FERMENTATION CHARACTERISTICS AND NUTRITIONAL VALUE OF STORED AND FRESH DAIRY CATTLE WASTE ENSILED WITH CROP RESIDUES

by

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INTRODUCTION

When commercial fertilizers were not so readily available, dairymen sought to use waste in a manner that could enhance productivity of the land, allowing more animals and ultimately more income. By the mid-1950's beneficial values of animal wastes began to be overlooked. Commercial fertilizer was readily available, and allegedly more cost effective than manure. Handling animal waste became a necessary cost to production with no direct financial benefit. The trend in dairy production has been towards fewer farms but higher producing cows and larger herds.

Presently, the situation is changing and dairymen are again looking at cost-offsetting beneficial uses of waste. Waste handling systems vary due to nearness to urban centers, cropping practices, climate and farmers' preferences. The control of odors and flies and cow cleanliness are also related to manure handling and disposal. Factors affecting dairy waste system selection, in addition to climate, topography and soils, are housing, feeding regimen, animal type and herd size.

The type of housing will be a major factor in determining whether the manure will be handled as a solid or as a liquid (slurry). This waste to most dairymen means manure--a combination of feces, urine, bedding and unconsumed feed. It may also include milk house wastes. Chemical, microbial and physical properties of waste are important characteristics to those who wish to use them in a constructive way--

turning them from a waste to a resource.

Several technologies have been developed for processing animal manures for feed. Those that show promise for dairy waste are physical separation, dehydration, composting and ensiling. Ensiling, usually with other ingredients, has been shown to be effective in destroying potential pathogens as well as improving the palatability of the wastes. In order to effectively utilize the waste from dairy farms, which are high in moisture, it would be necessary to ensile with materials which are low in moisture two or more times per week, which is not practical unless a large number of animals can be concentrated.

A recent development in the handling of dairy waste is the use of slurry storage tanks. These tanks could be useful in a system of waste handling and feeding. This would permit accumulation of sufficient amounts of waste to utilize equipment and labor efficiently. However, prior to embraking on this kind of venture, critical information is needed concerning the ensiling characteristics of the dairy waste stored in these tanks.

The present study was undertaken to investigate the nutritional characteristics of dairy waste stored in slurry tanks and to develop practical methods of ensiling the waste.

LITERATURE REVIEW

Cattle Waste

General Characteristics of Dairy Cattle Waste. Loehr (1974) noted that the daily manure production from dairy cattle was about 7 to 8% of the animal body weight and that fresh mixtures of feces and urine averaged 80 to 88% moisture. With the current relatively standard dairy diets, the basic components of N, P and K in feces and urine are reasonably predictable. The Midwest Plan Service's "Structures and Environment Handbook" estimates that dairy cattle excrete, N = .041 kg/day for each 100 kg of body weight, P = .0073 kg/day for each 100 kg of body weight, K = .027 kg/day for each 100 kg of body weight. To this should be added other minerals or compounds that were ingested by the cow and will also be excreted. Dairy manure undergoes chemical changes during handling and storage. Nitrogen losses of 50% are not uncommon, ammonia is released and this may add to the corrosiveness and odor nuisances of dairy manure. Notwithstanding these drawbacks, substantial nutrients are retained in dairy waste to justify its use as a feed ingredient.

Studies have frequently involved the use of solid portion after separating the liquid phase through some form of a vibrating screen. The solid phase is then known as Dairy Waste Fibre (DWF). The chemical composition will vary with the type of separator used and the plane of nutrition of the cows. Staples et al. (1981), after separating the liquid phase, reported the chemical composition of DWF. Dry matter was

28%. Ash and acid detergent lignin (ADL) were high while N was low. The DWF contained 77% neutral detergent fiber (NDF), making it comparable in fiber content to many low quality forages. Generally speaking, calcium content was high and other minerals were much lower, while there was no apparent accumulation of heavy metals, like Cd and Pb.

Nutritive Value of Cattle Waste

Chemical Composition. According to Church (1969), the composition of fecal material from animals is made up of: a) undigested feed residues, b) cellular debris and metabolites of microorganisms that grow in the large intestine and some from the forestomach in ruminants, c) products excreted into the gut, d) cellular debris of the mucosa of the gut and e) bile and residues of gastric, pancreatic and enteric juices. The chemical composition is difficult to characterize since numerous factors can affect this.

The type of diet is one factor that affects composition. Studies by Dowe et al. (1955) showed that feces from steers fed diets with corn to alfalfa hay ratios of 1:1, 2:1, 3:1, 4:1 and 5:1, had dry matter contents ranging from 23.3 to 26.9%. The average 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 the cattle fed diets composed of 1:1, 2:1, 3:1, 4:1 and 5:1 ratios of corn to alfalfa,

respectively. They concluded that as the ratio of corn to hay increased in the diet of the steer, dry matter, crude protein and NFE increased. Crude fiber decreased as the ratio of corn to hay increased.

Lucas et al. (1975) collected uncontaminated fecal waste from steers fed a 50% roughage ration, dried it at 120 C and showed that it 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. Lipstein and Bernstein (1973) reported chemical composition values of cattle waste for crude protein, ether extract, crude fiber, ash, NFE and gross energy as 13.1, 2.0, 24.2, 31.3, 29.5% and 3.27 Kcal/g, respectively, dry basis. Johnson (1972) presented data on composition from typical Oklahoma cattle feedlot waste, mainly from stockpile manure. Samples were analyzed from a lot in which cattle were fed a growing diet and another in which cattle were on a finishing diet. Results on a dry matter basis showed samples contained 14.8 and 19.2% crude protein; 2.9% ether extract (value for one sample); 24.4 and 17.3% acid-detergent fiber and 43.5 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 waste varies with the diet as well as the manner in which it is handled.

Proximate and Van Soest analyses were conducted on waste from cattle fed a low or high roughage diet (Braman, 1975). Waste from cattle fed a low-roughage diet was higher in dry matter, crude protein, ether extract, NFE and lower in ash, crude fiber, acid detergent fiber (ADF) and neutral detergent fiber (NDF), compared to waste from cattle fed a high roughage diet.

Utilization of Cattle Waste by Ruminants. Factors which influence digestibility in ruminants include (Church, 1969): 1) plane of nutrition, 2) species and breed differences, 3) nutrient deficiencies, 4) amount of fiber and/or lignin in the feed, 5) factors affecting appetite, 6) the associative effect of feedstuffs, 7) feed preparation, 8) frequency of feeding and 9) adaptation to ration changes. Thomas et al. (1970) substituted 39% dehydrated dairy cattle feces in a corn-corn cob diet to sheep. The feces were substituted for soybean meal, corn starch and corn cobs, resulting in approximately 40% of the dietary crude protein from dehydrated cattle feces. The dry matter digestibility of the waste diet was 58%. Dry matter digestibility of drhydrated cattle feces, calculated by difference, was 29%. In subsequent studies, Thomas et al. (1970) and Bucholtz et al. (1971) reported that less of the absorbed nitrogen from cattle feces was retained than from other nitrogen sources tested. In another study by Smith et al. (1971) dehydrated dairy cattle manure from cows fed equal dry matter levels from alfalfa hay, corn silage and concentrates was fed to sheep.

Four diets were used: 1) unground manure, 2) unground manure and soybean meal, 9:1, 3) ground manure and 4) ground manure and soybean meal. Apparent digestibilities of dry matter and nitrogen were 26.9 and 31.2; 25.9 and 47.6; 22.0 and 32.2; and 27.7 and 52.4% for diets 1, 2, 3 and 4, respectively. Apparent digestibility of dry matter and nitrogen was significantly higher for unground manure alone or supplemented with soybean meal than for ground manure.

In an experiment by McClure et al. (1971), feces from beef steers on a finishing diet containing either whole shelled corn or crimped corn alone and with 9.1 kg corn silage per head per day, were dried and incorporated into the following diets for a sheep digestion trial: 1) control (no feces); 2) 45% feces from cattle fed whole shelled corn; 3) 45% feces from cattle fed crimped corn; 4) 45% feces from cattle fed shelled corn plus silage; 5) 45% feces from cattle fed crimped corn plus silage; 6) 94% feces, one half from cattle fed whole shelled corn and the other half from cattle fed crimped corn. Diets 1 through 5 contained 20% alfalfa meal. The rest of the diets consisted of ground shelled corn. Apparent dry matter digestibilities were 80.2, 59.8, 60.9, 53.1, 52.4 and 40.3% for diets 1 through 6, respectively. Digestion coefficients for crude protein followed a similar trend as those for dry matter.

Anthony (1970) used a 20% roughage basal diet, containing 73.0% ground snapped corn in two experiments to determine the digestibility of washed, autoclaved and untreated wet cattle manure. The manure was collected daily from animals fed that particular diet, making this a continuous recycling program. The manure was mixed with the basal diet

in 40:60 ratio. In one experiment with yearling steers, two digestion trials were conducted with the following diets: 1) basal; 2) 40% washed manure and 60% basal; 3) 40% autoclaved manure and 60% basal; 4) corn silage, ground ear corn and supplementation with urea, cottonseed meal, minerals and vitamin A. Apparent digestion coefficients of 63, 67, 61 or 68% for dry matter and 50, 56, 51, and 35% for crude protein were reported for diets 1 to 4, respectively. In a second experiment the basal diet was fed alone or with 40% wet untreated manure or autoclaved manure to rumen fistulated steers. Dry matter digestion coefficients of 40, 47, and 46% were reported for the respective diets. Digestion coefficients for both manure containing diets were significantly higher than for the basal diet alone.

Cereco silage, a feedstuff produced by fermenting manure from cattle fed 70% dry rolled corn diet was fed to 300 kg steers in a digestibility trial (Ward et al. 1974). Steers were fed either cereco silage or corn silage plus protein and vitamin supplements. Digestibility values were shown to be similar for the two silages. TDN content of cereco and corn silage was 57.1 and 62.2%, respectively. However, dry matter intake was lower for the cereco silage.

