FERMENTATION, UTILIZATION, AND PALATABILITY OF SWINE WASTE ENSILED WITH VARIOUS PROPORTIONS OF GROUND ORCHARDGRASS HAY OR GROUND CORN GRAIN

by

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INTRODUCTION

Recent trends in the swine industry to more total confinement of the entire production cycle has brought about a major waste disposal problem. Many large confinement enterprises exist on a very minimal amount of land which makes the traditional method of waste disposal, back onto the land, difficult, if not impossible.

Previous work with cattle has shown the feeding of broiler litter to be a successful method of disposing of litter and a useful protein supplement and energy source. Researchers have also successfully fed ensiled cattle waste to cattle.

Swine waste is high in nitrogen and various minerals which may be utilized by feeding. Animal wastes could be an economical source of feed while alleviating some of the waste disposal problems. Previous work has shown the dry matter digestibility of swine feces by swine to be 50%, while amino acid digestibilities ranged from 51 to 65 percent. It was reported that feed consumption decreased when fresh feces was mixed with a basal corn-soybean meal diet and limited-fed to mature gilts. The decrease in consumption was not as severe when dried feces was added instead of fresh feces.

The FDA has concerns regarding feeding of animal wastes. The apprehension of the Agency involves possible toxic levels of certain drugs, pesticides and minerals, and the possibility of disease transmission. Drying at high temperatures has been effective in destroying potential pathogens and removal of excess moisture. However, the high cost of energy needed to dry feces makes this an expensive method of preparing swine waste prior to incorporation into a feeding program.

Ensiling has been effective in preserving and simultaneously improving palatability of a feedstuff. The rapid change in pH and heat produced in the ensiling process could be an effective method of destroying pathogenic organisms. In fact, proper ensiling of animal wastes has been effective in destroying pathogens. Previous work with cattle waste and broiler litter have shown ensiling to be a practical method of preserving and storing these wastes for future use.

The present studies were undertaken to evaluate the fermentation characteristics of various proportions of swine waste and orchardgrass hay or ground corn grain when ensiled, and their subsequent nutritive value and palatability when incorporated into the diets of ruminants and nonruminants.

LITERATURE REVIEW

Poultry Waste

The two main sources of poultry waste are: 1) broiler litter and 2) caged layer manure. Broiler litter generally consists of excreta, spilled feed, feathers and bedding material. Caged layer manure consists of excreta, feathers, spilled feed and broken eggs.

Broiler Litter. The crude protein content of broiler litter varies according to the amount of spilled feed, density of the birds, number of cycles of birds, and the type and quantity of litter used (Forsht *et al.*, 1974). Bhattacharya and Fontenot (1965) found that broiler litter contained 32.6% crude protein. Hileman (1967) found the crude protein value of litter to be 30.6 percent. Crude protein values of litter have been shown to vary from a low of 25.3% (Couch, 1974) to a high of 42.5% (Fontenot *et al.*, 1971). Fontenot and Webb (1971) found considerable variation in 13 litter samples obtained from three major broiler producing areas of Virginia (30.0 ± 2.67%).

Bhattacharya and Fontenot (1966) fractionated the total nitrogen of broiler litter into 44.3% protein, 55.6% non-protein, 28.8% uric acid and 15.4% ammonia nitrogen, when the bedding material used was wood shavings. Comparable values were obtained when peanut hull litter was used. When the aforementioned litters were fed at 25% and 50% of the diet, values for digestible energy, metabolizable energy and total digestible nutrients (TDN) did not significantly differ between the kinds and amounts of litter fed.

Belasco (1954) found that uric acid is attacked by rumen bacteria and will support bacterial growth. Similar results were reported by Jurtshuk et al. (1958). Looper and Stallcup (1958) reported that ammonia in litter was a potential source of nitrogen for ruminants. Similar results were reported by Bryant and Robinson (1962, 1963). Oltjen et al. (1968), in a 21-day study, showed that percent nitrogen retained was higher for steers fed uric acid than for those fed urea, biuret or urea phosphate as the only nitrogen source in purified diets.

Bhattacharya and Fontenot (1965) reported positive nitrogen balance in lambs when 100% of the dietary nitrogen was from broiler litter. Ammerman et al. (1966) found a significant increase in apparent digestibility of crude protein and nitrogen retention in lambs when poultry litter was supplemented to a basal diet. The apparent digestibility of crude protein in broiler litter, calculated by difference, was 72.5% for sheep when supplemented for 50% of the entire ration (Bhattacharya and Fontenot, 1966). Similar results were observed by McInnes et al. (1968).

Poultry litter contains large amounts of calcium (2.35 ± .9%) and phosphorus (1.8 ± .4%), compared to natural feedstuffs (Bhattacharya and Taylor, 1975).

Perez-Aleman et al. (1971) fed broiler litter (hard wood shavings) as a filler to growing swine at levels of 10, 20, and 30% of the ration dry matter. Poor feed conversion occurred with increasing increments of broiler litter in the ration.

