOH may be more feasible. In fact, Klopfenstein *et al*. (1972) reported improved ($P<.05$) *in vitro* dry matter digestibility values for alfalfa stems, whole plant corn silage, corn cobs and corn stalks by addition of 3 to 5% NaOH, dry basis, and water to 50% moisture. Similarly, Feist *et al*. (1970) reported that addition of 5 to 6% NaOH (w/w) resulted in maximum improvement in *in vitro* dry matter digestibility of aspen and red oak wood.

All three factors studied, roughage level, drying method and chemical treatment, significantly ($P<.01$) affected IVDMD of cattle fecal waste (table 1 of appendix). All two factor interactions and the three factor interaction were also significant ($P<.01$).

Although all three factors affected ($P<.01$) IVDMD of the waste, roughage level in the diet of cattle producing the waste and addition of NaOH had greater effects on IVDMD than did drying method. Thus, it was apparent that these factors warranted further study in subsequent *in vivo* digestion trials.

Collection and Treatment of Cattle Fecal Wastes

Apparent Digestibility of Cattle Rations

Apparent digestibility of proximate components of the high- and low-roughage rations fed to steers is presented in table 5. Apparent digestibility of all components was significantly lower for the high-roughage ration, except crude fiber, which was higher ($P<.01$). The differences were usually 10 percentage units or more for all components except ether extract, in which the difference amounted to 4.4 percentage units.

Nitrogen Utilization and Ruminal Fluid and Blood Parameters

Data concerning the utilization of nitrogen in the high- and low-roughage steer rations are presented in table 6. Daily nitrogen intake was quite similar, 96.29 and 95.67 g per day, for steers receiving the high- and low-roughage rations, respectively.

However, as indicated by the lower fecal nitrogen excretion, more ($P<.01$) nitrogen was abosrbed by steers receiving the low-roughage than by those receiving the high-roughage ration. Urinary nitrogen excretion

TABLE 5. APPARENT DIGESTIBILITY OF CATTLE RATIONS

Component	Ration	
	High-roughage[a]	Low-roughage[b]
	%	%
Dry matter	67.0[c]	78.3
Crude protein	53.3[c]	66.4
Crude fiber	60.3[c]	50.6
Ether extract	75.6[d]	80.0
NFE	73.9[c]	84.2

[a]Contained 50% roughage, as fed.
[b]Contained 10% roughage, as fed.
[c]Value is significantly ($P<.01$) different from that for the low-roughage ration.
[d]Value is significantly ($P<.05$) lower than for the low-roughage ration.

TABLE 6. NITROGEN UTILIZATION, RUMINAL FLUID pH AND AMMONIA NITROGEN, AND BLOOD UREA VALUES FOR STEERS FED HIGH-AND LOW-ROUGHAGE RATIONS

Item	Ration	
	High roughage[a]	Low roughage[b]
No. of steers	6	6
Nitrogen utilization		
Nitrogen intake, g/day	96.29	95.67
Nitrogen excretion, g/day		
Fecal	45.04[c]	32.14
Urinary	51.08	50.83
Nitrogen retention		
Grams per day	.17[c]	12.70
Percent of nitrogen intake	.2[c]	13.3
Percent of absorbed nitrogen	.3[c]	19.9
Ruminal fluid		
pH	6.72[c]	5.79
NH_3-N, mg/100 ml	30.26	34.64
Blood urea, mg/100 ml	12.26	12.95

[a]Contained 50% roughage, as fed.
[b]Contained 10% roughage, as fed.
[c]Values for the high-roughage ration are significantly different ($P<.01$) from those for the low-roughage ration.

was not significantly different between steers fed the two rations. Nitrogen retention was very low for steers receiving the high-roughage ration, .17 g per day. In fact, three of the six steers receiving the high-roughage ration exhibited negative nitrogen balances. Again, the very low values of .2 and .3% for nitrogen retention, expressed as percent of nitrogen intake and percent of absorbed nitrogen, respectively, indicate the poor utilization of nitrogen in the high-roughage ration. Steers receiving the low-roughage ration retained 12.70 g of nitrogen per day, considerably more ($P<.01$) than steers receiving the high-roughage ration. Nitrogen retention, expressed as percent of nitrogen intake or percent of absorbed nitrogen was also greater ($P<.01$) for steers receiving the low-roughage than for those receiving the high-roughage ration.

Ruminal fluid pH and ammonia nitrogen, and blood urea values for steers receiving the high- and low-roughage rations are presented in table 6. Ruminal fluid pH was lower ($P<.01$) for steers receiving the low-roughage ration than for those receiving the high-roughage ration, 5.79 vs. 6.72, probably a reflection of the greater rate of fermentation due to a higher concentration of readily fermentable carbohydrates in that ration, as compared to the high-roughage ration. Ruminal fluid ammonia nitrogen values of 30.26 and 34.64 mg per 100 ml of ruminal fluid for steers fed the high- and low-roughage rations, respectively, were not significantly different. Similarly, blood urea values for steers fed the two rations were not significantly different.

Composition of Cattle Fecal Wastes

Proximate and Van Soest composition, and gross energy content of dried cattle fecal waste collected and processed during the steer trials are presented in table 7.

Crude protein content of untreated and NaOH treated, high-roughage cattle fecal waste was 18.0 and 14.9%, respectively. Corresponding values were 20.7 and 17.0%, respectively, for fecal waste from cattle fed the low-roughage ration. Both untreated and NaOH treated low-roughage cattle fecal wastes had higher crude protein contents than the corresponding high-roughage wastes. There was a sizable depression in crude protein content of both kinds of waste with NaOH treatment. On a percentage basis, the magnitude of the depression in crude protein content following treatment with 3% NaOH was almost identical, approximately 17%, for both high- and low-roughage fecal wastes. The depression in crude protein content following NaOH treatment was probably the result of nitrogen loss as ammonia. Investigation of the pH of wet cattle fecal waste showed that pH of high- (50%) and low-(13%) roughage waste was elevated from 6.6 and 6.1 to 11.8 and 11.7, respectively, by addition of 3% NaOH (w/w), wet basis (table 3 of appendix). Initial and post-treatment pH values were similar for both high- and low-roughage cattle fecal wastes. Certainly one would expect some nitrogen loss at this high pH, particularly at the drying temperature of 120 C. Also, since the addition of 3% NaOH (w/w) on a wet basis amounted to approximately 16.6 and 13.5% (w/w) on a dry basis for high- and low-roughage fecal waste, respectively, there was a dilution effect from the NaOH addition.