Performance of Ruminants Fed Cattle Wastes. Anthony and Nix (1962) reported a recycling system for manure whereby this material was collected daily through the addition of water and the solid material was allowed to settle, with the aqueous layer being poured off. This solid material was mixed in a 40:60 proportion with basal feed. This diet was fed to beef animals over a 54-d period and the daily gain for

the test period was 1.54 kg with a feed conversion of 648 kg per 100 kg of gain. In another experiment, Bandel and Anthony (1969) prepared a material they termed wastelage by ensiling 57 parts of manure with 43 parts of ground coastal Bermudagrass hay. Five treatments were used. Ratios of wastelage to whole corn were 1 to 4, 2 to 3 and 3 to 2. Wastelage to ground corn ratio of 2 to 3 was also studied and wastelage fed alone was the control treatment. The average daily gains were .94, 1.05, 1.19, .72 and 1.09 kg, respectively, for the wastelage fed alone, the wastelage fed in 2 to 3 ratio with whole corn and ground corn, the wastelage fed in 3 to 2 and 1 to 4 with whole corn. In three experiments utilizing six treatments, four containing manure as wastelage and two as control, Anthony (1971b) reported a general improvement in animal performance in favor of the waste containing diets. Carcass grade as measured by fat thickness, rib eye area, percent fat in kidney, pelvic and heart and marbling also favored the manure containing diets.

Anthony (1970) fed diets containing 40% washed cattle waste solids either untreated, or cooked, compared to a basal diet. Average daily gain (kg) and feed efficiency (fed/gain) for 1) basal, 2) basal with cooked, 3) basal with washed manure were: 1) 1.24, 8.14; 2) 1.23, 8.48; 3) 1.08, 9.0, respectively. Dry matter intake of manure containing diets was higher than that of the basal, but intake of basal feed per unit of gain was less than for the manure containing diets.

Smith and Gordon (1971) fed three diets containing dehydrated dairy cattle manure (including some peanut hull bedding), corn meal and supplemental urea to equalize the crude protein. The three diets contained dehydrated manure and corn meal in 1:1, 2:1, and 3:1 ratios.

Average daily dry matter intakes by growing steers were approximately 3% of body weight for all treatments. They 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/kg of gain for the three respective diets. Westing and Brandenberg (1974) compared the performance of feedlot cattle fed an experimental diet containing 14% composted beef feedlot waste (as fed basis) and a control diet. They reported similar gains, carcass characteristics and taste panel results for cattle fed the two diets. Cattle receiving the waste containing diet, however, required more feed per unit of gain than those fed the control diet.

Schake et al. (1977) reconstituted sorghum grain with water or cattle excrement. They reported that excrement was more effective than water as a reconstitution medium if excrement to grain ratios did not exceed 1:1.6. They also reported that reconstitution with excrement improved the utilization of sorghum grain by 12.6% over the control group. Cattle fed the excreta containing diet had higher dressing percentage and more carcass fat than the control group.

Wastelage plus vitamin A and mineral supplements has been shown by Anthony (1967) to be a satisfactory maintenance diet for ewes and brood cows. Bollar et al. (1974) in their studies fed 100% alfalfa hay pellets, or alfalfa hay and feedlot manure in a 50:50 or 25:75 ratios, respectively, to breeding ewes. No ill effects were reported, and pregnancy rates tended to be slightly higher for the ewes on the manure containing diets, compared to those on alfalfa pellets only.

Ensiled Waste. Wastelage, an ensiled product of 57 parts wet manure and 43 parts hay, was performed by Anthony (1967) and later by other workers (Bandel and Anthony, 1969). Harpester et al. (1975) conducted studies on a similar product composed of 60% fresh manure and 40% chopped grass hay. Vetter and Burroughs (1974) ensiled 20 to 27% cattle excreta with corn forage and corn grain and reported no differences in performance and palatability, compared to basal diets. Ward and Beede (1973) compared "cereco" silage, a fermented processed waste from manure of finishing cattle consuming 75 to 80% concentrate diets with corn silage. When fed at 25 and 50% of the diet, cereco silage was as acceptable as corn silage. Newton et al. (1977) compared digestibility and performance by cattle fed dehydrated and ensiled cattle waste, and found no differences in digestibility and performance.

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

Drying by the use of heat 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). This method may have limited use because of the high energy input.

Innoculation. Improving the protein content by innoculation was investigated by Singh and Anthony (1968) and Moore and Anthony (1970).

These workers acid extracted the fiber portion of cattle waste, neutralized it and added it back to the soluble portion. This mixture was then innoculated with yeast cells and allowed to ferment at 40 C for 48 h. The innoculated waste contained 19% crude protein, compared to 7.4% crude protein, dry basis, for the acid extracted residues.

Chemical Treatment. Sodium hydroxide (NaOH) treatment of cattle waste to increase fiber digestibility has been investigated by Smith et al. (1969,1970) and Lucas et al. (1975b). Their data indicate that the digestibility of the fiber components was significantly improved by treating waste with an average of 3% NaOH, wet basis. Smith et al. (1971) used diets composed of 83% dairy cattle barn waste, 10% corn meal and 7% soybean meal. The dairy waste was subjected to chemical treatment and the diets were fed to sheep. Dry matter digestibilities were 23.0, 27.3, 34.6 and 35.3% for diets containing untreated, sodium hydroxide treated, sodium peroxide treated and sodium chlorite treated dairy cattle waste, respectively. Smith et al. (1971) also reported apparent digestibility values for nitrogen were 47.5, 46.7, 52.3 and 58.3, respectively.

Lamm et al. (1979) ensiled 60% cattle waste with 40% hay, wet basis. The animals were on a 70% concentrate diet. The mixture was treated with increasing levels of NaOH (0 to 12%, dry basis) prior to ensiling. Lactic acid production and pH were optimum at 0 and 2% NaOH. Digestibility of dry matter, NFE, crude fiber, organic matter and nitrogen retention were enhanced with 4% NaOH (dry basis) treatment.

Solid and Liquid Separation. Johnson et al. (1974) used a vibrating-screen separator with different screen sizes (8, 20, 40 and 60 mesh per 2.5 cm) to separate solids from dairy cow manure which had been diluted 1 to 15 with water. Dry matter digestibilities were 30, 26, 25 and 21% for the 8, 20, 40 and 60 mesh per 2.5 cm, respectively.

Menear and Smith (1973), using a continuous feed screen press, showed that dairy cattle manure can be fractioned into two portions with greatly different physical and chemical properties. The manure press cake was high in cell wall contents (70%) and the liquid fraction was high in crude protein (49.6%, dry basis).

Value of Cattle Waste in Non-Ruminant Diets. Microbial synthesized B-complex vitamins appear in the feces. This was shown by Hammond (1942). In 1944, he showed that dried cattle manure, when supplemented with riboflavin and vitamin A, was a highly satisfactory substitute for alfalfa leaf meal in poultry rations. The dried manure was reported to be similar in composition to and vitamin content of alfalfa leaf meal.

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. Nitrogen retention for the dried manure, determined by regression, was zero. The dried manure contributed no metabolizable energy when fed to broilers 28 to 55 d of age, but for layers the dried cattle manure supplied approximately .50 Kcal of metabolizable energy per gram. The authors concluded that the lack of nutritional contributions from dried cattle waste makes it unsuitable for inclusion in poultry diets, unless the purpose is to

lower nutrient density. Bohstedt et al. (1943) reported that cattle manure replaced the need fro brewers yeast or alfalfa meal in pig diets. They suggested that the nutritive value of the manure was not entirely the result of undigested grains.

Swine Waste

Orr et al. (1971) reported that corn-soybean meal diets with 22% dried swine feces were accepted by swine up to 95% of the amount consumed by the controls.

Kornegay et al. (1977) fed unprocessed and dried swine feces in two metabolism trials and reported apparent digestibility values for dry matter, crude protein and energy, calculated by difference, as 48, 60 and 47% respectively. Berger et al. (1980) ensiled orchardgrass hay with swine waste in various ratios. Ensiling parameters as measured by pH and lactic acid levels, were best for the 40:60 to the 60:40 mixtures. Dry matter digestibility was similar for the mixtures as for orchardgrass hay alone. Dry matter intake was also comparable to that of orchardgrass hay alone.

Yokoyama and Nummy (1976) ensiled corn plant (77%) and swine waste (23%) and reported pH and lactic acid levels as 3.9 and 8.3%, respectively.

Poultry Waste

Ensiled Caged Layer Waste. Saylor and Long (1974) ensiled corn stover with caged layer waste in various ratios. The 40:60 ratio was

reported to have the highest in vitro digestibilities for organic matter and crude protein. Chopped whole corn plant was ensiled with 5, 10 and 15% dried caged layer waste (Kali and Merrill, 1975). The diets were readily consumed. Veyez and Dobbins (1975) ensiled 30% dried caged layer waste, 50% ground corn and 20% poultry litter supplemented with molasses. The silage mixtures were readily consumed by Holstein steers. Samuels (1980) ensiled caged layer waste with sugarcane bagasse at various levels. Dry matter digestibility was highest for the silage with 60% caged layer waste compared to 30 and 40% levels. Kutty and Prasad (1980) prepared silages by enriching sugarcane tops with 1% urea and dried poultry waste to supply 15 and 30% of the total dry matter. Nitrogen digestibility and retention were higher for lambs fed 30% waste, compared to those fed urea treated silage.

Ensiled Broiler Litter. Ensiling broiler litter is considered the most economical method of processing the litter (Smith and Wheeler, 1979). Harmon et al. (1975a) ensiled 15 and 30% broiler litter with corn forage, dry basis, and reported apparent digestible dry matter was comparable to that of corn silage. Jacobs (1975) carried out experiments with wethers fed broiler litter and barley (50:50, dry basis) either unprocessed or ensiled for 3 or 6 w. Ensiling increased feed intake or wethers. He observed increased digestibility of dry matter and nitrogen in the ensiled mixtures compared to the unprocessed mixture. Caswell et al. (1977) ensiled broiler litter containing 19% moisture with corn grain (26% moisture) in a 1:2 ratio. Ensiling parameters were not as good as for corn ensiled alone.

Potential Hazards from Feeding Animal Waste

Pathogenic Bacteria and Molds. Harmon et al. (1975b) reported a lower coliform count in corn-litter silages compared to control corn silage. Creger et al. (1973) reported that litter silage tested negative for coliforms, salmonella and staphylococci. Temperature and pH play a vital role in destroying salmonella in ensiled mixtures (McCaskey and Anthony, 1975). The minimum temperature and pH suggested for the destruction of salmonella was 25 C and 4.5, respectively.