Lactating ewes fed a ration containing 23% ground poultry litter performed similarly to ewes fed a control ration containing soybean meal (Noland _et al._, 1955). Fontenot _et al._ (1966) reported similar performance and carcass quality in steers fed a ration containing 25% broiler litter (corn cob base) and steers fed a control ration, plus a small amount of long hay. Feed efficiency for the litter containing ration was 9% higher than the control ration. Beef cows have been successfully wintered for over 5 years on a ration consisting of 80% broiler litter and 20% corn grain plus small amounts of roughage without any detrimental effects (Webb _et al._, 1978). Stonestreet _et al._ (1966) reported that 2.5 kg of broiler litter were equivalent to 1.0 kg of soybean meal based on performance of cattle fed corn silage supplemented with broiler litter or soybean meal.

Caged Layer Manure. The crude protein content of caged layer wastes averaged 28% (Bhattacharya and Taylor, 1975). Liebholz (1969) reported that caged layer wastes contained 41% of the total nitrogen as amino acid nitrogen and that the NPN portion consisted largely of uric acid. Brugman _et al._ (1964) reported digestion coefficients of 77.8, 44.4, 91, and 59.2%, respectively, for crude protein, ether extract, crude fiber, and gross energy in poultry wastes fed to bulls. Lowman and Knight (1970), in sheep digestion trials, found that crude protein digestibility of poultry waste was 77.2%. Bull and Reid (1971) fed cattle a 5% protein diet alone, or supplemented with air dried chicken waste at three levels, and found the crude protein digestibility ranged between 73 and 83%, when calculated by difference.

Many researchers have shown the nitrogen of caged layer waste to be less digestible than that of barley or soybean meal (Lowman and Knight, 1970; Bucholtz et al., 1971). However, El-Sabban et al. (1970) found higher nitrogen retention in lambs fed diets containing caged layer waste, compared to those fed diets containing soybean meal. Bucholtz et al. (1971) reported no significant difference in nitrogen retention when sheep were fed supplements of either dried caged layer waste or soybean meal. Smith and Calvert (1972) reported similar findings. Lowman and Knight (1970) and Bull and Reid (1971) reported caged layer waste contained 3500 kcal of gross energy per kilogram. They found that the apparent digestibility of dry matter in caged layer waste was approximately 60% when fed to sheep.

Bhattacharya and Taylor (1975) reported calcium and phosphorus levels of caged layer waste of 8.8% and 2.5%, respectively. Bull and Reid (1971) found the availability of calcium and phosphorus of caged layer wastes was 92 and 70%, respectively, in ruminant diets when caged layer waste was the only source of supplemental nitrogen.

Rusnak et al. (1966) reported comparable daily gains of steers without any significant differences in carcass traits when the diets were supplemented with either autoclaved poultry waste or soybean meal. Smith and Calvert (1972) reported that when dried poultry waste was substituted into the diet of growing lambs for 0, 50, and 100% of the nitrogen provided by soybean meal, average daily gains were decreased slightly.

Only limited work has been done with feeding poultry waste to nonruminants. This may be due partly to the high levels of uric acid in the total nitrogen content which is of no value to nonruminants (Lee and Blair, 1972). Geri (1968) substituted dried poultry manure at levels of 7 and 10% for bran in trials with growing pigs. He found similar growth rates but feed efficiency decreased with increasing manure in the diet. Similar feed efficiencies were recorded by Phelps (1969) when dried poultry house litter was included in the diets of growing and finishing swine, compared to the finishing diet alone. Perez-Aleman et al. (1971) found a significant linear relationship between the level of manure and growth rate, and feed efficiency when 10, 20, and 30% dried poultry manure was added to a conventional diet. With every 10% increase in poultry manure, the reduction of growth was .02 kg per day and feed efficiency was decreased .25 unit.

Flegal and Zindel (1971) fed dried poultry waste to growing chicks and found that feed efficiency was inversely related to the amount of poultry waste in the diet.

Cattle Waste

Over 80% of the total livestock waste produced annually consists of cattle waste (Van Dyne and Gilbertson, 1978).

The composition of cattle waste varies with the type of ration fed and the type of surface on which the waste was collected. Anthony (1971) reported crude protein and ash contents for cattle waste were

20.3% and 11.5%, respectively. Westing and Brandenburg (1974) found crude protein and ash levels of 15.0 and 10.1%, respectively. The high ash content was probably due to soil contamination since the scrapings were from a dirt lot. Lucas et al. (1975) found that cattle waste from steers fed a ration containing 50% roughage contained 13.2% crude protein, 2.8% ether extract, 31.4% crude fiber, 5.4% ash, 47.2% NFE, and 4728 kcal gross energy/kg, dry basis. Harpster et al. (1978) reported that cattle waste analyzed 17.2% crude protein, 3.2% ether extract, 27.9% crude fiber, 43.1% NFE, 8.6% ash and 4736 kcal gross energy/kg.