TABLE 7. CHEMICAL COMPOSITION OF DRIED FECAL WASTES

Item	Kind of Waste			
	High-roughage waste[a]		Low-roughage waste[b]	
	Untreated	Treated[c]	Untreated	Treated[c]
Chemical composition				
Dry matter, %	94.3	92.6	95.6	94.5
Composition of dry matter, %				
Crude protein	18.0	14.9	20.7	17.0
Crude fiber	20.5	17.8	15.7	12.4
Ether extract	2.6	1.6	4.7	1.5
Ash	9.9	26.4	8.3	23.1
NFE	49.0	39.3	50.6	46.0
Cell solubles	41.1	69.7	48.0	75.2
Cell walls	58.9	30.3	52.0	24.8
Hemicellulose	17.6	3.1	31.3	9.7
Acid-detergent fiber	41.3	27.2	20.7	15.1
Lignin	18.3	11.1	9.0	5.5
Cellulose	21.1	15.0	11.7	9.2
Insoluble ash	1.9	1.1	.9	.4
Gross energy, kcal/kg dry matter	4698	3873	4812	4257

[a]Feces collected from steers fed a 50% roughage ration.
[b]Feces collected from steers fed a 10% roughage ration.
[c]Treated by adding 3% NaOH (w/w), wet basis.

Crude fiber was higher in untreated and NaOH treated high-roughage waste, 20.5 and 17.8%, respectively, than in untreated or treated low-roughage waste, 15.7 and 12.4%, respectively. Crude fiber content of both the high- and low-roughage waste was decreased by treatment with 3% NaOH. It appears that most of the decrease in crude fiber content was due to the dilution effect from adding NaOH.

Ash content of the untreated high- and low-roughage fecal waste was 9.9 and 8.3%, respectively. Ash content of NaOH treated high- and low-roughage fecal waste was quite high, 26.4 and 23.1%, respectively. Most of the difference in ash content of untreated and NaOH treated fecal wastes, both high- and low-roughage waste, appeared to be due to the added NaOH. Addition of 3% NaOH (w/w), wet basis, amounted to addition of 16.6 and 13.5% NaOH (w/w) on a dry basis, for high- and low-roughage fecal waste, respectively. The amount of NaOH added on a dry basis was different for the two types of fecal waste because of a difference in dry matter content of fresh feces from cattle fed the two diets.

NFE content of untreated cattle fecal wastes was higher than for treated wastes. This would appear to be due mainly to the high ash content of the treated wastes.

The proximate composition of the two kinds of untreated waste is generally in agreement with that reported by Dowe et al. (1955) for fecal waste from steers fed rations containing different amounts of roughage. They reported that the percentage of dry matter, crude protein and NFE in the fecal waste increased as the concentrate in the ration increased, while the percentage of crude fiber in the fecal waste increased as roughage in the ration increased.

Cell solubles content of NaOH treated wastes was higher than for untreated wastes. This difference is due mostly to chemical degradation of some cell wall material but the added NaOH would also contribute to this fraction. Cell solubles content of the untreated and NaOH treated low-roughage waste was greater than that for the corresponding high-roughage fecal waste.

There was approximately a 50% reduction in cell wall content of both high- and low-roughage cattle fecal waste following NaOH treatment. Although part of this reduction is a reflection of the dilution effect of the added NaOH, there was obviously considerable degradation of complex cell wall material to simpler components.

Hemicellulose content of cattle fecal waste differed greatly with roughage level and chemical treatment. Untreated high- and low-roughage waste contained 17.6 and 31.3% hemicellulose, respectively. Treatment with NaOH decreased hemicellulose content to 3.1 and 9.7% for high- and low-roughage waste, respectively. It appears that a large portion of the hemicellulose in both types of waste was solubilized by addition of 3% NaOH (w/w), wet basis. In view of the very low hemicellulose content of the NaOH treated fecal wastes, and the increases in cell solubles, it appears that a portion of the hemicellulose was solubilized by NaOH treatment. These results agree in general with those of Yu et al. (1975) who showed that cell wall content of wheat and oat straw was decreased by treatment with 6% NaOH (w/w), dry basis. They pointed out that the reduction in cell wall content was due almost entirely to a large reduction in hemicellulose content. Solubilization of hemicellulose would tend to increase the cell solubles content and decrease the cell wall content of the NaOH treated fecal waste.

Acid-detergent fiber content was about twice as great in untreated high-roughage waste as in untreated low-roughage waste, 41.3 vs. 20.7%. Acid-detergent fiber content of both types of fecal waste was decreased by about 30% by NaOH treatment. It appears that most of the reduction in acid-detergent fiber was due to the action of the added NaOH.

Untreated high-roughage fecal waste contained 18.3% lignin, about twice as much as the untreated low-roughage waste (9.0%). Lignin content of both high- and low-roughage fecal waste was decreased by about 40% by treatment with 3% NaOH (w/w), wet basis. Similarly, Smith et al. (1969) reported a 30% reduction in lignin content of dairy cattle waste following treatment with 3% NaOH, wet basis.

Cellulose content of untreated high- and low-roughage cattle fecal waste was 21.1 and 11.7%, respectively. Cellulose content of the waste was reduced to 15.0% for the high-roughage waste and to 9.2% for the low-roughage waste by addition of 3% NaOH (w/w), wet basis. On a percentage basis, the reduction in cellulose content was slightly greater for the high-roughage fecal waste than for the low-roughage waste. This difference may have been due to the higher cellulose content of the high-roughage waste.

Gross energy content of the untreated high- and low-roughage cattle fecal waste was 4698 and 4812 kcal per kilogram of dry matter, respectively. The gross energy content of the wastes was decreased to 3873 and 4257 kcal per kilogram of dry matter for high- and low-roughage fecal wastes, respectively, by treatment with NaOH. Most of this decrease is probably the dilution effect of the added NaOH. Also, some energy loss may accompany the action of NaOH on the waste. This loss was apparent when NaOH was added to the waste. The waste became very warm and appeared somewhat charred after the NaOH and fecal waste were thoroughly mixed.

In Vivo Digestion Experiment

Apparent Digestibility

Apparent Digestibility and Available Energy of Rations. The apparent digestibility, and TDN and metabolizable energy content of the basal and four waste containing rations are presented in table 8.