Aflatoxins, especially from Aspergillus flavus, are metabolites that could be produced in animal feeds that support the growth of these fungi (Cast, 1978). Aflatoxin formation has been reported by Hendrickson and Grant (1971) to be higher in fresh cattle waste than in stockpiled waste. Westing and Brandenburg (1974) reported that a 60 d stockpiling period was effective in eliminating aflatoxins.

Hormones and Medicinal Drugs. Mellin and Erb (1966) reported feces and urine were rich sources of estrogens in cycling cows. Subcutaneous implants of 24 or 36 mg diethylstibestrol (DES) in growing heifers caused a significant increase in estrogen excretion for 60 d (Callantine et al., 1961). Lambs given an oral dose of DES at levels of 1 and 2 mg daily excreted 76 and 84% of the intake (Story et al., 1957). However, Westing and Brandenburg (1974) found no detectable levels of DES in livers of steers fed a 14% cattle waste diet. Studies by Westing and Brandenburg (1974) indicate that antibiotic residues were absent in stockpiled cattle waste. Webb and Fontenot (1975) in two trials with broiler litter reported that no detectable levels of the

various antibiotics and coccidiostats were detected in tissues of steers that were fed the litter.

Pesticides. Fontenot et al. (1971a) reported mean DDT and DDT metabolite value .095 ppm for broiler litter samples from three major broiler producing areas in Virginia. Feeding broiler litter at 25 and 50% of the diet did not affect levels of pesticides in the liver and omental fat of yearling steers. Westing and Brandenburg (1974) reported total DDT levels in kidney fat of steers fed a 14% cattle waste (dry basis) diet as .14 compared to .11 ppm, dry basis, for the control diet. Rabon(2-chloro-1(2,4,5,-trichlorophenyl) vinyl dimentyl phosphate) is administered orally to control ectoparasites and fly larvae in manure. Feeding Rabon at levels up to 250 ppm did not affect dairy cattle performance and the pesticide did not accumulate in the milk (Miller and Gordon, 1973). Ivey et al. (1968) also reported that Rabon is relatively non-hazardous.

Minerals. The major minerals of concern to the Food and Drug Administration (FDA) are arsenic, cadmium, mercury, selenuim and lead. These minerals have the potential to accumulate in meat, milk and eggs (Anonymous, 1977). Many minerals, such as cadmium, lead and mercury, are poorly absorbed from the digestive tract (Underwood, 1977) and may accumulate in excreta. Potential mineral toxicity can arise when feeding animal wastes across species. Fontenot et al. (1971a) fed ewes 25 and 50% broiler littler for 254 d and reported mortality rates of 64 and 55%, respectively, due to cooper toxicity.

Webb and Fontenot (1975) in two feeding trials of 121 and 198 d, fed broiler litter at 25 and 50%. Following a 5-d withdrawal period, cattle were slaughtered and liver and longissimus muscle were assayed for arsenic. The highest average value of .627 ppm, dry basis, was observed in cattle fed 50% litter. This value is below the FDA tolerance level of 1 ppm. Sheep were fed poultry waste at 0, 25 and 50% of the diet in an 88-d feeding trial and teh respective copper levels were 30, 24, 35 ppm, dry basis (Thomas et al., 1972). At slaughter, liver and kidney copper values were not significantly different across treatments.

Regulatory Aspects of Feeding Animal Waste

The Food and Drug Administration (FDA) in a policy statement in 1967 indicated that it did not sanction the feeding of poultry litter to animals and this policy was expanded to include other animal species (Taylor, 1971, and Taylor et al., 1974). The Association of American Feed Control Officials (AAFCO, 1979) developed a model regulation for processed animal wastes. In 1980, FDA issued a policy revoking its announced policy regarding the use of poultry litter as animal feed ingredient. The FDA authorized the individual states to govern the use of animal waste.

Composition and Nutritive Value of Sugarcane Molasses

The composition of molasses varies with the source but in general molasses is composed of 63.5% sucrose and reducing sugars, .9% N,

.07% P and 1.15% Ca (Wythes et al., 1978). Reaves and Henderson (1963) estimated that 25 to 50% of the nutritive value of molasses may be lost in the fermentation process. Allen and Fitch (1942) and McCullough and Neville (1960) reported improved performance of steers fed molasses treated alfalfa silage compared to the controls fed alfalfa silage alone. Dry matter intake and average daily gain were greater for the molasses silage compared to the control. Huffman et al. (1957) and Mather et al. (1960) reported that molasses treated (5%) alfalfa silage supported and maintained milk production at the same level as the control group fed corn silage. Soybean silage with 4% molasses (King, 1944) was fed to dairy cows with no difference in milk production compared to alfalfa silage.

Nutritive Value of Corn Stover and Straw

Crop residues are by-products of grain production which includes the stalks, leaves, cob and husks left in the field after harvesting the grain. The composition of the residues is variable. Leask and Daynard (1973) reported that 38% of the above ground dry matter of corn was stover. In the United States alone, corn crop residues are estimated to be 162 million metric tons of dry matter (Keys and Smith, 1981) which is approximately equivalent to the amount of grain produced. Corn stover contains considerable energy but is deficient in nitrogen, minerals and vitamins (Colenbrander et al., 1973). Colenbrander et al. (1971) reported that corn stover contained 6.4% crude protein, 68.7% NDF, 47% ADF, 21.7% hemicellulose, 31.8% cellulose and 7.9% lignin.

Braman and Abe (1977) reported that dried, untreated wheat straw contained 2.8% crude protein, 4.3% ash, 81.8% cell wall constituents, 42.7% ADF and 36.6% crude fiber. An earlier report by Klenett et al. (1972) showed wheat straw contained 3.1% crude protein and 41.7% crude fiber. Oat straw was reported by Saxena et al. (1971) to contain 5.2% crude protein, 73.4% NDF, 56.5% ADF, 10.5% acid detergent lignin and 2.7% silica.

The stage of maturity of the forage plants has tremendous impact on the feeding value and digestibility by ruminants. It has been established that as plants mature, the lignin content increases (Kamstra et al., 1958), and lignin has very low digestibility. Braman and Abe (1977) reported that untreated wheat straw had an in vitro dry matter digestibility of 24.3%. This can be improved by treating with chemicals such as sodium hydroxide. Klopfenstein (1978) reported that chemical treatment of crop residues increased digestibility by 10 to 20 percentage units.

JOURNAL ARTICLE

Summary

A small silo study was conducted to determine the optimum combination of slurry and fresh dairy waste and crop residues to achieve good ensiling. Slurry waste that had been accumulated in slurry storage tanks and dairy waste scraped from the barn were ensiled with ground corn stover, with and without the addition of 5% molasses, to achieve two dry matter levels of 30 and 35%.

Fermentation, as measured by pH, lactic acid and disappearance of soluble carbohydrates, occurred in all silage mixtures. Lactic acid levels indicated that a more desirable fermentation had occurred in the waste silages containing molasses. Total and fecal coliforms and salmonella, shigella and proteus organisms were either destroyed or essentially eliminated following ensiling.

A large silo study was conducted with the mixtures containing molasses. The fresh waste was diluted with water to achieve the same dry matter levels as the slurry waste. The mixtures for the 30 and 40% dry matter levels were 71:39 and 64:36 cattle waste to wheat straw, wet basis.

Active fermentation occurred in all silages and pH was lower and lactic acid levels were much higher than they were in the small silo.

In a metabolism trial conducted with lambs, the following diets were fed: 1) 50% orchardgrass hay, 38.3% ground corn, 11.4% soybean meal and .3% limestone (basal diet); 2) 50% basal and 50% ground wheat

straw ensiled at 50% dry matter (negative control); 3) 50% basal and 50% 71:29 slurry-wheat straw silage; 4) 50% basal and 50% 64:36 slurry-wheat straw silage; 5) 50% basal and 50% 71:29 fresh waste-wheat straw silage and 50% basal and 50% 64:36 fresh waste-wheat straw silage (proportions of basal and silages were on a dry basis).

Apparent dry matter digestibility was higher ($P < .01$) for the basal diet than for the silage diets and was higher for the waste containing silages ($P < .05$) than for the wheat straw silage diet. Dry matter digestibility of the waste-containing silages, calculated by difference, was not different, but was higher ($P < .01$) than for the ensiled wheat straw alone. Nitrogen digestibility was higher ($P < .05$) for the waste containing silages, compared to the wheat straw silage but lower ($P < .05$) than the basal ration.

All lambs were in positive nitrogen balance, with the lambs fed the 71:39 slurry waste silage slightly higher than for those fed the other diets. The lambs fed the basal and wheat straw silages had similar nitrogen retention.

Ruminal ammonia levels were highest ($P < .05$) for the lambs fed the basal and lowest for those fed the wheat straw silage diet. There were no significant differences ($P < .05$) among the waste-containing silages.

The palatability trial with lambs was conducted using 50% basal and 50% of the silages, dry basis. Dry matter intake was highest ($P < .05$) for the basal diet. Dry matter intake among the silage diets was lowest ($P < .05$) for the slurry waste silage diets. Among the waste-containing silage diets, dry matter intake tended to be higher

for the fresh waste silages, compared to the slurry waste silages of similar dry matter.

Introduction

Intensive management systems of the dairy cattle industry have led to problems of waste accumulation and disposal. The traditional method of disposal has been the application of the waste on farm land. However, the increasing volume of waste produced annually, the high cost of transportation and environmental concerns have stimulated the development of alternative uses.

Animal wastes possess substantial nutritional value (Hammond, 1942; Lillie et al., 1948), especially for ruminants. In order for these waste materials to be used as animal feed, it is essential that they are free from pathogenic organisms which may present a potential health hazard to both livestock and humans.

Ensiling of waste usually with other ingredients (Anthony, 1969, 1970; Harmon et al., 1975) has been effective in destroying salmonella and coliforms. Dairy cattle waste presents a problem because of its high moisture content and that it cannot be ensiled alone. Storage of the waste also presents problems. Bates (1976) and Bates and Anderson (1979) conducted a study on potential problems associated with manure-storage pits and concluded that units of this type must have a carefully planned ventilation system to avoid odor build up. There were also problems with gutter cleanliness. In order to effectively utilize the waste, it would be necessary to ensile with materials low in

moisture two or more times per week, which is not practical unless a large number of animals can be concentrated.