Tinnimit et al. (1972) used dehydrated dairy cattle feces from cows on a corn silage and concentrate ration to supply 39 and 44% of the ration dry matter and 40 and 46% of the crude protein. When fed to sheep, the apparent digestibility of dry matter and crude protein was significantly lower for the rations containing the waste than for the control ration. When fed to steers as 31.5% of the dry matter and 65% of the crude protein along with corn silage, the apparent digestibility of dry matter, organic matter, ash, crude protein, and lignin decreased. Nitrogen retention, percent of absorbed nitrogen retained, and TDN were significantly lower for rations containing feces, compared to the control ration.

Lucas et al. (1975) determined the apparent digestibilities of heat treated dried steer feces were 16.6% for dry matter, 14.4% for organic matter, 24.4% for crude protein, 26.9% for ether extract, 17.3% for crude fiber, and 16.9% for NFE. The reported values for

TDN, digestible and metabolizable energy were 18.6%, 763 kcal/kg and 485 kcal/kg, dry basis.

Hammond (1942) used cattle waste as a vitamin source for growing chicks. Bohstedt et al. (1943) used cattle waste as a B vitamin supplement for pigs. Hammond (1944) supplemented cattle manure for alfalfa meal in poultry diets. Durham et al. (1966) used air dried cattle waste in catfish diets.

Swine Waste

Kornegay et al. (1977) reported the following values for swine waste: 23.5% for crude protein, 8.0% for ether extract, 14.7% for crude fiber, 15.3% for ash, 38.3% for NFE, and 4570 kcal gross energy/kg, dry basis. Pearce (1977) found that swine waste collected from 21 different commercial piggeries contained 18.9% crude protein, 6.6% ether extract and 18.1% ash. Waste from 24 commercial piggeries contained 19.0% crude protein, 5.0% ether extract, 18.2% crude fiber, and 16.3% ash, dry basis, respectively (Hilliard, 1977).

The chemical composition of dried swine feces was 23.9% crude protein, 9.5% ether extract and 15.0% ash, dry basis (Orr, 1974). Similar results were reported by Eggum and Christiansen (1974).

Tinnimit et al. (1972) collected and dried swine feces from finishing swine fed a 12% protein corn-soybean meal diet. The feces were substituted into a basal sheep ration to supply 32.4% of the dry matter and 89.0% of the crude protein. Sheep receiving the basal corn-soybean meal ration had a significantly higher nitrogen retention than sheep receiving the dried swine feces ration. Sheep fed the ration containing dried swine feces showed significantly lower apparent digestibility of dry matter, organic matter, nitrogen and ash.

Diggs <u>et al</u>. (1965) incorporated swine feces into the diets of finishing swine. The basal was a 14% protein corn-soybean meal ration for which either 15 or 30% of the swine feces was substituted. Average daily gains of the pigs fed the three rations were .71, .78, and .70 kg, respectively. Feed efficiencies were 3.63, 3.67, and 4.64 kg feed/kg gain, respectively. No difference was noted between treatments in the taste of the meat by a trained organoleptic panel.

Orr (1974) substituted dried swine feces, dried poultry waste, and oxidation ditch liquor into swine rations. The feeding of dried swine feces significantly reduced feed efficiency and average daily gain. Fecal and urinary output significantly increased when dried swine feces replaced the major portion of the soybean meal. When dried swine feces were fed with ground corn grain, most digestion coefficients were reduced, compared to a basal corn-soybean meal diet. When oxidation ditch liquor was fed, pig performance did not improve and the digestion coefficients for dry matter, energy, protein, and minerals decreased.

Harmon <u>et al</u>. (1971) fed oxidation ditch mixed liquor (ODML) to swine by mixing it daily with a 12% protein corn-soybean meal diet in the ratio of 2:1. The dry matter of the ODML was maintained at 3% and the oxygen content at 3.5 ppm. The other treatments consisted of the 12% protein corn-soybean meal diet alone and mixed with water in a ratio of 2 parts water to 1 part corn-soybean meal. Weight gains and feed efficiency were found to be higher for pigs on the ODML ration than the other two rations.

Harmon et al. (1972) collected waste in an oxidation ditch from swine fed a 12% protein corn-soybean meal diet. The oxidation ditch was drained and the oxidation ditch residue (ODR) was collected from the bottom of the ditch. The top layer of slime was found to contain 31.8% crude protein while the lower layer contained 24.5% crude protein, dry basis. Composites of the top and bottom layers averaged 27.7% crude protein, dry basis. The ODR was mixed and thoroughly dried at 40 Centigrade. The incorporation of ODR into the diets of Sprague-Dawley rats resulted in reduced feed efficiency with increasing levels of ODR. Eggum and Christensen (1974) reported crude protein digestibility of 60% and a biological value of 70% when Wistar rats were fed diets containing dried pig feces.

Harmon et al. (1973) fed swine a 12% protein corn-soybean meal diet and used ODML as a supplemental source by providing it in place of water. The ODML contained 2.5% dry matter and had 45% crude protein, dry basis. Higher average gains and better feed efficiency were observed in pigs receiving ODML than those receiving water.