Dry matter digestibility of the basal ration was 76.6%, and was greater ($P<.05$) than that of either of the four cattle fecal waste containing rations. Dry matter digestibility was lowest for the ration containing untreated high-roughage waste, 63.0%, indicating that the dry matter contributed by the untreated high-roughage fecal waste was poorly digested. Apparent dry matter digestibility of the ration containing untreated low-roughage waste was 70.3%, considerably greater ($P<.05$) than that of the untreated high-roughage fecal waste. Dry matter in the ration in which NaOH treated high-roughage cattle fecal waste had been substituted for 25% of the basal ration was 70.5% digestible, greater ($P<.05$) than that of the ration with untreated high-roughage cattle fecal waste. It is interesting that the ration containing NaOH treated high-roughage waste and the untreated low-roughage waste had similar dry matter digestibilities by sheep, 70.5 and 70.3%, respectively. The ration containing NaOH treated low-roughage cattle fecal waste had the highest

TABLE 8. APPARENT DIGESTIBILITY AND TDN AND METABOLIZABLE ENERGY CONTENT OF SHEEP RATIONS[a]

	Ration				
		High-roughage waste[b]		Low-roughage waste[c]	
Item	Basal	Untreated	Treated[d]	Untreated	Treated[d]
No of animals	6	6	6	6	6
Apparent digestibility, %					
Dry matter	76.6[e]	63.0[f]	70.5[g]	70.3[g]	74.1[h]
Organic matter	76.4[e]	62.9[f]	69.8[g]	71.0[g]	73.5[h]
Crude protein	60.4[e]	50.5[f]	48.3[f]	56.0[e]	49.8[f]
Crude fiber	55.8[e]	36.0[f]	51.5[g]	48.4[g]	57.0[e]
Ether extract	84.7[e]	79.0[f]	81.0[f,g]	82.4[g]	81.5[g]
NFE	84.4[e]	73.4[f]	79.6[g]	79.9[g]	83.1[e]
Cell solubles	83.9[e]	74.6[f]	76.5[g]	78.3[h]	79.0[h]
Cell walls	58.5[e,g]	42.9[f]	56.0[e]	55.5[e]	61.3[g]
Acid-detergent fiber	41.0[e]	24.3[f]	35.3[g]	34.5[g]	41.9[e]
Cellulose	47.3[e]	32.6[f]	45.8[e,g]	43.3[e]	53.0[g]
Hemicellulose	74.8[e]	67.8[f]	86.3[g]	72.7[e]	85.5[g]
Energy	75.1[e]	61.3[f]	67.2[g]	69.2[g]	71.8[h]
TDN, %	77.9[e]	63.9[f]	66.7[f]	71.9[h]	70.6[h]
Metabolizable energy, kcal/kg dry matter	2732[e]	2208[f]	2344[g]	2518[h]	2596[h]

[a]Fecal waste containing rations were composed of 75% basal plus 25% of the respective dried cattle fecal waste, as fed.
[b]Feces collected from steers fed a 50% roughage ration.
[c]Feces collected from steers fed a 10% roughage ration.
[d]Treated by adding 3% NaOH (w/w), as fed basis.
[e,f,g,h]Means in same row having different superscripts are significantly different ($P<.05$).

digestibility by sheep of any of the fecal waste containing rations, 74.1%. Dry matter digestibility was decreased by only 2.5 percentage units, from 76.6 to 74.1%, by substitution of NaOH treated low-roughage cattle fecal waste for 25% of the basal ration, as fed basis, but this decrease was significant ($P<.05$).

Apparent digestibility of organic matter in the five sheep rations was very similar to that for dry matter digestibility, although the values tended to be slightly lower than for dry matter. Values for apparent digestibility of organic matter in rations containing the untreated and NaOH treated low-roughage cattle fecal waste, 71.0 and 73.5% respectively, were not significantly different.

Apparent digestibility of crude protein in the basal, basal plus untreated high-roughage waste, basal plus NaOH treated high-roughage waste, basal plus untreated low-roughage waste, and basal plus NaOH treated low-roughage waste rations was 60.4, 50.5, 48.3, 56.0 and 49.8%, respectively. Substitution of cattle fecal waste for 25% of the basal ration decreased ($P<.05$) apparent digestibility of crude protein in the sheep rations, with the exception of the ration containing untreated low-roughage fecal waste.

Apparent digestibility of crude fiber in the basal ration, 55.8%, was depressed ($P<.05$) by substitution of untreated high- or low-roughage cattle fecal waste, to 36.0 and 48.4%, respectively. The magnitude of the depression in apparent digestibility of crude fiber was much greater with substitution of the untreated high-roughage waste than from substitution of untreated low-roughage waste. Substitution of NaOH treated high-roughage cattle fecal waste for 25% of the basal ration decreased apparent digestibility of crude fiber from 55.8 to 51.5%. However, substitution of NaOH treated low-roughage cattle fecal waste increased apparent digestibility of crude fiber from 55.8 to 57.0%, reflecting the high digestibility of crude fiber in the NaOH treated low-roughage cattle fecal waste.

Apparent digestibility of NFE in the basal, basal plus untreated high-roughage, basal plus NaOH treated high-roughage, basal plus untreated low-roughage and basal plus NaOH treated low-roughage cattle fecal waste containing rations was 84.4, 73.4, 79.6, 79.9 and 83.1%, respectively. Apparent digestibility of NFE in the NaOH treated low-roughage waste containing ration was not significantly lower than that of the basal ration. However, apparent digestibility of NFE in the other waste containing rations was lower ($P<.05$) than for the basal ration. The lowest value was for the ration containing the untreated high-roughage waste.

Apparent digestibility of cell solubles in the sheep ration was depressed ($P<.05$) by substitution of all kinds of cattle fecal waste.

Cell walls in the untreated high-roughage waste containing ration were much less ($P<.05$) digestible than in the basal ration alone, 42.9 vs. 58.5%. However, substitution of the other wastes for 25% of the basal did not significantly decrease ration cell wall digestibility. In fact, apparent digestibility of cell walls was increased from 58.5 to 61.3% by substitution of NaOH treated low-roughage waste for 25% of the basal ration. The considerable difference in apparent digestibility of cell walls in rations containing untreated and NaOH treated fecal wastes, reflects the sizable improvement in apparent digestibility of cell walls in the wastes due to NaOH treatment.