A recent development in storing dairy cattle waste is the use of slurry storage tanks, which facilitates handling and feeding. This would permit accumulation of sufficient quantities of waste to utilize equipment and labor effectively. However, prior to embarking on this kind of venture, critical information is needed concerning the stability and ensiling characteristics of the dairy waste stored in these tanks. This experiment was designed to determine the nutritional characteristics of fresh dairy waste (24 h old) and dairy slurry stored in slurry tanks, to determine the optimum combination(s) of dairy waste and other ingredients in order to achieve good ensiling and to test the effectiveness of ensiling dairy waste on the destruction of potential pathogens.

Experimental Procedure

Small Silo Study. A small silo study was conducted to determine the fermentation characteristics, microbial parameters and optimum combination of dairy waste and corn stover needed to achieve good ensiling. Waste[1] was collected from dairy cattle housed on solid concrete floor without bedding. Two waste sources were collected--fresh waste (24 h old) and slurry waste (stored in slurry tanks for at least 6 mo). The dairy cattle were fed a conventional corn silage and concentrate

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[1]Obtained from Stevens Dairy Farm, Fincastle, Va.

diet, supplemented with vitamins and minerals.

The fresh waste was scraped from the barn and collected into a 210 liter metal drum double lined with .08 mm polyethylene bags. The slurry waste was collected in a similar drum. The slurry in the storage tank was mixed for about 1 h and a sample obtained through a delivery side arm on the storage tank. Both fresh and slurry waste sources were transported to Blacksburg and ensiled the same day. Corn stover was ground in a tub grinder[2] through 1.9 cm screen. Silages were prepared by adding the dairy waste to pre-weighed corn stover in a mixer to achieve the required ratios of waste to corn stover (wet basis). The fresh and slurry wastes were ensiled in proportions to achieve 30 and 35% dry matter levels, with and without the addition of 5% molasses. Fourteen kilograms of each mixture were prepared.

Six laboratory silos per treatment, each containing about 2 kg of mixture, were prepared. The materials for ensiling were firmly packed in 3.8 liter cardboard containers, double lined with polyethylene bags. Each bag was individually sealed after expelling air. Samples for microbial analysis were aseptically taken and placed in sterile plastic bags and frozen until tests were initiated with 24 h. Samples for dry matter were also taken.

After 42 days, one silo in each treatment was opened and the appearance and odor were noted. The top 5 cm of the ensiled material were removed and samples were taken aseptically from the center. Water extracts of the pre- and post-ensiled mixtures were prepared by mixing

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[2]Sperry-Holland, New Holland, Pa.

25 g samples with 225 ml of sterile distilled water in sterile .5 liter jars in a Waring blender (Harris et al., 1975). The suspension was then filtered through four layers of cheesecloth and the filtrate was immediately used for the quantitative tests for total coliforms (Anonymous, 1967), fecal coliforms (Millipore, 1973) and qualitative tests of salmonella, shigella and proteus (Lewis, 1964). The filtrate was also used to measure pH (electrometrically), lactic acid (Barker and Summerson, 1941, as modified by Pennington and Sutherland, 1956), volatile fatty acids (Erwin et al., 1961) and water soluble carbohydrates (Dubois et al., 1956, as adapted to corn plants by Johnson et al., 1966). Dry matter of all the samples was determined by weighing 200 g duplicate samples and drying in a forced-draft oven at 60 C for 48 h.

Large Silo Study. Based on the results of the small silo study, a large silo study was conducted in which dairy cattle waste and rye straw were ensiled in proportions to obtain dry matter levels of 30 and 40%. Both fresh waste and slurry were ensiled with 5% dry molasses. The proportions of slurry waste and straw corrected for molasses were 71:29 and 64:36 for the 30 and 40% dry matter levels, respectively. The wastes were collected from the same sources as for the small silo study. Rye straw was ensiled at 50% dry matter by addition of water. Wastes were obtained from storage tanks (slurry) and from scraping directly from the barns (fresh). Samples were taken for chemical and microbial assays. Preparation of the slurry mixtures was achieved by adding weighed amounts of slurry onto pre-weighed ground rye straw in a

scale equipped mixing wagon. The fresh waste was diluted with water to the same dry matter as the slurry. The wastes were slowly added to ground rye straw, followed by addition of the molasses. Mixing was in a horizontal mixer for approximately 30 min. Mixtures were directed into 210 liter metal drums double lined with .08 mm polyethylene bags. As the mixtures were delived into tne drums, samples were taken aseptically for microbial analysis within 24 h. Samples were also taken, subsampled and frozen for chemical analysis. The silages were packed tightly to exclude air by trampling and the polyethylene bags were individually sealed. All silos were allowed to ensile for a minimum of 42 d. Upon opening, the top 5 cm of each silo were discarded. Samples were aseptically taken for determination of microbial counts, fermentation characteristics, Van Soest components and crude protein.

Digestibility and Nitrogen Balance Trial. This study was conducted to determine the apparent digestibility and nitrogen utilization by ruminants of the waste-straw silages from the large silos. The following diets were fed: Basal diet composed of 50% orchardgrass hay (IFN 1-03-427), 38.3% corn (IFN 4-02-931), 11.4% soybean meal (IFN 5-20-637) and .3% limestone (IFN 6-02-632): 1) alone or in a 50:50 ratio with 2) 30% DM ensiled slurry-straw, 3) 40% DM ensiled slurry-straw, 4) 30% DM ensiled fresh waste-straw, 5) 40% DM fresh waste-straw and 6) 50% DM ensiled straw. Dry matter intake was equalized (700 g) among treatments. Ten grams of iodized salt were fed per day. One half of the diet was fed at 0500 h and the other half

at 1700 h. Water was available at all times except at each feeding.

Two metabolism trials were conducted using 18 crossbred wethers with an average weight of 30 kg. The animals were placed in three blocks of six animals each according to breeding, and the sheep within each block were randomly allotted to metabolism stalls and to the treatments. In re-randomization for the second trial, animals were not allowed to receive the same diet as in the previous trial.

The lambs were treated for internal parasites immediately after being placed in the metabolism stalls, similar to those described by Briggs and Gallup (1949), which permitted separate collection of urine and feces. A 5-day adaptation period to the stalls was followed by a 10-day transition period, a 10-day preliminary period and a 10-day period during which urine and feces were collected. The diets were sampled at each feeding 2 d before the start and 2 d prior to the end of the collection period. Samples were frozen in plastic bags. At the end of the sampling period (10 d), samples were composited and subsampled for chemical analysis. Refusals were collected daily and frozen. These were composited and subsampled for chemical analysis at the end of the trial.

Feces were collected each morning and dried in a forced draft oven at a maximum of 60 C until the next morning. They were composited in metal cans, by animal. At the end of the trial, fecal composites were weighed, mixed and subsampled. Urine was collected in polyethylene bottles which contained 15 ml of a 1:1 (w/w) solution of concentrated H_2SO_4 and water. The urine was diluted to a constant weight with water and a 2% sample was taken and placed in tightly capped

bottles and refrigerated. The samples were subsampled at the end of the trial and frozen for later nitrogen determination.

Duplicate 200 g samples of the diet components were dried in a forced draft oven at a maximum of 60 C for 48 h for dry matter determination. These samples, following equilibration with air, and the dry feces were ground through a 1 mm screen and analyzed for dry matter (AOAC, 1980), neutral detergent fiber (Van Soest and Wine, 1967), acid detergent fiber (Van Soest, 1963), lignin, cellulose and ash (Van Soest, 1968). Hamicellulose was determined by difference. Kjeldahl nitrogen (AOAC, 1980) was determined on the wet feed ingredients, the dry samples and the urine.

Ruminal fluid samples were obtained on the last day of collection via a stomach tube 2 h post feeding. The samples were strained through four layers of cheesecloth and the pH was determined electrometrically. The ruminal fluid was analyzed for ammonia nitrogen (Conway, 1958) and volatile fatty acids (Erwin et al., 1961). Volatile fatty acids were determined on a Perkin-Elmer 881 gas chromatograph. Blood samples were taken 6 h after feeding by jugular puncture and analyzed for blood urea nitrogen (Coulombe and Favreau, 1963).

Sheep Palatability Trial. A palatability study was conducted with 30 crossbred wether lambs averaging 30 kg body weight. The lambs were assigned to five blocks by breed and weight and randomly allotted within blocks to the six diets given for the matabolism study. Lambs were placed in individual 6 m x 2 m stalls in a semi-enclosed barn. Water was provided ad libitum and lambs had access to iodized salt.

The lambs were provided with fresh feed every 12 h at about 10% in excess of intake. A 2-d adaptation period was followed by a 5-d transition, 7-d preliminary and a 7-d measurement period. During the measurement period, refusals were collected once daily and dried at 100 C in a forced draft oven. Diet samples were taken during the trial, frozen and later composited, subsampled and dried for dry matter determination.

All lambs were weighed before the start and at the end of the palatability trial. The average weight was used to determine metabolic size ($W_{kg}^{.75}$), on which dry matter intake was calculated.

Statistical Analyses. Statistical analyses were performed by the General Linear Models (GLM) of the statistical analysis system (SAS, 1979). Results of the small silo study were analyzed as a 2 x 2 x 2 factorial arrangement of treatments using the orthogonal contrasts: 1) slurry vs fresh waste, 2) dry matter, 3) additives, 4) interactions.

The results of the metabolism and palatability trials were analyzed using GLM (SAS, 1979). The following orthogonal contrasts were tested: 1) slurry vs fresh waste, 2) basal vs silages, 3) straw vs waste, 4) dry matter, 5) DM x kind of waste (fresh vs slurry).

RESULTS AND DISCUSSION

Chemical Composition and Fermentation Parameters

Small Silo Study. The dry matter content of the fresh dairy waste and slurry was 13.8 and 4.4% respectively (table 1). The crude protein content of the fresh waste and slurry was 14.8 and 16.5%, dry basis, respectively. The crude protein content of the fresh waste is slightly lower than the value of 17.2% reported by Lamm et al. (1979) for cattle waste but comparable to the value of 13.2%, dry basis, reported by Lucas et al. (1975) for cattle feces. Similar crude protein levels to those in the present study were reported by Smith et al. (1971) for dried dairy cattle manure and Lipstein and Burnstein (1973) for dried cattle manure. Neutral detergent fiber (NDF), cellulose and hemicellulose were higher in the fresh waste than slurry waste used in this study. The NDF value for the fresh waste is similar to that reported by Shorter et al. (1981) for cattle fed a high roughage diet. The ADF, cellulose, hemicellulose and lignin values reported were all slightly lower than those obtained by Lucas et al. (1975) for cattle feces and Smith et al. (1971) for dairy cattle manure.