Kornegay et al. (1977) fed both fresh and dried swine feces in two metabolism trials by substituting the feces for 21.7 and 37.3% of the basal dry matter. Digestibilities determined by difference were 48.0% for dry matter, 46.7% for energy, 31.6% for ash, 40.9% for crude fiber, 54.1% for ether extract, 60.1% for crude protein, 51.4% for protein and 45.9% for NFE. Fecal output increased as the amount of feces in the ration increased.

Pearce (1975) substituted dried swine manure in rations for cattle. Digestibilities determined by extrapolation for the swine manure fractions were: 29% for dry matter, 36% for organic matter, 31% for crude protein, 18% for ether extract, 32% for crude fiber, 27% for acid-detergent fiber, and 43% for NFE.

Studies of Ensiling Animal Waste

Poultry Waste. Creger *et al*. (1973) ensiled accumulated broiler litter with various amounts of water to bring the moisture content in the range of 35 to 38 percent. The litter was ensiled for a minimum of 6 weeks prior to opening. A 120-day feeding trial was conducted in which 15 heifer calves were fed the litter silage *ad libitum* plus a constant amount of a mixture of ground milo, dehydrated alfalfa meal, soybean meal, molasses and Vitamins A and D. The heifers had an average daily gain of 1.16 kg and consumed an average of 5.45 kg of silage per day. Retail cuts from all treatments were tested by an organoleptic test panel and were rated acceptable for juiciness, tenderness, and flavor.

Harmon *et al*. (1975a) compared the fermentation characteristics of corn forage harvested at two different stages of maturity, ensiled alone, with .5% urea, or with broiler litter composing 15, 30 or 45% of the dry matter. The silages containing urea and litter had a higher initial and final pH than the control silages. The addition of broiler litter to the silages resulted in a significant increase in dry matter, crude protein and ash content of the silages.

Harmon _et al_. (1975b) used the above treatments except the 45% litter in palatability and metabolism trials with sheep. Dry matter digestibility was similar for all treatments. Crude protein digestibility decreased with increased maturity of the corn forage. Each additional increase of litter to the corn forage within a maturity resulted in an increase in crude protein digestibility. Forage maturity had no effect on dry matter intake. Dry matter intake was significantly higher for silages containing litter than those containing urea or the control silage, within a maturity.

The optimum moisture level for optimum fermentation of broiler litter, as measured by pH, lactic acid content, levels of acetic acid and water soluble carbohydrate was 40% (Caswell _et al_., 1978). Rations for wethers were formulated to supplement 50% of the total nitrogen using heat processed litter, litter silage containing 22 or 44% moisture, or soybean meal. The ration supplemented with processed litter had the lowest nitrogen retention, but the apparent digestibilities of the rations supplemented with litter were not significantly different.

Caswell _et al_. (1977) reported that fermentation characteristics were better for corn ensiled alone than for the corn ensiled with broiler litter (2:1). Digestion trials with lambs and palatability trials with cattle were conducted with rations containing ensiled corn, ensiled corn with litter, ensiled corn plus processed litter, and ensiled corn plus soybean meal. The nitrogen intake for all the supplemental rations was similar. Crude protein digestibility was lowest for the ensiled corn, highest for the ensiled corn plus soybean, and intermediate for the litter containing rations. Digestion coefficients for dry matter, crude fiber, and NFE were not significantly different. Dry matter intake tended to be higher for the cattle fed litter than for those fed the soybean meal plus ensiled corn ration.

In vitro digestibility of organic matter and crude protein digestibility following a 60-day ensiling period were found to be significantly lower for cornfield residues and oatstraw ensiled alone than when each was ensiled with cattle or poultry manure in a 2:3 ratio (Saylor and Long, 1972).

Saylor and Long (1974) evaluated the following proportions of caged layer wastes and ground hay after ensiling for 60 days: 60:40, 70:30, 80:20, 90:10, and 100:0. Mixtures containing 90 and 100% caged layer waste putrefied. Mixtures containing 60, 70, and 80% caged layer waste had pH values of 5.2, 6.8, 7.1; lactic acid values of 15.6, .7, .1 mg/g; and crude protein values of 20.0, 17.7, and 13.3%, respectively. All differences were significant between treatments. The addition of 5% corn to the mixtures at ensiling had no effect on the fermentation parameters.

Cattle Waste. Anthony (1966) combined manure from cattle fed a high energy diet with ground Coastal Bermudagrass hay in a ratio of 57:43 and ensiled. The ensiled product, "wastelage", contained 12.4% crude protein, dry basis, and 51.4% dry matter. A diet containing 63% wastelage (dry basis) was fed to four steers in two balance trials. Wastelage was highly palatable and no feeding problems developed. In another trial using 21 ewes which were fed either Coastal Bermudagrass hay alone or with wastelage, the ewes receiving wastelage ate less hay per day and remained in better condition.

Anthony (1969) fed two groups of steers either a fattening ration or a mixture of wastelage and whole shelled corn in a 2:3 ratio. The animals on the wastelage treatment were given a specified amount of liquid nitrogen supplement daily. Results showed the steers receiving wastelage gained faster than the controls. Carcasses from all treatments graded choice.