Apparent digestibility of acid-detergent fiber was decreased ($P<.05$) by 16.7 percentage units, from 41.0 to 24.3%, by substitution of untreated high-roughage waste in the basal ration. Substitution of NaOH treated high-roughage waste or untreated low-roughage waste resulted in decreases ($P<.05$) in digestibility to 35.3 and 34.5%, respectively. Apparent digestibility of acid-detergent fiber was actually slightly increased by substitution of NaOH treated low-roughage cattle fecal waste, again reflecting the high digestibility of fiber in NaOH treated low-roughage cattle fecal waste.

Substitution of untreated high-roughage waste decreased apparent digestibility of cellulose in the ration from 47.3 to 32.6% ($P<.05$). Apparent digestibility of cellulose in the NaOH treated high-roughage and the untreated low-roughage waste containing rations was not significantly different from that of the basal ration.

Apparent digestibility of hemicellulose in the basal ration was decreased ($P<.05$) from 74.8% to 67.8% by substitution of untreated high-roughage cattle fecal waste for 25% of the basal ration. Substitution of untreated low-roughage waste did not significantly affect apparent digestibility of hemicellulose in the ration. However, substitution of NaOH treated high- and low-roughage waste resulted in increased ration hemicellulose digestibilities (86.3 and 85.5%, respectively). The increase in apparent digestibility of hemicellulose of over 10 percentage units with substitution of either of the NaOH treated wastes for 25% of the basal ration reflects the high digestibility of hemicellulose in the NaOH treated wastes.

Apparent digestibility of energy in the basal ration was 75.1%. Substitution of any of the four types of cattle fecal waste for 25% of the basal ration resulted in depressions ($P<.05$) in apparent digestibility of gross energy in the ration. Of the cattle fecal waste containing rations, apparent digestibility was lowest for the untreated high-roughage waste containing ration, 61.3%, and highest for the NaOH treated low-roughage waste containing ration, 71.8%.

TDN content of the basal ration was 77.9%, significantly greater than that of any of the cattle fecal waste containing rations. TDN content of the untreated and NaOH treated high-roughage waste containing rations, 63.9 and 66.7% respectively, was lower ($P<.05$) than that of the untreated and NaOH treated low-roughage waste containing rations, 71.9 and 70.6%, respectively.

Metabolizable energy content of the sheep rations was also decreased ($P<.05$) by substitution of all four types of cattle fecal waste. However, the magnitude of the decrease was much less for rations containing low-roughage waste than for those containing high-roughage cattle fecal waste. Also, the metabolizable energy was higher for the rations containing waste which had been treated with NaOH, the difference being significant for the high-roughage waste.

Apparent Digestibility of Waste. Values for apparent digestibility, and TDN and metabolizable energy content of dried untreated and NaOH treated cattle fecal wastes, calculated by difference, are presented in table 9. Apparent digestibility of dry matter in untreated high-roughage waste by sheep was very low, 24.3%. However, this value is higher than that of 16.6%, determined for comparable waste in a previous study (Lucas et al., 1975) using steers. Apparent digestibility of fecal waste dry matter was greater ($P<.01$) for low-roughage waste than for high-roughage waste. The difference was especially large for the untreated wastes, the value of 52.9% for the low-roughage waste being over twice that for the comparable high-roughage waste. Treating cattle fecal waste with 3% NaOH (w/w), wet basis, significantly increased apparent digestibility of fecal dry matter. The increase was particularly striking for the high-roughage waste (24.3 vs. 52.9%). Although treating both kinds of waste with NaOH increased apparent dry matter digestibility, the magnitude of the increase was much greater for the high-roughage waste than for the low-roughage waste. The roughage level X NaOH treatment interaction was significant.

Similarly, apparent digestibility of organic matter was higher ($P<.01$) for the low-roughage than the high-roughage wastes, and was improved ($P<.01$) by NaOH treatment. Again, the magnitude of the increase in apparent digestibility of organic matter following NaOH treatment was much greater for the high-roughage waste. The roughage level X NaOH treatment interaction was significant. It is of interest to note the considerable difference between apparent digestibility of dry matter and organic matter for the NaOH treated wastes. There was a difference of 8.4 and 3.9 percentage units between dry matter and organic matter digestibility values for NaOH treated high- and low-roughage wastes,

TABLE 9. APPARENT DIGESTIBILITY AND TDN AND METABOLIZABLE ENERGY CONTENT OF DRIED TREATED AND UNTREATED CATTLE FECAL WASTE

Item	Kind of waste			
	High roughage waste[a]		Low roughage waste[b]	
	Untreated	Treated[c]	Untreated	Treated[c]
Apparent digestibility[d], %				
Dry matter[f,g,h]	24.3	52.9	52.9	67.0
Organic matter[f,g,k]	22.5	44.5	55.2	63.1
Crude protein[f,g]	32.1	20.8	49.1	29.1
Crude fiber[f,g]	3.2	43.0	32.6	60.1
Ether extract[i]	55.8	55.7	77.3	59.6
NFE[f,g,k]	30.7	55.9	63.3	77.6
Cell solubles[f,g,h]	28.9	54.5	55.1	65.8
Cell walls[f,g]	21.1	49.2	50.9	70.6
Acid-detergent fiber[f,g]	8.1	26.8	22.3	44.4
Cellulose[f,g]	15.2	43.3	35.0	68.5
Hemicellulose[g,h,i]	50.8	248.5	69.8	121.2
Energy[f,g]	25.0	41.6	54.2	62.3
Digestible energy[d,f], kcal/kg dry matter	1290	1461	2635	2643
TDN[e,f,h], %	24.7	34.7	55.5	50.1
Metabolizable energy[d,f,j], kcal/kg dry matter	835	1089	1979	2205

[a]Feces collected from steers fed a 50% roughage ration.
[b]Feces collected from steers fed a 10% roughage ration.
[c]Treated by adding 3% NaOH (w/w), wet basis.
[d]Calculated by difference by the method of Crampton and Harris (1969).
[e]Calculated using digestion coefficients calculated by difference by the method of Crampton and Harris (1969).
[f]Significantly ($P<.01$) different for high- and low-roughage wastes.
[g]Significantly ($P<.01$) different for untreated and NaOH treated wastes.
[h]Significant ($P<.01$) roughage level X NaOH treatment interaction.
[i]Significantly ($P<.05$) different for high- and low-roughage wastes.
[j]Significantly ($P<.05$) different for untreated and NaOH treated wastes.
[k]Significant ($P<.05$) roughage level X NaOH treatment interaction.

respectively. This difference appears to indicate that the added NaOH was highly digestible, and possibly tended to inflate dry matter digestibility values for the treated fecal waste. However, it is evident from the large improvement in organic matter digestibility of both kinds of waste, particularly the high-roughage waste, that digestibility of the wastes was improved considerably by NaOH treatment.