The pH of the fresh manure was lower than for the slurry which may suggest that some fermentation had occurred (table 1). The initial pH of silages differed ($P < .05$) between the two waste sources reflecting differences in pH of the wastes (table 2). Initial lactic acid levels were .2% or less of the dry matter. The initial soluble carbohydrates

TABLE 1. CHEMICAL COMPOSITION AND FERMENTATION CHARACTERISTICS OF DAIRY CATTLE WASTE AND GROUND CORN STOVER, SMALL SILO STUDY

Item	Fresh waste	Slurry	Corn stover
Chemical composition			
Dry matter %[a]	13.8	4.4	91.2
Crude protein[b]	14.8	16.5	5.9
Neutral detergent fiber	58.6	53.2	79.2
Acid detergent fiber	40.1	40.0	48.6
Cellulose	21.3	19.1	37.5
Hemicellulose	18.5	13.2	30.6
Lignin	12.3	12.0	8.7
Fermentation parameters[c]			
pH	5.4	7.1	8.2
Lactic acid[b]	.34	.2	0.0
Water soluble[b] carbohydrates	3.8	4.9	6.4

[a]Each value represents the average of 5 samples

[b]Percent of dry matter

[c]Average of two samples

TABLE 2. FERMENTATION CHARACTERISTICS OF THE DAIRY WASTE-CORN STOVER SILAGE MIXTURES, SMALL SILO STUDY

Item	No Additive				Molasses[a]				SEM
	Slurry		Fresh Waste		Slurry		Fresh Waste		
	30% DM[b]	35% DM[b]	30% DM[b]	35% DM[b]	30% DM[b]	35% DM[b]	30% DM[b]	35% DM[b]	
pH									
Pre-ensiled[c]	7.20	7.90	5.9	6.1	6.9	7.8	5.7	6.1	.05
Post-ensiled[cdfg]	5.5	5.2	5.3	5.1	5.1	5.1	4.8	4.8	.04
Lactic Acid[e]									
Pre-ensiled	.1	.09	.13	.13	.2	.3	.2	.2	.03
Post-ensiled[dfhi]	.5	.23	.21	.51	2.1	2.34	2.60	2.5	.10
Water Soluble Carbohydrates[e]									
Pre-ensiled[cd]	5.2	4.8	3.7	4.8	7.5	6.3	5.5	7.2	.11
Post-ensiled[ghi]	1.6	1.1	1.1	1.4	3.3	1.4	1.8	2.3	.06

[a] Five percent molasses, dry basis

[b] Estimated dry matter

[c] Slurry and fresh waste differ ($P < .05$)

[d] Waste without additive differ from wastes with additive ($P < .05$)

[e] Percent of the dry matter

[f] Waste by additive interaction ($P < .05$)

[g] Dry matter by additive interaction ($P < .05$)

[h] Waste by dry matter interaction ($P < .01$)

[i] Waste by dry matter by additive interaction ($P < .01$)

were higher ($P < .05$) in the mixtures containing blackstrap molasses. There was a general tendency for initial water soluble carbohydrates to be higher for the higher dry matter mixtures when fresh waste was used and an inverse trend for the slurry.

After ensiling all silages had mold growth at the top but generally the manure odor was eliminated. The fresh waste silages with addition of molasses had an aroma indicative of satisfactory ensiling. The other silages had stronger, more pungent smells.

The post-ensiled pH values (table 2) were higher than the value of 4.0 to 4.2 reported by Anthony et al. (1973), but comparable to the drop in pH to about 5.0 reported by McClure et al. (1973) for wastes ensiled with straw. Post-ensiled lactic acid levels were quite low for ensiled mixtures without additive. The addition of molasses increased lactic acid levels ($P < .05$). During the fermentation process water soluble carbohydrates were used as the substrate for acid production as shown by the decrease in water soluble carbohydrates during ensiling. The higher levels of the water soluble carbohydrates in the waste silages with additive may explain the higher levels of lactic acid in these ensiled mixtures, compared to those without additive. There was a waste by additive and waste by dry matter interactions ($P < .05$) for post ensiled lactic acid, and dry matter by additive and waste by additive interactions ($P < .01$) for the post-ensiled water soluble carbohydrates. Woolford (1972) indicated that species such as Streptococcus fecalis produce lactic acid between pH 6.5 and 5.0 and Lactobacillus plantarum produce the acid at pH below 5.0. The pH of the ensiled mixtures ranged from 4.8 to 5.5 which falls within the range of the lactic

acid producing bacteria. However, the lower levels of lactic acid in the waste mixtures without additive may be due to conversion to volatile fatty acids or lack of fermentable carbohydrates. Cornman (1979) ensiled various proportions of rye straw to waste and reported an increase in lactic acid from 1.65 to 4.16% of the dry matter. A similar value of 4.79% was reported by Harpster et al. (1978).

Acetic, propionic and buytric acids were the only volatile fatty acids detected, with acetic acid accounting for over 50% of the total VFA production (table 3). Fresh waste silages tended to have a higher level of acetic acid than slurry silages, while the propionic and butyric acid levels were higher for the slurry silages compared with those of the fresh waste silage. Molasses addition did not affect VFA concentration. However, there was a waste by additive interaction ($P < .01$) for acetic acid and DM by additive interaction ($P < .01$) for propionic acid.

Total coliforms were detected in all pre-ensiled mixtures, with higher counts in the fresh waste silages than the slurry silage (table 4). Proteus were cultured in all fresh waste silages but not in the slurry silage. This trend seems to suggest that some fermentation might have taken place in the slurry waste prior to ensiling. Ensiling eliminated total coliforms in the slurry silage and reduced total and fecal coliforms in the fresh waste silages without additive and eliminated all of the organisms on mixtures with additive. Knight et al. (1977) found no detectable levels of coliforms after 5 d of ensiling rations containing cattle waste. McCaskey and Anthony (1975) observed a decrease in coliform counts from 917×10^6 to 1.2×10^3/g in cattle

TABLE 3. EFFECT OF ENSILING VARIOUS PROPORTIONS OF DAIRY WASTE AND CORN STOVER UPON VOLATILE FATTY ACID PRODUCTION, SMALL SILO

	No Additive				Molasses[a]				
	Slurry		Fresh Waste		Slurry		Fresh Waste		
Volatile fatty acids	30% DM[b]	35% DM[b]	30% DM[b]	35% DM[b]	30% DM[b]	35% DM[b]	30% DM[b]	35% DM[b]	SEM
	%, dry basis								
Acetic[cdeg]	2.4	2.1	3.3	3.3	2.4	2.5	4.5	4.5	.06
Propionic[cf]	1.1	.8	.7	.4	.8	.8	.5	.5	.04
Butyric[c]	.9	.8	.3	.2	.1	.6	.3	.2	.03
Total[cdefg]	4.4	3.7	4.3	3.9	3.3	3.9	5.3	5.2	.03

[a]Five percent molasses, dry basis

[b]Estimated dry matter

[c]Slurry and fresh waste differ ($P < .05$)

[d]Waste with molasses and without molasses differ ($P < .05$)

[e]Waste by additive interaction ($P < .01$)

[f]DM by additive interaction ($P < .01$)

[g]Waste by additive by DM interaction ($P < .05$)

TABLE 4. MICROBIAL ANALYSIS OF PRE- AND POST-ENSILED MIXTURES, SMALL SILO

Item	No Additive				Molasses[a]			
	Slurry		Fresh Waste		Slurry		Fresh Waste	
	30% DM[b]	35% DM[b]	30% DM[b]	35% DM[b]	30% DM[b]	35% DM[b]	30% DM[b]	35% DM[b]
Pre-ensiled[c]								
Total coliforms (10^3)[e]	1.05	.1	248	187.0	.6	.04	196.0	161.0
Fecal coliforms (10^3)[e]	-	-	106.0	90.9	-	-	89.0	70.8
Proteus[ef]	-	-	+	+	-	-	+	+
Post-ensiled[d]								
Total coliforms (10^2)[e]	-	-	.2	-	-	-	-	-
Fecal coliforms (10^2)[e]	-	-	.5	.5	-	-	-	-
Proteus[fg]	-	-	-	-	-	-	-	-

[a]Five percent molasses, dry basis

[b]Estimated dry matter

[c]Each value represents the mean of two samples

[d]Each value represents the mean of six samples

[e]Number of bacteria per gram of silage

[f]Qualitative analysis (+) indicates proteus cultures and (-) indicates no bacteria cultured

[g]No salmonella or shigella were cultured

waste diets ensiled for 4 d. Albert et al (1977), Berger et al. (1981) and Corman et al. (1981) reported elimination of proteus ensiled from mixtures containing wastes of different sources when the pH was between 4.4 and 5.2.

Large Silo Study. Van Soest components of the wastes used for the large silos were similar to those used in the small silo study (table 5). Molasses was added to all silages in the large silo study because of the production of higher levels of lactic acid and the improved smell associated with those silages in the small silo study.

Water soluble carbohydrate level was also higher in this study than that observed by Aines et al. (1980). Cell wall fractions of the ensiled mixtures were similar between the two sources of waste. The crude protein and ash content appear to decline as the amount of waste in the mixture declined.

There were decreases in the NDF, ADF, cellulose and hemicellulose compared to the initial mixtures, but the crude protein levels were essentially unchanged between the pre and post-ensiled mixtures (table 7). Bacterial breakdown and solubilization of the cell wall constituents may be responsible for the decrease.