Yearling cattle fed a conventional ration or a silage composed of 48% corn, 12% Coastal Bermudagrass hay, and 40% cattle manure produced comparable daily gains and high quality carcasses, but the manure silage ration cut feeding costs 8% (Anthony, 1974). Steers weighing 363 kg were maintained on a ration composed of fermented cattle manure from cattle fed an all concentrate ration, and bedded with straw (McClure et al., 1973).

Ward and Beede (1973) tested the digestibility of "Cerola", a washed and screened solid cattle waste product which is fermented with 5% molasses. Cerola contained 54.0% dry matter, 11.0% crude protein, 14% crude fiber, 66% NFE, and 5% ash. The digestion coefficients of lambs fed Cerola were dry matter, 75.7%; crude protein, 63.9%; ether extract, 85.3%; crude fiber, 49.7%; and NFE, 89.0%. The amount of protein intake by the lambs was enough to maintain weight, but did not support any gains.

When steers were fed either Cerola or corn silage, the digestion coefficients were similar, although the corn silage was somewhat more acceptable. However, when corn silage was supplemented with 25 and 50% Cerola, it was as acceptable as corn silage alone.

Vetter and Burroughs (1974) ensiled 20 to 27% cattle waste with corn forage and corn grain and reported no differences in performance or palatability when compared to the basal rations. Harpster et al. (1975) ensiled levels of 40 to 100% fresh cattle waste with grass hay and found no difference in dry matter intake, feed efficiency, and daily gains when silages containing 60% or less cattle waste were fed.

Westing and Brandenburg (1974) fed steers a typical high energy ration or a ration containing 14% beef feedlot waste which had been composted for 60 days. During the 184-day trial feed consumption, daily gains, and feed conversion were similar for both rations; however, total feed costs were $15 per head less for cattle fed the ration containing waste. No significant differences were found between the carcass yields and grades, or in flavor, juiciness, and tenderness of the meat when evaluated by a trained organoleptic test panel.

"Cornury", a 1:3 mixture of dairy cattle manure and shelled corn which was allowed to ensile for 3 weeks, was fed to yearling steers alone, with corn silage, with corn silage and soybean meal, or with a 14% crude protein finishing ration with corn silage (Williams et al., 1974). The average crude protein of the cornury was 10%. Respective average daily gains for the above rations were 1.52, 1.34, 1.49 and 1.60 kilograms. Feed efficiency and feed costs per kilogram of gain were lowest for the cattle fed the cornury ration.

Newton et al. (1977) fed a control ration containing 79% ground shelled corn, 20% Bermudagrass pellets, and 1% urea or an ensiled wastelage ration composed of 60% control ration and 40% cattle manure to 18 heifers. Average daily gains and feed efficiency favored the basal ration, but differences were not significant. In another trial, there was no significant difference in digestibility between dried and ensiled cattle waste (Newton et al., 1977).

Schake et al. (1977) reconstituted sorghum grain and found cattle waste was more effective as a reconstitution media than water when the cattle waste to grain ratio did not exceed 1:1.6. Feed per unit of gain for the sorghum grain dry, reconstituted with water and reconstituted with cattle waste were 4.99, 4.46, and 4.36 kg, on a dry basis.

Swine Waste. Overhults et al. (1978) looked at the use of anaerobic fermentation of swine waste as a method of enhancing animal performance when refeeding swine waste. Feeding trials were conducted with growing swine fed a basal ration (typical corn-soybean meal), basal plus 20% waste (unfermented) and basal plus 20% waste (fermented), dry basis. The pH of the initial mixtures ranged from 6.2 to 6.6. After ensiling for 1 week, the pH of the ensiled mixtures ranged from 4.6 to 4.8. Feeds containing waste had higher ash and ether extract content than the basal ration. Growing-finishing pigs readily accepted the unprocessed and fermented feed containing the waste. Average daily gains for manure fed pigs was lower than for those receiving the basal. The amount of corn-soybean meal ration required to produce a kilogram of gain was substantially less for pigs fed the recycled manure ration. The pigs receiving the anaerobically fermented waste ration had better feed efficiency than those consuming the unfermented waste ration.

Regulatory Aspects of Feeding Animal Wastes

The Food and Drug Administration (FDA) does not sanction the feeding of poultry litter and waste from other animal species to animals because of potential hazards from drug residues and contamination by pathogens (Kirk, 1967; Taylor, 1971; Taylor *et al*., 1974). The agency has stated it will take action only if waste found in interstate commerce is contaminated with harmful residues or pathogens (Taylor and Geyer, 1977).

Recently the FDA published a statement entitled "Recycled Animal Waste" (Federal Register 42, 1977). This document seeks information and supportive data from research already conducted, seeks ideas on regulating animal wastes and other issues pertinent to the area of waste feeding.