Apparent digestibility of crude protein was quite low in all wastes, with the exception of untreated low-roughage cattle fecal waste, 49.1%. Crude protein digestibility was lower ($P<.01$) for the high-roughage than the low-roughage waste. The low value of 32.1% for untreated high-roughage waste is very similar to the value of 32% reported by Smith et al. (1971) for ground dairy cattle waste and is in the same range as that of 26.1% determined in a previous study using steers (Lucas et al., 1975). Apparent digestibility of crude protein was significantly decreased by treating the wastes with 3% NaOH (w/w), wet basis. As indicated by the crude protein content of the wastes shown in table 7, there was some loss of nitrogen associated with NaOH treatment. In view of the lowered crude protein digestibility following NaOH treatment, it appears that that portion of the nitrogen remaining was less available to the animal than that which was lost during treatment.

Apparent digestibility of crude fiber was significantly affected by roughage level in the diet of animals producing the waste, as well as NaOH treatment. Crude fiber digestibility in the untreated low-roughage waste was 32.6%, about ten times the value of 3.2% for untreated high-roughage waste. Sodium hydroxide treatment of the high-roughage waste increased apparent digestibility of crude fiber from 3.2 to 43.0% and about doubled digestibility of crude fiber in the low-roughage waste from 32.6 to 60.1%.

Apparent digestibility of NFE was also significantly greater for the low-roughage waste than for the high-roughage waste. Treating the wastes with NaOH increased ($P<.01$) NFE digestibility, with the magnitude of the increase being much greater for the high-roughage waste. The roughage level X NaOH treatment interaction was significant.

Cell solubles in low-roughage fecal wastes were significantly more digestible than those in high-roughage wastes. Sodium hydroxide treatment resulted in a significant increase in digestibility of cell solubles from the wastes, from 28.9 to 54.5% for the high-roughage waste. The presence of residual NaOH may have tended to elevate values for digestibility of cell solubles for the NaOH treated fecal wastes. Also, the apparent solubilization of highly digestible hemicellulose (table 7) would tend to increase the digestibility of cell solubles.

Apparent digestibility of cell walls, acid-detergent fiber and cellulose was significantly greater for the low-roughage waste than the high-roughage waste. For instance, acid-detergent fiber in the untreated low-roughage waste was three times as digestible than that in the untreated high-roughage waste. Treating the fecal wastes with NaOH increased ($P<.01$) digestibility of these fiber components considerably. The improvement was especially striking for the high-roughage waste. Apparent digestibility of high-roughage waste cell walls, acid-detergent fiber and cellulose was more than doubled by NaOH treatment. For instance, high-roughage fecal cell wall digestibility was increased from 21.1 to 49.2% by NaOH treatment. The sizable increases in digestibility of these fiber components following NaOH treatment indicate that fiber in the NaOH treated fecal waste was degraded by chemical action and/or rendered more accessible to attack by microbial enzymes.

Hemicellulose digestibility values were higher than those for other fiber components, but followed the same general pattern. Apparent digestibility values in excess of 100% were determined for both of the NaOH treated wastes. The reason for these values in excess of 100% is not readily apparent. Similarly, hemicellulose digestibility values in excess of 100% were calculated by difference from data reported by Smith et al. (1969) for dairy cattle waste treated with 3% sodium peroxide, wet basis. In their study wet treated waste was mixed with corn silage and frozen until feeding. They suggested that the peroxide may have increased digestibility of hemicellulose in the corn silage. This appears likely since the mixture was wet. Although the NaOH treated waste was dried and mixed with the dry basal ration just prior to feeding, it is possible that these inflated values may have resulted from action of NaOH on hemicellulose in the basal ration after being consumed by sheep. If digestibility of hemicellulose in the basal ration was increased by NaOH, digestibility values for hemicellulose in the NaOH treated fecal waste, calculated by the difference method, would be inflated.

Apparent energy digestibility for the low-roughage waste was significantly greater than that for the high-roughage waste. For instance, energy in untreated low-roughage waste was 54.2% digestible, whereas that in untreated high-roughage waste was only 25% digestible.

Similarly, digestible energy content of the waste, expressed as kilo-calories per kilogram of dry matter, was significantly greater for the low-roughage than the high-roughage waste. Apparent energy digestibility was increased ($P<.01$) by treating the waste with NaOH. However, digestible energy content of the waste was not significantly increased by NaOH treatment. It is apparent however that NaOH treatment did increase the digestible energy content of the wastes, particularly the high-roughage waste.

TDN content of the low-roughage waste was significantly greater than that of the high-roughage waste. The values for the untreated low- and high-roughage wastes were 55.5 and 24.7%, respectively. Although NaOH treatment did not significantly affect TDN content of the wastes, there was a significant roughage level X NaOH treatment interaction. NaOH treatment of the high-roughage waste increased TDN content by 10.0 percentage units, but decreased TDN content of the low-roughage waste by 5.4 percentage units. The low TDN values for the NaOH treated wastes, which do not appear to agree with energy digestibility values, appear to be caused mostly by the lower digestible crude protein and ether extract content of the NaOH treated wastes.

Metabolizable energy content of the fecal waste was greater ($P<.01$) for the low-roughage than high-roughage waste, and was significantly increased by NaOH treatment.

Addition of 3% NaOH (w/w), wet basis, to the low-roughage waste amounted to addition of 13.5% NaOH (w/w), dry basis. In spite of the residual NaOH which would dilute the waste, the digestible energy content was similar to that of the untreated low-roughage waste (2635 vs. 2643 kcal/kg dry matter). Corrected for the added NaOH content, the digestible energy content of the NaOH treated low-roughage waste would be 3055 kcal/kg of dry matter, 16% higher than for the untreated waste. Similar corrections would apply for the high-roughage waste and for other measures of available energy for both kinds of waste.