The pH of the pre-ensiled mixtures (table 8) were similar except for the wheat straw mixture which was lower ($P < .01$). Lactic acid traces were observed in the pre-ensiled mixtures and this may suggest that some fermentation occurred since there was at least a 12 h delay between collecting, mixing and sampling of the wastes silages. Water soluble carbohydrate levels were slightly lower than for the small silo

TABLE 5. CHEMICAL COMPOSITION AND FERMENTATION CHARACTERISTICS OF DAIRY WASTE AND GROUND RYE STRAW, LARGE SILO

Item	Fresh Waste	Slurry	Wheat Straw
Chemical composition			
Dry matter %	16.8	5.6	89.6
Crude protein[a]	15.3	20.1	10.8
Neutral detergent fiber[a]	58.7	52.9	78.3
Acid detergent fiber[a]	40.4	39.6	49.6
Cellulose[a]	21.6	20.0	38.6
Hemicellulose[a]	18.3	13.3	28.7
Lignin[a]	12.5	12.1	14.3
Ash[a]	20.1	22.1	4.8
Fermentation characteristics[b]			
pH	8.20	7.20	6.85
Lactic acid %[a]	.10	.30	.06
Water soluble carbohydrates[a] %	7.3	6.8	6.08

[a]Percent of dry matter

[b]Each value represents average of two samples

TABLE 6. CHEMICAL COMPOSITION OF VARIOUS INITIAL PROPORTIONS OF DAIRY WASTE AND WHEAT STRAW, LARGE SILO

Components	Slurry silage		Fresh waste silage		Wheat Straw[b]
	30% DM[a]	40% DM[a]	30% DM[a]	40% DM[a]	
Dry matter, %	32.2	40.8	30.9	39.6	50.7
Crude protein[c]	12.4	11.9	11.2	10.8	9.8
Neutral detergent fiber[c]	68.7	67.1	69.9	71.3	77.4
Acid detergent fiber[c]	45.1	44.4	45.9	47.2	49.6
Cellulose[c]	32.8	31.6	33.8	34.9	38.6
Hemicellulose[c]	23.6	22.7	24.0	24.1	27.8
Lignin[c]	10.6	10.7	11.1	10.8	13.4
Ash[c]	8.3	7.9	7.1	6.8	5.3

[a]Estimated dry matter

[b]Water added to ensile at 50% dry matter

[c]Percent of dry matter

TABLE 7. CHEMICAL COMPOSITION OF BASAL DIET AND SILAGES[a] FED IN THE SHEEP METABOLISM AND PALATABILITY TRIALS

Components	Basal	Slurry silage		Fresh waste silage		Wheat straw[c]
		30% DM[b]	40% DM[b]	30% DM[b]	40% DM[b]	
Dry matter %	89.1	30.5	35.0	29.1	34.2	45.7
Crude protein[d]	14.1	11.8	11.5	10.8	10.5	9.7
Neutral detergent fiber[d]	44.3	55.5	56.4	58.5	57.4	57.9
Acid detergent fiber[d]	26.9	35.7	36.1	36.4	36.9	37.9
Cellulose[d]	20.6	26.4	26.3	28.1	27.7	28.6
Hemicellulose[d]	17.4	19.8	20.3	22.1	20.5	20.0
Lignin[d]	5.7	7.9	8.3	8.8	8.4	10.7
Ash[d]	5.9	8.2	7.6	7.0	6.7	5.1

[a]Addition of 5% molasses, dry basis to all silages

[b]Estimated dry matter

[c]Water added to wheat straw to ensile at 50%, dry basis

[d]Percent of dry matter

TABLE 8. FERMENTATION CHARACTERISTICS OF THE SILAGES USED IN THE LARGE SILO STUDY, PRE- AND POST-ENSILING PARAMETERS

Item	Slurry silage		Fresh waste silage		Wheat straw[b] silage	SEM
	30% DM[a]	40% DM[a]	30% DM[a]	40% DM[a]		
pH						
Pre-ensiled[c]	7.8	7.9	7.9	7.8	7.2	.01
Post-ensiled	4.7	4.8	4.7	4.7	4.5	.08
Lactic Acid[d]						
Pre-ensiled	.2	.3	.3	.2	.2	0
Post-ensiled[cef]	6.0	6.8	6.3	5.9	3.7	.08
Water Soluble Carbohydrates[d]						
Pre-ensiled[e]	5.1	4.9	5.3	5.7	5.9	.07
Post-ensiled[cef]	1.4	1.1	1.0	1.1	2.0	.05

[a]Estimated dry matter

[b]Wheat straw ensiled at 50% dry matter

[c]Dairy waste and wheat straw silages differ ($P < .01$)

[d]Percent of dry matter

[e]Slurry and fresh waste silages differ ($P < .05$)

[f]DM by kind of waste interaction ($P < .01$)

study. The post-ensiled pH was lower in the large silo study compared to that of the small silo. Lactic acid levels were considerably higher in the large silo study, compared to that of the small silo. There were no pH differences between the waste silages but the post-ensiled lactic acid levels were higher ($P < .05$) for the slurry compared to the fresh waste silage. The waste silages were also higher ($P < .01$) in lactic acid than straw silage. Undoubtedly, the addition of molasses to the waste silages contributed to this difference. Waste source did not appear to adversely influence the ensiling process as indicated by the ensiling parameters (table 8). However, there was a DM by kind of waste interaction ($P < .01$) for post-ensiled lactic acid and water soluble carbohydrates. The pH of the ensiled wheat straw tended to be lower than that of the other silages, which may be due to a lower buffering capacity of the wheat straw. Following ensiling, water soluble carbohydrates decreased in all silages. The disappearance of water soluble carbohydrates in the large silo study was considerably higher than in the small silo study of corresponding dry matter level. This may be indicative of a higher level of fermentation in the larger silo.

Of the volatile fatty acids (VFA), only acetic acid was detected in the silages (table 9). A possible explanation of this trend may be offered by the different biochemical pathways involved in silage fermentation. It is well known that the pathway of homofermentation of hexoses, according to the Embden-Meyerhof scheme, in its initial stages, leads to pyruvate. Pyruvate is then hydrogenated to lactic acid (Franke and Buchta, 1960). In an earlier research report by

TABLE 9. EFFECT OF ENSILING VARIOUS PROPORTIONS OF DAIRY WASTE AND WHEAT STRAW UPON VOLATILE FATTY ACID PRODUCTION, LARGE SILO STUDY

Volatile fatty acids, %	Slurry silage		Fresh waste silage		Wheat straw[b]	SEM
	30% DM[a]	40% DM[a]	30% DM[a]	40% DM[a]		
	%, dry basis					
Acetic[cdef]	2.4	1.9	1.8	3.1	2.6	.03
Propionic[e]	.0	.0	.0	.0	1.1	.01
Isobutyric[e]	.0	.0	.0	.0	.4	.02
Butyric[e]	.0	.0	.0	.0	.7	.01
Total[cdef]	2.4	1.9	1.8	3.1	4.8	.05

[a]Estimated dry matter (DM)

[b]Water added to ensile at 50% dry matter

[c]30% DM and 40% DM waste silages differ ($P < .01$)

[d]Slurry and fresh waste silages differ ($P < .01$)

[e]Waste silages differ from straw silage ($P < .01$)

[f]DM by kind of waste interaction ($P < .01$)

Fred et al. (1921), the accumulation of acetic acid in silage was due to the activity of heterofermentative lactobacilli. This is in contrast to current knowledge which indicates that heterofermentation according to the Dickens-Horecker-mechanism is initiated by an asymmetric split of glucose into one molecule of CO_2, one molecule of ethanol and one molecule of lactate. Nelson and Werkman (1935) assumed that ethanol was dehydrogenated by lactobacilli, while Peterson and Fred (1920) believed lactic acid would be oxidized in a second step to pyruvate and acetate. This possibility has been recognized by Bucher (1970). Pentoses, often common components in silages, derived from hemicellulose hydrolysis (Dewar et al., 1963), are metabolized by producing nearly equimolar amounts of lactic and acetic acids. Other organic acids, notably citrate and malate are also fermented, resulting in the formation of lactate, acetate, formate and ethanol (McDonald and Whittenbury, 1973). The ensiling parameters of the large silo study, as indicated by pH, lactic acid production and disappearance of water soluble carbohydrates, suggest that good fermentation occurred.

The trend in microbial populations (table 10) are similar to those reported for the small silo study. Initial total and fecal coliforms counts were higher in the fresh waste silages. Proteus organisms were detected in all silages but were considerably higher in the fresh waste silages, compared with those of the slurry silages. Ensiling resulted in the total destruction of total and fecal coliforms except for a small number in the 30% fresh waste silage mixture. McCaskey and Anthony (1975) reported a significant effect of temperature on the survival of coliforms and other bacteria in silage containing 45

TABLE 10. MICROBIAL ANALYSIS OF PRE- AND POST-ENSILED MIXTURES, LARGE SILO STUDY

Item	Slurry silage		Fresh waste silage		Wheat straw[b]
	30% DM[a]	40% DM[a]	30% DM[a]	40% DM[a]	
Pre-ensiled					
Total coliforms (10^3)[c]	15.9	12.2	315	240.5	.0
Fecal coliforms (10^3)[c]	6.3	5.8	280.0	201.5	.0
Proteus[de]	+	+	++	++	+
Post-Ensiled					
Total coliforms (10^2)[c]	.0	.0	.8	.0	.0
Fecal coliforms (10^2)[c]	.0	.0	.4	.0	.0
Proteus[de]	-	-	-	-	-

[a]Estimated dry matter

[b]Water added to ensile at 50% dry matter

[c]Number of bacteria/gram silage

[d]Qualitative analysis, (+) indicates proteus was culture and (-) indicates no bacteria

[e]No salmonella or shigella were cultured

parts ground shelled corn, 15 parts corn silage and 40 parts cattle waste. Caswell et al. (1977) detected coliforms in ensiled broiler litter-high moisture corn mixture with a pH of 6.77. Albert (1977) reported the survival of coliform bacteria in 80:20 and 60:40 mixtures of ensiled corn forage-caged layer waste with pH of 6.78 and 7.03, respectively. The pH values observed by these workers are considerably higher than those observed in this study. Ensiling was effective in completely eliminating proteus organisms in all silages. Based on the ensiling parameters of the waste silages, the destruction or reductions in microbial counts and the complete elimination of fecal odor from the silages, ensiling may be an acceptable way to utilize slurry waste.