Health Aspects of Feeding Animal Wastes

Griel *et al*. (1969) reported incidences of abortion in beef cows which had been fed litter from a roaster operation. The rations fed these animals consisted of 4.09 kg mixed hay, 2.05 kg corn silage, corn fodder free choice, and 1.54 kg roaster litter, daily. Part of the breeding herd had received litter while the others did not. Of the 10 animals not receiving supplemental litter in their ration, one was diagnosed not pregnant. Of the 33 animals fed rations supplemented with litter, 13 were reported as not pregnant and 7 actually aborted. The date of gestation at which abortion occurred ranged from 105 to 204 days. The aborting animals were diagnosed as not clinically ill and their placentas were expelled normally. It was observed that much of the herd receiving litter showed estrogenic behavior, but upon withdrawal from the litter supplement, the estrogenic behavior and abortions ceased. When the feeding program of the roasters was reviewed, it was discovered that low levels of dienestrol diacetate (150-250 ppm) were added to the roaster ration. Analysis of the litter showed it contained 10 mg per 100 g, which is 10 times greater than the level found in forage crops. It was also pointed out by the authors that DES has been fed to heifers at levels higher than that found in the litter without causing abortions.

Fontenot et al. (1971) showed copper toxicity from feeding broiler litter to ewes. The broiler litter contained 195 ppm copper, dry basis. This high level of copper was due to the incorporation of copper sulfate in the broiler diet as a growth stimulant and anthelmintic. One ewe receiving a 50% litter ration died of copper toxicity after 137 days on trial. After 254 days on trial, 64% of the ewes receiving a 50% broiler litter ration and 55% of the ewes receiving the 25% broiler litter ration had died due to copper toxicity. Sheep have been shown to be much more sensitive to elevated copper levels in the diet than cattle (Underwood, 1977).

In a six-year study, Webb *et al.* (1978) wintered beef cows for a five-month period on the following rations: 1) hay, 2) 80% litter plus 20% corn, and 3) 80% litter plus 20% corn grain plus 160 ppm copper. An increase was observed in liver copper levels over the wintering period in cows on the litter rations, but a rapid decline was observed over the summer grazing period. No incidence of copper toxicity was observed and performance was not affected by treatment.

No ill effects on health or performance were noted in cattle and sheep fed ensiled cattle waste (Anthony, 1969).

Problems of Feeding Animal Waste

Pathogenic Organisms. In a statement issued by the FDA, the potential transmission of pathogenic organisms is a major concern in the feeding of animal wastes (Taylor, 1971; Taylor *et al.*, 1974). Singh (1974) showed that common ingredients used in the feed industry contain pathogenic organisms.

The intestinal tracts of animals contain many microorganisms including coliforms. Coliform bacteria are facultative anaerobes which show optimum growth at body temperature (37 C). Coliforms are involved in a number of diseases such as cholera, scours, cystitis in the urogenital tract, and local infections. Since coliforms are thermophilic and do not form spores, they are easily destroyed.

Two members of the coliform group are *Escherichia coli* and *Aerobacter aerogenes* (Pelczar and Reid, 1965). Kroulik *et al.* (1955) showed *Aerobacter* coliforms to be quite commonly found in plant material.

The pathogenic bacteria Salmonella, Shigella, and Proteus spp, and members of the Enterobacteriaceae family, are involved in central nervous system disorders, bone infections, abortion, and gastroenteritis (Burrows, 1968). Poultry acquire Salmonella and Proteus spp congenitally and from other infected fowl. Smith et al. (1964) showed Shigella spp to be rarely found in domestic fowl.

Halbrook et al. (1951) reported fewer total coliforms and yeasts in litter allowed to accumulate for 1 year than in litter which had only accumulated for 1 week. The pH of the accumulated litter was higher than that changed weekly, indicating the higher pH may be detrimental to yeasts, molds, and coliforms. Liming litter caused an increase in pH and a decrease in the number of molds, yeasts, and coliforms in the litter.

Harry and Hemsley (1964) made coliform counts from the dust in broiler houses and found .2 to .8 million coliforms per gram of dust. When broiler litter was stored "as is" or with a moisture level of 40%, there was a marked decrease in coliform survival rate in the 40% moisture litter.

Alexander et al. (1968) analyzed 44 samples of poultry litter of which 26 were being fed to livestock. Positive tests were found for Clostridium, Corynebacterium, Salmonella, Mycobacterium, Actinobaccili and the other members of the Enterobacteriaceae family and for Salmonella. Zindel (1970) found Bacillus spp, Proteus spp, E. coli and other members of the Enterobacteriaceae family in 40% of the fresh poultry fecal samples analyzed. Coliforms were present in 60%

of the samples. Schefferle (1965) found total bacteria counts in fresh litter ranged from 10 to 150 billion per gram, with coryneform bacteria being the most prevalent especially when pH was high. Lovett et al. (1971) analyzed litter which had accumulated for 1 week and reported 10% of the total bacteria to be coliforms. E. coli made up about 33% of the total coliforms.