Nitrogen Utilization

Data concerning utilization of nitrogen by sheep from the basal and dried cattle fecal waste containing rations is presented in table 10. Nitrogen intakes were somewhat greater for sheep receiving the rations containing fecal waste, resulting from higher nitrogen content in the substituted feces than in the basal ration. Fecal nitrogen excretion was greater ($P < .05$) for sheep fed the rations containing fecal waste than for those fed the basal ration, reflecting the lower apparent digestibility of nitrogen in the cattle fecal wastes than in the basal ration. Differences in fecal nitrogen excretion among the fecal waste containing rations were not significant. Urinary nitrogen excretion tended to be less for sheep receiving the basal, basal plus NaOH treated high-roughage and basal plus NaOH treated low-roughage fecal waste rations than for those receiving the untreated high- or low-roughage waste containing ration. Nitrogen retention expressed as grams per day, percent of nitrogen intake or percent of absorbed nitrogen, was lowest for sheep receiving the untreated high-roughage waste containing ration, less ($P < .05$) than that for sheep receiving the basal ration. Nitrogen retention was not significantly different among the four waste containing

TABLE 10. UTILIZATION OF NITROGEN IN BASAL AND DRIED CATTLE FECAL WASTE CONTAINING RATIONS[a]

		Ration			
		High-roughage waste[b]		Low-roughage waste[c]	
Item	Basal	Untreated	Treated[d]	Untreated	Treated[d]
No. of animals	6	6	6	6	6
Nitrogen intake, g/day	12.56	14.49	13.43	14.86	14.24
Nitrogen excretion, g/day					
Fecal	4.97[e]	7.17[f]	6.82[f]	6.53[f]	7.15[f]
Urniary	5.78[e]	7.00[f]	5.52[e]	7.50[f]	5.86[e]
Nitrogen retention					
Grams per day	1.81[e]	.32[f]	1.09[e,g]	.83[f,g]	1.23[e,g]
Percent of N intake	14.4[e]	2.2[f]	8.1[g]	5.6[f,g]	8.6[g]
Percent of absorbed N	23.9[e]	4.4[f]	16.5[e,g]	10.0[f,g]	17.3[e,g]

[a]Fecal waste containing rations were composed of 75% basal and 25% waste, as fed.
[b]Feces collected from steers fed 50% roughage ration.
[c]Feces collected from steers fed 10% roughage ration.
[d]Treated by adding 3% NaOH (w/w), wet basis.
[e,f,g]Means in the same row with different superscripts are significantly different ($P<.05$).

rations. However, there was a tendency for higher nitrogen retention in sheep fed rations containing NaOH treated cattle fecal waste.

Ruminal Fluid and Blood Parameters

Ruminal fluid pH and ammonia nitrogen and blood urea values for sheep fed the basal and fecal waste containing rations are presented in table 11. Ruminal fluid pH values for the sheep fed the basal ration and untreated and NaOH treated low roughage cattle fecal waste containing rations were 6.49, 6.56 and 6.54, respectively, lower ($P<.05$) than values of 6.78 and 6.82 for those fed rations containing untreated and NaOH treated high roughage fecal waste, respectively. The reason for the difference in ruminal fluid pH is not readily apparent, since the possibility of a more rapid rate of fermentation occurring in ruminal fluid of sheep with lower pH values is not supported by ruminal fluid VFA data presented in table 12. Also, ruminal fluid ammonia nitrogen values do not appear to support the ruminal fluid pH difference.

Evidently, ruminal fluid buffering capacity was sufficient to prevent a rise in ruminal fluid pH as a result of feeding rations containing NaOH treated fecal wastes. The pH of the NaOH treated wastes fed in this study was not determined, but the pH of comparably treated wastes was found to be in excess of 11.4 after drying.

Ruminal fluid ammonia nitrogen concentrations were not significantly different among treatments. However, ruminal fluid ammonia nitrogen concentration tended to be lower in sheep receiving NaOH treated fecal waste containing rations. Similarly, Shin et al. (1975b) reported a

TABLE 11. RUMINAL FLUID pH AND AMMONIA NITROGEN AND BLOOD UREA OF SHEEP FED BASAL AND FECAL WASTE CONTAINING RATIONS

	Rations				
		High-roughage waste[a]		Low-roughage waste[b]	
Item	Basal	Untreated	Treated[c]	Untreated	Treated[c]
Ruminal fluid					
pH	6.49[d]	6.78[e]	6.82[e]	6.56[d]	6.54[d]
NH_3-N, mg/100 ml	31.33	29.87	21.64	30.74	24.28
Blood urea, mg/100 ml	8.78	11.27	8.13	10.29	8.63

[a]Feces collected from steers fed a 50% roughage ration.
[b]Feces collected from steers fed a 10% roughage ration.
[c]Treated by adding 3% NaOH (w/w), wet basis.
[d,e]Means in the same row having different superscripts are significantly different (P<.05).

depression in ruminal fluid ammonia nitrogen concentration for wethers receiving NaOH treated wheat straw.

Blood urea concentrations were not significantly different among treatments. However, blood urea concentrations tended to be higher for sheep receiving the two untreated cattle fecal waste containing rations.

Ruminal fluid volatile fatty acid concentrations of sheep fed the basal ration and dried cattle fecal waste containing rations are presented in table 12. Concentration of acetic acid, expressed as umoles/ml of ruminal fluid, was greater ($P<.05$) for sheep receiving either of the rations containing NaOH treated fecal waste than that for those receiving the basal ration or the ration containing untreated high roughage waste. Concentration of propionic acid, expressed as umoles/ml of ruminal fluid, was greater ($P<.05$) for sheep receiving the ration containing NaOH treated low-roughage waste than that for those receiving the other rations, with the exception of the NaOH treated high-roughage waste containing ration. Ololade _et al_. (1972) reported a significant increase in propionic acid concentration in ruminal fluid of wethers fed a NaOH treated 50 to 50 mixture of barley straw and grain. In the present study concentrations of other individual volatile fatty acids were not significantly different when expressed as umoles/ml of ruminal fluid. Concentration of total volatile fatty acids, expressed as umoles/ml of ruminal fluid was greater ($P<.05$) for sheep receiving the ration containing NaOH treated low-roughage than for sheep receiving the basal ration or untreated high-roughage waste containing ration. Total volatile fatty acid concentration for sheep receiving the ration containing NaOH treated low-roughage waste was not significantly