Metabolism and Palatability Trials

Apparent Digestibility. Apparent digestibility of the dry matter in the basal diet was 70.1%, compared to the range of 52.7 to 56.0 for the silage diets ($P < .01$), (table 11). Values for crude protein were 68.3% for the basal and 59.3 to 64.1% for the silage diets ($P < .01$). There were no differences between the waste silages but the values for these silages were higher ($P < .05$) than for the wheat straw silage. Apparent dry matter digestibility tended to be higher for diets containing silages with higher levels of cattle waste. Apparent digestibility of the Van Soest components indicates that the basal diet was the most digestible ($P < .01$) for all components and the wheat straw silage diet was generally the least digestible ($P < .05$). Lignin digestibility was lower ($P < .01$) for all the silage containing diets than the basal diet. There was a general tendency for the apparent digestibility of the Van

TABLE 11. APPARENT DIGESTIBILITY OF CELL WALL FRACTIONS BY SHEEP FED BASAL DIET AND DAIRY WASTE-WHEAT STRAW SILAGES

Components	Diets[a]						
	Basal	Basal + slurry silage		Basal + fresh waste silage		Basal + wheat straw[b] silage	SEM
		30% DM[bc]	40% DM[bc]	30% DM[bc]	40% DM[bc]		
	%						
Dry matter[deg]	70.1	56.0	54.6	55.0	54.8	52.7	.44
Neutral detergent fiber[d]	61.7	46.7	46.3	47.8	46.8	44.5	.75
Acid detergent fiber[def]	59.9	43.1	42.8	44.2	43.5	39.2	.83
Hemicellulose[d]	64.3	53.1	52.7	53.7	52.2	52.9	.75
Cellulose[defg]	67.9	54.7	52.3	54.8	54.3	49.6	1.34
Lignin[d]	34.4	17.9	16.7	18.9	11.1	8.2	2.46
Crude protein[de]	68.3	64.1	61.1	62.0	59.3	59.6	.82

[a]Each value represents the mean of six animals

[b]Diets contained 50% basal and 50% silage, dry basis

[c]Estimated dry matter

[d]Basal and silages differ (< .01)

[e]30% and 40% DM waste silages differ (P < .01)

[f]Slurry and fresh waste differ (P < .01)

[g]DM and kind of waste interaction (P < .01)

Soest components to be higher with the higher level of waste. There were no significant differences between the slurry and fresh waste silages at similar dry matter level. Hemicellulose digestibility was comparable in all silages. However, cellulose digestibility was higher ($P < .01$) for the 30 than 40% DM waste silages.

The apparent digestibility of the lignin was relatively high, which may be due to artifact lignin produced as a result of heat damage during drying of the samples. Artifact lignin is the result of non-enzymatic browning reaction which is catalyzed by moisture and forms insoluble nitrogen residues. Apparent lignin content of grasses has been reported by Van Soest (1964) to increase by as much as three times the true value as a result of heat damage during drying at 80 to 100 C.

The apparent digestibility of crude protein was low for the wheat straw silage diet, which is probably due to the lower crude protein content of this silage. Holter and Reid (1959) reported that apparent digestibility increases exponentially as the concentration of crude protein increases in forages.

Apparent dry matter digestibility of the waste silages calculated by difference (Crampton and Harris, 1969) were similar, ranging from 38.3 to 40.8% (table 12). Apparent digestibility of crude protein was not different between the waste silages and ranged from 55.7 to 58.2% of the dry matter. The apparent digestibility of the cell wall fractions was not different ($P > .05$) between the waste silages. However, there was difference in apparent digestibility of NDF and ADF between the low and high DM slurry silages. The apparent digestibilities of all components were higher ($P < .05$) for waste silages compared with

TABLE 12. APPARENT DIGESTIBILITY OF DAIRY WASTE-WHEAT STRAW SILAGES BY SHEEP

Component[a]	Slurry silage		Fresh waste silage		Wheat straw[c]	SEM
	30% DM[bc]	40% DM[bc]	30% DM[bc]	40% DM[bc]		
	%					
Dry matter[d]	40.8	39.6	38.3	38.7	30.1	.86
Neutral detergent fiber[d]	34.2	30.5	31.4	31.3	25.3	1.26
Acid detergent fiber[d]	25.8	22.7	25.2	24.0	18.5	.85
Cellulose[d]	37.2	36.3	37.6	36.3	29.7	3.87
Hemicellulose[d]	38.9	39.0	40.7	39.4	31.1	.89
Lignin[d]	12.7	13.0	14.7	13.4	10.5	.72
Crude protein[d]	58.2	57.8	56.0	55.7	39.8	1.46

[a]Calculated by difference by the method of Crampton and Harris (1969)

[b]Estimated dry matter

[c]Each value represents the mean of six animals

[d]Waste silages and wheat straw silage differ ($P < .05$)

wheat straw silage alone. Within a given waste source, digestion coefficients tended to be higher as waste increased in the silage. Dry matter apparent digestibility values in all silages were lower than the average value of 52% reported by Anthony (1966) for an ensiled mixture of Coastal Bermudagrass hay and cattle manure. Cornman et al. (1981) reported dry matter digestibility of 36.19% for an ensiled mixture (60:40) of cattle waste and ground rye straw, which is slightly lower than the waste silages in this study.

In the present study, crude protein digestibility was not different ($P > .05$) between the waste sources and dry matter levels. However, with each type of waste, crude protein digestibility tended to be higher with thehigher level of waste in the silage. Lowman and Knight (1970) and Samuels et al. (1980) reported a linear increase in crude protein digestibility of the diet as dried poultry excreta was increased in the diet of sheep.

Nitrogen Utilization. Nitrogen intake, expressed as grams per day, increased with increasing levels of waste but was highest for those lambs on the basal diet (table 13). The wheat straw silage diet had the lowest ($P > .05$) intake of nitrogen, due to the lower crude protein content of the diet. Fecal nitrogen excretion was higher ($P < .05$) for sheep fed the silages than for those fed the basal. Fecal nitrogen excretion was lower ($P > .05$) for the wheat straw silage compared to the waste containing silages. Differences in fecal excretion among the waste silages were not significant, but the general trend within each waste source was towards increased fecal nitrogen excretion with

TABLE 13. NITROGEN UTILIZATION BY SHEEP FED BASAL AND DAIRY WASTE-WHEAT STRAW SILAGES

	Diets[a]					
		Basal + slurry silage		Basal + fresh waste silage		
	Basal	30% DM[bc]	40% DM[bc]	30% DM[bc]	40% DM[bc]	Basal + wheat straw silage[b]	SEM
Nitrogen intake, g/d[def]	15.5	14.2	13.8	13.6	13.0	12.4	
Nitrogen excretion, g/d							
Fecal[dfg]	4.9	5.1	5.6	5.2	5.3	4.8	.11
Urinary[d]	5.9	3.7	3.6	3.3	3.5	3.8	.56
Total	10.8	8.8	9.2	8.5	8.8	8.6	.03
Nitrogen retention							
Grams per day	4.8	5.4	4.6	5.1	4.2	3.8	.58
Percent of intake	30.7	38.3	33.6	37.6	32.6	30.4	3.98
Percent of absorbed	44.8	59.4	56.3	60.5	54.8	40.1	5.97

[a] Each value represents the mean of six animals

[b] Diets contained 50% basal and 50% silage, dry basis

[c] Estimated dry matter

[d] Basal and silages differ ($P < .05$)

[e] Slurry and fresh waste silages differ ($P < .05$)

[f] Waste silages differ from wheat straw silage ($P < .05$)

[g] 30 and 40% DM waste silages differ ($P < .05$)

increased dry matter level. Urinary excretion of nitrogen was higher ($P < .05$) for the sheep fed the basal diet, compared with the silage diets. There were no differences between the silages in urinary nitrogen excretion. With each waste source, total nitrogen excretion tended to be higher with the higher dry matter level, reflecting the higher fecal excretion. Nitrogen retention, expressed as grams per day, was not different ($P > .05$) between the basal diet and silage diets but the values for the waste silage diets tended to be higher than for the wheat straw silage diet. Nitrogen retention between the waste sources was not different. However, within the waste sources, there tended to be a greater retention of nitrogen with higher levels of waste in the silage. Nitrogen retention, expressed as a percent of intake or percent absorbed, tended to be lower for the basal diet than for the silage diets. The values also tended to be higher for the waste silage than the wheat straw silage diet. Within a given source of waste, retention in terms of percent of intake or percent absorbed, tended to increase with increased fecal waste in the silage.

Ruminal Fluid and Blood Parameters. Sheep fed the basal diet tended to have a lower rumen fluid pH value than those fed the silage diets (table 14). The pH was slightly higher for the sheep fed the slurry waste diets, compared with those fed the fresh waste diets. Ruminal fluid ammonia nitrogen was highest ($P < .05$) for sheep fed the basal diet compared with the silages. The lower ammonia-nitrogen values of the waste silages may indicate that fecal nitrogen is not readily attacked by rumen microbes. Lambs fed the wheat straw silage diet had the lowest

TABLE 14. RUMINAL FLUID pH, AMMONIA NITROGEN AND BLOOD UREA NITROGEN OF SHEEP FED A BASAL DIET AND DAIRY WASTE-WHEAT STRAW SILAGES

Item	Diets[a]						
		Basal + slurry silage		Basal + fresh waste silage			
	Basal	30% DM[bc]	40% DM[bc]	30% DM[bc]	40% DM[bc]	Basal + wheat straw silage[b]	SEM
Ruminal fluid pH	6.58	6.87	6.84	6.73	6.68	7.04	.17
Ruminal fluid NH_3-N, mg/dl[de]	26.08	18.57	18.17	17.33	17.40	13.32	.98
Blood urea-nitrogen, mg/dl[def]	24.38	18.65	15.78	17.58	15.15	11.08	1.28

[a]Each value represents the mean of six aminals

[b]Diets contained 50% basal and 50% silage, dry basis

[c]Estimated dry matter

[d]Basal and all silages differ ($P < .05$)

[e]Waste silages and wheat straw silage differ ($P < .05$)

[f]30 and 40% DM waste silages differ ($P < .05$)

($P < .05$) rumen ammonia nitrogen values, possibly due to the lower crude protein content or lower nitrogen availability of this diet. The rumen ammonia nitrogen levels observed in this study for lambs fed the waste silages compares favorably with 17.5 mg/dl reported by Cornman et al. (1981) when a 60:40 ratio (waste to rye straw) silage was fed to lambs as 50% of the total diet dry matter. Ruminal ammonia nitrogen tended to be higher for lambs fed the slurry waste silages compared with the fresh waste silages. Blood urea nitrogen levels followed the same trends as ruminal ammonia nitrogen. However, lambs fed the 30% DM waste silage diet had higher ($P < .05$) blood urea nitrogen, compared with those fed the 40% DM waste silage diet. Preston et al. (1965) found a high correlation between nitrogen intake and blood urea nitrogen levels.