Kraft et al. (1969) reported Salmonella spp were present in 10 of 32 composited samples of caged layer manure. There was a decrease in Salmonella spp numbers in the older samples. Alexander et al. (1968) found Salmonella spp present in freshly stacked broiler litter but absent after 1 to 2 months of stacking.

Tucker (1967) orally inoculated day old chicks with a salmonella organism and recorded its survival in litter with 44 and 21.6% moisture. Salmonella organisms in the litter with 44% moisture were destroyed at 8 weeks but persisted in litter containing 21.6% moisture at 19 weeks.

Clostridium organisms, which can cause such diseases as blackleg, gas gangrene, and enterotoxemia, may persist at alkaline conditions. Alexander et al. (1968) isolated clostridium organisms from poultry litter being fed to livestock, but found them to be non-pathogenic when tested on guinea pigs.

Fontenot et al. (1971) reported that autoclaving at 116 C under steam pressure of 10.6 kg/cm^2 for 30 to 120 minutes, dry heat at 100 C up to 48 hours, and fumigation with ethylene oxide or beta-propiolactone did not completely sterilize broiler litter. However, dry heating for 3 hours at 150 C did produce a sterile product. The difficulty and impracticability of trying to attain a sterile product led these workers to adapt the standards set for pasteurized milk (Anonymous, 1967) as a method of evaluating various processing methods. These adopted standards for broiler litter were met by dry heating at 150 C for 15 to 30 minutes at litter depths of .6 to 1.2 centimeters.

Caswell et al. (1975) pasteurized litter by dry heat treatment at 150 C for 20 minutes with litter at a thickness of .6 cm; autoclaving for a minimum of 10 minutes; dry heat for 15 minutes at 150 C at litter depths between .6 to 2.5 cm with the addition of 1, 2 or 4 g of paraformaldehyde to 100 g of litter; and ethylene oxide fumigation for a minimum of 30 minutes. All samples tested negative for salmonella, shigella and proteus organisms. Coliforms were completely destroyed by all treatments except ethylene oxide fumigation.

Methyl bromide fumigation was effective in destroying salmonella when the litter was high in moisture (Harry et al., 1973). *E. coli* were found to be more resistant to methyl bromide fumigation than salmonella. Will et al. (1973) inoculated a model oxidation ditch containing cattle manure with salmonella. The temperature, dissolved oxygen, and pH of the ditch were closely observed. At 20 C, salmonella survived 17 days after inoculation, and at 2 C, survived 47 days.

Ciordia and Anthony (1969) found that wastelage, an ensiled cattle waste product, contained no parasitic nematode larvae although they were initially present in the cattle feces used to prepare the wastelage.

Creger et al. (1973) reported that the bacterial count of ensiled broiler litter was 165 million organisms per gram. The ensiled material was negative for salmonella and coliforms.

Harmon et al. (1975a) conducted a laboratory experiment in which two maturities of corn forage were ensiled either alone, with .5% urea, or with broiler litter added at 15, 30 and 45% of the total dry matter. Total bacteria counts in the silages were in excess of 3 million per gram, with silages having the highest levels of litter having the highest counts. Coliform counts were lower in silages containing the more mature corn forage. This reduction in coliform numbers was probably due to the rapid drop in pH and the heat of fermentation associated with the ensiling process. There was no effect with increasing the amount of litter in the silage on total coliform numbers.

Vezey and Dobbins (1975) ensiled mixtures of 50% ground corn, 30% caged layer waste and 20% broiler litter. Following fermentation the pH was 4.8 and microbial analyses revealed no salmonella or proteus organisms were present. Ensiled mixtures of ground corn plus broiler litter and broiler litter plus dried molasses had pH values of 6.2 and 6.1, respectively. Both of these ensiled mixtures gave a positive test for proteus organisms, but not salmonella.

McCaskey and Anthony (1975) reported the survival rate of 27 salmonella cultures inoculated into a mixture of 45% corn, 15% corn forage and 40% cattle manure. Salmonella organisms were eliminated in 3 to 4 days and coliforms decreased significantly. The pH range for the ensiled mixture ranged from 4.0 to 4.5.

Caswell et al. (1978) ensiled broiler litter at moisture levels of 15.6, 20, 30, 40, and 50 percent. There was a general decrease in coliforms after ensiling and complete destruction of all coliforms in litters containing more than 20% moisture. Salmonella organisms were not present in either the initial or final samples; however, proteus organisms were found in the initial, but not the final samples.

There was a reduction in total bacteria and complete destruction of coliforms following ensiling in which corn forage was ensiled alone or with caged layer waste in proportions of 80:20 and 60:40, dry basis (Albert, 1977). All the ensiled materials showed a 10 fold increase in lactic acid.

Broiler litter (13% moisture) was ensiled alone and with water or whey (93% moisture) to obtain moisture levels of 30, 40, 50, 60 and 70 percent (Duque et al., 1978). Total coliforms and proteus organisms were present in the initial mixtures but were not present in the ensiled material at any of the moisture levels.