TABLE 12. RUMINAL FLUID VOLATILE FATTY ACID CONCENTRATIONS OF SHEEP FED BASAL AND DRIED FECAL WASTE CONTAINING RATIONS

Item	Ration				
		High-roughage waste[a]		Low-roughage waste[b]	
	Basal	Untreated	Treated[c]	Untreated	Treated[c]
Volatile fatty acids, u moles/ml					
Acetic	41.41[d]	42.83[d]	53.25[e,f]	49.02[d,e]	60.32[f]
Propionic	12.92[d]	13.32[d]	17.46[d,e]	14.64[d]	20.25[e]
Butyric	9.68	11.33	9.05	13.36	12.72
Valeric	.63	.62	.60	.74	.86
Isobutyric	.56	.81	.82	.94	1.08
Isovaleric	.65	.78	.90	.91	1.09
Total	65.85[d]	69.68[d]	82.08[d,e]	79.61[d,e]	96.31[e]
Volatile fatty acids, moles/100 moles					
Acetic	63.45	61.88	64.93	61.81	62.84
Propionic	19.30	19.07	21.38	18.45	20.84
Butyric	14.41[d,e]	15.84[d]	10.93[e]	16.46[d]	13.26[d,e]
Valeric	1.00	.91	.72	.97	.86
Isobutyric	.81	1.19	.97	1.16	1.09
Isovaleric	1.04	1.12	1.08	1.15	1.11

[a]Feces collected from steers fed a 50% roughage ration.
[b]Feces collected from steers fed a 10% roughage ration.
[c]Treated by adding 3% NaOH (w/w), wet basis.
[d,e,f]Means in same row having different superscripts are significantly different ($P<.05$).

different from that for sheep receiving the NaOH treated high-roughage waste or untreated low-roughage waste containing rations. When expressed as moles/100 moles, the proportions of individual volatile fatty acids were not significantly different among rations, with the exception of butyric acid. A greater ($P<.05$) proportion of the total volatile fatty acids was contributed by butyric acid in ruminal fluid of sheep receiving the untreated high- or low-roughage fecal waste containing rations than for sheep receiving the NaOH treated high-roughage fecal waste containing ration.

In conclusion, it is apparent that fecal waste from steers fed a 50% roughage diet is of limited value for refeeding to ruminants. This conclusion is in agreement with a previous study (Lucas et al., 1975). Fecal waste from steers fed a 10% roughage diet, similar to a finishing feedlot diet, appears to be of much greater value for refeeding than high-roughage waste. In fact, the digestible protein and energy content of the untreated low-roughage waste is comparable to that of good quality orchardgrass hay (NRC, 1971).

Treating cattle fecal waste with 3% NaOH, wet basis, resulted in a sizable improvement in digestibility of fiber in both high- and low-roughage cattle fecal waste. Somewhat greater improvement was noted for the high-roughage waste. This improvement was reflected in increased organic matter digestibilities for both kinds of treated waste. However, loss of some nitrogen and decreased availability of the remaining nitrogen accompanied NaOH treatment of the wastes. It is likely, that treatment of cattle fecal waste with the high level of NaOH used in this study would not be economically feasible. Previous work with low quality roughages has shown that addition of a much lower level of NaOH (4 to 6 percent, dry basis) will substantially improve the nutritive value of these materials (Klopfenstein and Woods, 1970; Yu et al., 1975). Addition of lower levels of NaOH to fecal wastes may result in sufficient improvement in nutritive value to be economically feasible.

SUMMARY

A preliminary *in vitro* digestion study was conducted to investigate the effect of roughage level in the diet of steers producing fecal waste, drying method and NaOH treatment, on *in vitro* dry matter digestibility of cattle fecal wastes. All three factors significantly ($P<.01$) affected *in vitro* dry matter digestibility of cattle fecal wastes.

In vivo digestion trials were conducted to study the apparent digestibility of untreated and NaOH treated fecal waste from steers fed rations containing different roughage levels. In each of the two trials, three yearling steers were fed a 50% roughage ration and three were fed a 10% roughage ration. High- and low-roughage rations contained 13.4 and 13.6% crude protein, dry basis. Apparent digestibility of dry matter was 67% for the steers fed the high-roughage and 78% for those fed the low-roughage ration.

One-half of the feces from steers fed each ration was treated by adding 3% NaOH (w/w), wet basis. All feces were then dried at 120 C for 24 hours. Dried, untreated high-roughage (UHR) fecal waste, treated high-roughage (THR) fecal waste, untreated low-roughage (ULR) fecal waste, and treated low-roughage (TLR) fecal waste contained 18.0, 14.9, 20.7 and 17.0% crude protein and 20.5, 17.8, 15.7 and 12.4% crude fiber, dry basis, respectively.

A digestion trial was conducted with 30 wether lambs fed the following rations: (1) 100% basal, (2) 75% basal and 25% UHR fecal

waste, (3) 75% basal and 25% THR fecal waste, (4) 75% basal and 25% ULR fecal waste, and (5) 75% basal and 25% TLR fecal waste. The basal contained 30% roughage and analyzed 11.7% crude protein, dry basis. Apparent digestibility of proximate and Van Soest components in the basal ration was generally decreased by substitution of all kinds of fecal waste, with the exception of fiber components in the ration containing NaOH treated low-roughage waste. TDN and metabolizable energy content of all the rations containing dried cattle fecal waste were lower ($P<.01$) than for those of the basal ration.

Apparent digestion coefficients for cattle fecal wastes, calculated by difference, were: 24.3, 52.9, 52.9 and 67.0 for dry matter; 32.1, 20.8, 49.1 and 29.1 for crude protein; and 3.2, 43.0, 32.6 and 60.1 for crude fiber in UHR, THR, ULR and TLR waste, respectively. In general, apparent digestion coefficients for ULR waste were much higher than those for UHR waste. Untreated high-roughage waste appears to be of limited protein and energy value for refeeding to ruminants. However, untreated low-roughage waste appears to have considerable refeeding value, being comparable to good quality orchardgrass hay with respect to digestible protein and energy content. NaOH treatment of high- and low-roughage cattle fecal wastes resulted in a significant increase in apparent digestibility of most components studied. The increases in apparent digestibility of fiber components of the NaOH treated wastes were sizable, especially for the high-roughage waste. Addition of the high level of NaOH used in this study may not be economically feasible. However, addition of lower levels, as have been used in treatment of other low quality roughages, may result in sufficient improvement in nutritive value to be economically feasible.