Expressed as μ moles/ml, ruminal fluid acetic acid was highest ($P < .05$) for sheep fed the basal diet when compared to the silage containing diets (table 15). The sheep fed the wheat straw silage diet tended to have lower values, compared to the waste silage diets. No consistent differences were noted for propionic, isobutyric, butyric and isovaleric acids.

Within the waste sources, there was a decrease in acetic acid levels with lowered proportions of waste. Total levels of VFA tended to be higher as waste level increased in the diet. Valeric acid was detected only in the sheep fed the basal and 40% DM slurry waste silage diets. Isovaleric acid was higher ($P < .05$) for sheep fed the basal diet, compared with the silage diets. There were no differences between the silage diets.

TABLE 15. RUMEN FLUID VOLATILE FATTY ACID CONCENTRATIONS, METABOLISM STUDY

Item	Diets[a]						
	Basal	Basal + slurry silage		Basal + fresh waste silage		Basal + wheat straw silage[b]	SEM
		30% DM[bc]	40% DM[bc]	30% DM[bc]	40% DM[bc]		
Volatile fatty acids, μ mole/ml							
Acetic[d]	60.27	53.03	48.62	51.98	46.15	43.43	3.58
Propionic[d]	26.62	20.55	20.33	20.70	19.57	17.13	2.34
Isobutyric[d]	.95	.72	.68	.82	.78	.66	.06
Butyric[d]	6.75	4.88	5.02	5.18	5.85	4.66	.50
Isovaleric[d]	1.77	1.20	1.08	1.15	1.05	.98	.10
Valeric	.10	.00	.10	.00	.00	.00	.06
Total[d]	96.46	80.38	75.83	79.83	73.40	66.86	5.59
Volatile fatty acids, moles/100 moles							
Acetic	62.98	66.10	58.12	64.98	61.67	64.68	2.75
Propionic	27.02	25.40	26.55	25.97	27.65	26.00	1.81
Isobutyric	1.02	.93	.87	1.03	1.08	.97	.08
Butyric[e]	7.10	6.07	6.32	6.58	8.13	6.87	.54
Isovaleric[d]	1.82	1.53	1.38	1.47	1.47	1.48	.13
Valeric	.12	.00	.12	.00	.00	.00	.07

[a]Each value represents the mean of six animals

[b]Diets contained 50% basal and 50% silage dry basis

[c]Estimated dry matter

[d]Basal and silages differ ($P < .05$)

[e]Slurry and fresh waste differ ($P < .05$)

[f]Waste silages with different dry matter differ ($P < .05$)

Palatability Trial. Dry matter intake, expressed as grams per day, was higher ($P < .05$) for sheep fed the basal diet compared with those fed the silage diets (table 16). Intake tended to be lower for lambs fed the 30% DM silage diet compared to those fed the 40% DM silage diet. Dry matter intake tended to be higher for the fresh waste silage diets compared to slurry waste diets when expressed as g/d, but not when expressed on the basis of metabolic size. Fontenot et al. (1971) reported a decline in feed intake with increases in the level of broiler litter in the diet of steers, while Samuels (1980) reported that as the proportion of caged-layer waste increased in the diet, dry matter intake increased. No such differences were obtained in the present study. Dry matter intake when expressed on the basis of metabolic size tended to be higher for the basal diet compared to the silage diets and there were no differences between the wheat straw and waste containing silage diets.

TABLE 16. DRY MATTER INTAKE OF SHEEP FED A BASAL DIET, DIETS CONSISTING OF DAIRY WASTE-WHEAT STRAW SILAGE

Item	Diets[a]						
	Basal	Basal + slurry silage		Basal + fresh waste silage		Basal + wheat straw silage[c]	SEM
		30% DM[bc]	40% DM[bc]	30% DM[bc]	40% DM[bc]		
Grams per day[d]	1111.20	817.60	802.80	876.80	864.20	856.00	36.81
Grams per $W_{kg}^{.75}$ per day	43.50	39.84	40.16	40.20	39.58	37.00	1.97

[a]Each value represents the mean of five animals

[b]Estimated dry matter

[c]Diets contained 50% basal and 50% silage, dry basis

[d]Basal and all silages differ ($P < .01$)

CONCLUSIONS

Dairy waste accumulation has been of concern to the dairy farmer since the advent of intensive agriculture. Two problems of major concern are pollution and odor.

Recently renewed interest in ensiling of waste has offered alternative outlets for the disposal of these wastes. Dairy waste presents a special problem in having a high moisture content and cannot be ensiled alone. However, crop residues may be ensiled with the waste to achieve the desired dry matter for good fermentation.

The results of the small silo study suggest that ensiling with addition of molasses was beneficial in the fermentation process. Microbial populations were essentially destroyed and the odor was eliminated. These are desirable parameters in any recycling process that incorporates animal waste.

In the large silo study, the fermentation parameters as measured by lactic acid, pH and disappearance of soluble carbohydarates, conclusively indicate that good fermentation occurred in the silages. Sheep fed the ensiled waste silage diets retained a higher proportion of nitrogen than the wheat straw diet and digestibility also tended to favor the waste diets. Voluntary dry matter intake was lower for the slurry waste, compared with the fresh waste, however, the waste silage diets were more palatable than the wheat straw diet. The results in this study seem to suggest that dairy cattle waste stored as slurry in slurry storage tanks can be accumulated until sufficient quantities are

available for ensiling with low moisture crop residues without appreciable loss of nutrients, at least for the winter months, when low temperatures and freezing may limit volatilization of nitrogen in the form of ammonia. Nutrient characterization of slurry waste stored during summer may need investigation.

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APPENDIX

TABLE 1. EXAMPLE OF ANALYSIS OF VARIANCE, STORED AND FRESH DAIRY CATTLE WASTE-RYE STRAW SILAGES, LARGE SILO STUDY

General Linear Models Procedure

Dependent Variable: pH

Source	DF	Sum of Squares	Mean Square	F Value	PR > F[a]	R-Square	C.V.
Model	9	2.10498462	0.23388718	5.67	0.0013	0.761191	4.3511
Error	16	0.66040000	0.04127500				
					ROOT MSE	pH MEAN	
Corrected Total	25	2.76538462			0.20316250	4.66923077	

Source		Type III SS	F Value	PR > F[a]
Treat	4	0.16460000	1.00	0.4377
Rep	5	1.92635000	9.33	0.0003

[a]Level of significance

TABLE 2. EXAMPLE OF ANALYSIS OF VARIANCE, STORED AND FRESH DAIRY CATTLE WASTE-RYE STRAW SILAGES, SHEEP METABOLISM TRIAL

General Linear Models Procedure

Dependent Variable: DMDIG[a]

Source	DF	Sum of Squares	Mean Square	F Value	PR > F[b]	R-Square	C.V.
Model	11	1313.05620748	119.36874613	101.76	0.0001	0.979009	1.8938
Error	24	28.15292517	1.17303855				
Corrected Total	35	1341.20913265			ROOT MSE 1.08306904	DMDIG MEAN 57.18928571	

Source		Type III SS	F Value	PR > F[a]
Trial	1	1.03361111	0.88	0.3572
Treat	5	1227.43501701	209.27	0.0001
Trial * Treat	5	84.54757937	14.42	0.0001

[a]Dry matter digestibility

[b]Level of significance

TABLE 3. EXAMPLE OF ANALYSIS OF VARIANCE, STORED AND FRESH DAIRY CATTLE WASTE-RYE STRAW SILAGES, SHEEP METABOLISM TRIAL

General Linear Models Procedure

Dependent Variable: ASHABS[a]

Source	DF	Sum of Squares	Mean Square	F Value	PR > F[b]	R-Square	C.V.
Model	11	11341.75330537	1031.06848231	1.12	0.3894	0.339023	177.3678
Error	24	22112.43438027	921.35143251				
Corrected Total	35	33454.18768565			ROOT MSE 30.35377131	ASHABS MEAN 17.11346111	

Source		Type III SS	F Value	PR > F[a]
Trial	1	516.38472081	0.56	0.4613
Treat	5	6113.24629698	1.33	0.2865
Trial * Treat	5	4712.12228758	1.02	0.4264

[a]Ash absorbed

[b]Level of significance

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FERMENTATION CHARACTERISTICS AND NUTRITIONAL VALUE OF STORED AND FRESH DAIRY CATTLE WASTE ENSILED WITH CROP RESIDUES

by

Michael Dennis Abazinge

(ABSTRACT)

A small silo study was conducted to determine the optimum combination(s) of fresh and stored dairy waste and corn stover to achieve good ensiling. Waste stored in a glass-lined metal storage tank (slurry) and fresh waste scarped from the floor were ensiled with ground corn stover in the following proportions to achieve 30 and 35% dry basis: 70:30 and 65:35 slurry to stover and 79:21 and 73:27 fresh waste to stover, with and without addition of 5% dry molasses. Mixtures were ensiled in 4 liter cardboard containers double lined with polyethylene. Decreased pH and high lactic levels were observed for the waste-stover silages containing molasses. Total and fecal coliforms and salmonella, shigella and proteus were essentially eliminated following ensiling. In a subsequent study mixtures of waste and wheat straw mixtures, wet basis, with 5% dry molasses to achieve 30 and 40% dry matter were ensiled in 210 liter metal drums double lined with polyethylene. Water was added to the fresh waste to equalize moisture between fresh and stored waste. Active fermentation occurred in all silages. In a metabolism trial sheep were fed a basal diet alone and with the ensiled mixtures (50:50, dry basis). A diet of 50:50 basal and ensiled wheat straw, dry basis, was also fed. Dry matter

digestibility was higher ($P < .05$) for the waste containing diets than for the wheat straw silage diet, but lower ($P > .01$) than for the basal diet. The dry matter digestibility of the silages, calculated by difference, was not different among the waste containing silages, but was higher ($P < .01$) than for the ensiled wheat straw. All lambs were in positive nitrogen balance and nitrogen retention was similar among the waste containing silages.