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APPENDIX

TABLE 1. ANALYSIS OF VARIANCE FOR 2 X 2 X 2 FACTORIAL FOR *IN VITRO* DIGESTION STUDY

Source	Degrees of freedom	Sum of squares	Mean squares	F
Total	95	18,191.75		
Trial	1	27.87	27.87	6.50*
Treatment	7	17,924.42	2560.63	596.88**
A[a]	1	7879.48	7879.48	1836.71**
B[b]	1	8739.59	8739.59	2037.20**
C[c]	1	131.39	131.39	30.63**
A X B	1	145.56	145.56	33.93**
A X C	1	294.04	294.04	68.54**
B X C	1	627.87	627.87	146.36**
A X B X C	1	106.49	106.49	24.82**
Trial X Treatment	7	30.03	4.29	1.64
Error	80	209.42	2.62	

[a]Factor A is roughage level in the diet of cattle from which fecal waste was collected (50 *vs.* 13% roughage).
[b]Factor B is chemical treatment 0 *vs.* 3% NaOH, by weight, (wet basis).
[c]Factor C is drying method (Freeze-drying *vs.* heat-drying).
*(P<.05)
**(P<.01)

TABLE 2. EXAMPLE OF ANALYSIS OF VARIANCE FOR CATTLE DIGESTION TRIALS (DRY MATTER DIGESTIBILITY)

Source	Degrees of freedom	Sum of squares	Mean squares	F
Total	11	497.44		
Trial	1	2.55	2.55	.18
Block	2	9.43	4.72	.33
Treatment	1	384.09	384.09	26.53**
Error	7	101.37	14.48	

**(P<.01)

TABLE 3. EFFECT OF NaOH TREATMENT ON pH OF HIGH-AND LOW-ROUGHAGE CATTLE FECAL WASTES[a]

Item	Kind of waste			
	High roughage waste[b]		Low roughage waste[c]	
	Untreated	Treated[d]	Untreated	Treated[d]
Initial[e]	6.62	11.80	6.16	11.71
After drying	6.62	11.42	5.99	11.45

[a]Values are the mean of 3 replicates.
[b]Collected from steers fed a 50% roughage ration.
[c]Collected from steers fed a 13% roughage ration.
[d]Treated by adding 3% NaOH (w/w), wet basis.
[e]Prior to drying.

TABLE 4. EXAMPLE OF ANALYSIS OF VARIANCE FOR SHEEP RATION PARAMETERS (DRY MATTER DIGESTIBILITY)

Source	Degrees of freedom	Sum of squares	Mean squares	F
Total	29	684.65		
Block	5	10.95	2.19	1.14
Treatment	4	635.24	158.81	82.58**
Error	20	38.46	1.92	

**(P<.01)

TABLE 5. EXAMPLE OF ANALYSIS OF VARIANCE FOR CATTLE FECAL WASTE PARAMETERS

(DRY MATTER DIGESTIBILITY)

Source	Degrees of freedom	Sum of squares	Mean squares	F
Total	23	6535.58		
Block	5	313.92	62.78	2.14
Treatment	3	5780.96	1926.99	65.59**
Roughage level	1	2729.60	2729.60	92.91**
NaOH treatment	1	2733.44	2733.44	93.04**
Roughage X NaOH	1	317.92	317.92	10.82**
Error	15	440.70	29.38	

** (P<.01)

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COMPOSITION AND DIGESTIBILITY OF UNTREATED AND SODIUM HYDROXIDE TREATED FECAL WASTE FROM CATTLE FED HIGH OR LOW ROUGHAGE RATIONS

by

Donald Montgomery Lucas

(ABSTRACT)

A preliminary *in vitro* digestion study was conducted to investigate the effect of roughage level in the diet of steers producing fecal waste, drying method and NaOH treatment, on *in vitro* dry matter digestibility of cattle fecal waste. All three factors significantly ($P<.01$) affected *in vitro* dry matter digestibility of cattle fecal wastes.

In vivo digestion trials were conducted to study the apparent digestibility of untreated and NaOH treated fecal waste from steers fed rations containing different roughage levels. In each of two trials, three yearling steers were fed a 50% roughage ration and three were fed a 10% roughage ration. High- and low-roughage rations contained 13.4 and 13.6% crude protein, dry basis. Apparent digestibility of dry matter was 67% for the steers fed the high-roughage and 78% for those fed the low-roughage ration. One-half of the feces from steers fed each ration was treated by adding 3% NaOH (w/w), wet basis. All feces were then dried at 120 C for 24 hours. Dried, untreated high-roughage (UHR) fecal waste, treated high-roughage (THR) fecal waste, untreated low-roughage

(ULR) fecal waste, and treated low-roughage (TLR) fecal waste contained 18.0, 14.9, 20.7 and 17.0% crude protein and 20.5, 17.8, 15.7 and 12.4% crude fiber, dry basis, respectively. A digestion trial was conducted with 30 wether lambs fed the following rations: (1) 100% basal, (2) 75% basal and 25% UHR fecal waste, (3) 75% basal and 25% THR fecal waste, (4) 75% basal and 25% ULR fecal waste, and (5) 75% basal and 25% TLR fecal waste. The basal contained 30% roughage and analyzed 11.7% crude protein, dry basis. Apparent digestibility of proximate and Van Soest components in the basal ration was generally decreased by substitution of all kinds of fecal waste, with the exception of fiber components in the ration containing NaOH treated low-roughage waste. TDN and metabolizable energy content of all the rations containing dried cattle fecal waste were lower ($P<.01$) than for the basal ration.

Apparent digestion coefficients for cattle fecal wastes, calculated by difference, were: 24.3, 52.9, 52.9 and 67.0 for dry matter; 32.1, 20.8, 49.1 and 29.1 for crude protein; and 3.2, 43.0, 32.6 and 60.1 for crude fiber in UHR, THR, ULR and TLR waste, respectively. In general, apparent digestion coefficients for ULR waste were much higher than those for UHR waste. Untreated high-roughage waste appears to be of limited protein and energy value for refeeding to ruminants. However, untreated low-roughage waste appears to have considerable refeeding value, being comparable to good quality orchardgrass hay with respect to digestible protein and energy content. NaOH treatment of high- and low-roughage cattle fecal wastes resulted in a significant increase in apparent digestibility of most components studied. The increases in apparent digestibility of fiber components of the NaOH treated wastes were sizable, especially for the high-roughage waste. Addition of the high level of NaOH used in this study may not be economically feasible. However, addition of lower levels, as have been used in treatment of other low quality roughages, may result in sufficient improvement in nutritive value to be economically feasible.