Mycobacterium spp., which produce a positive test for tuberculosis in cattle, have been reported to survive in litter (Carriere et al., 1968). Both autoclaved and non-autoclaved litters were inoculated with 13 mg of wet avian tubercule bacilli per gram of litter. The autoclaved litter tested positive for the tubercule bacilli at 59 days. The non-autoclaved litter tested positive at 32 days but not at 47 days. Autoclaving may have removed competitive organisms which might have stopped or inhibited the growth of the tubercule bacilli.

Medicinal Drug Residues. Brugman et al. (1964) did not find zoalene, unistat, nicarbazin, furans and sulfaquinoxaline in laying house litter. Arsanilic acid was found at the level of .0048 percent. Poultry litter containing different levels of amprolium plus ethopabate and 3-nitro-4-hydroxyphenylarsonic acid was fed to lambs (Brugman et al., 1968). Upon slaughter, tissues from the heart, spleen, 12th rib, kidney, and brain were found to be negative for amprolium and arsenic.

Morrison (1969) reported arsenic levels from 15 to 30 ppm in litter from houses where roxarsone was fed. Alfalfa and clover from fields which had been fertilized with arsenic containing litter for 0, 2, or 20 years contained less than .2 ppm, whether fertilized for 0 or 20 years.

Messer et al. (1971) reported the presence of arsenic, furazolidone, and nitrofurazone in poultry litter from five operations. Arsenic ranged from .2 to 76.3 ppm, with a mean of 14.2 ppm. Furazolidone and nitrofurazone had means of 14.0 and 12.7 ppm, respectively.

Excreta from dairy cows fed 70 mg chlortetracycline daily contained 75% of the daily intake in the excreta (Elmund et al., 1971).

Creger et al. (1973) found broiler litter samples contained zinc bacitracin and 3-nitro-4-hydroxyphenylarsonic acid at levels of 1.5 and 68.5 ppm, respectively. The ration fed to the chicks which were raised on this litter contained amprolium and ethopabate but traces of these were not found in the litter. Tissue analysis of heifers fed this litter for 120 days were negative for the aforementioned medicinal drugs.

Tissue samples from the carcasses of steers fed a ration containing 14% stockpiled cattle waste, dry basis, tested negative for antibiotics (Westing and Brandenburg, 1974).

Broiler litter from several different locations in Virginia was found to contain 12.5 units penicillin/g, 10.9 ppm oxytetracycline, 12.5 ppm chlortetracycline, 7.2 units zinc bacitracin/g, 81.2 ppm nicarbazin, 27.3 ppm amprolium (Webb and Fontenot, 1975). In two steer feeding trials of 121 and 198 days, rations containing 0, 25, and 50% broiler litter were fed until 5 days prior to slaughter. Tissue samples from the loin eye muscle, kidney fat, and liver were assayed for levels of amprolium, nicarbazin and chlortetracycline. Chlortetracycline was detected in the kidney fat of one animal fed 25% and two animals fed 50% litter. Neither amprolium nor nicarbazin was found in any of the tissues analyzed (Webb and Fontenot, 1975).

Pesticide Residues. No significant differences were found in the level of DDE, DDT, TDE and endrin in the external fat (12th rib) of steers fed caged poultry waste or a control ration with soybean meal or urea as a supplement (El Sabban et al., 1970).

Messer et al. (1971) found DDE in only 2 of 10 samples of broiler litter. The levels were .01 and .02 ppm. Thirteen broiler litter samples from three major areas of broiler production in Virginia were found to contain DDT and its metabolites at .09 ppm ± .011 (Fontenot et al., 1971). These workers fed broiler litter at 0, 25, and 50% for 121 days, with a 5-day withdrawal, to yearling steers without any noticeable change in liver or omental fat.

Rabon is a common oral pesticide used to control internal parasites and fly larvae in feces. Residues of Rabon in hen manure were reported to be related to the level fed (Wasti et al., 1970). Miller and Gordon (1973) fed dairy cattle levels of Rabon up to 250 ppm without any effect on performance or accumulation in milk.

DDT was found in the kidney fat of finishing cattle fed a control ration and a ration containing 14% composted cattle manure (Westing and Brandenburg, 1974). Levels were .11 ppm and .14 ppm, dry basis, respectively.

Aflatoxin Residues. Aflatoxins are very potent carcinogens. Hendrickson and Grant (1971) reported higher levels of aflatoxins in fresh cattle waste than in stockpiled waste. Westing and Brandenburg (1974) reported no mycotoxins in cattle waste which was composted and stockpiled for 60 days. Lovett et al. (1972) isolated 13 toxigenic fungi in broiler litter; 11 of these cultures were also isolated in the feed.

Hormone Residues. Story et al. (1956) fed lambs DES at daily levels of 1 and 2 milligrams. Daily excretions were 76 and 84% of the daily dose. Westing and Brandenburg (1974) found no detectable levels of DES in livers of steers fed 14% cattle manure collected from steers which had received diethylstilbestrol.

Mellin and Erb (1966) reported that the natural levels of estrogen in feces and urine were high in cycling cows. Likewise, Mathur and Common (1969) found higher levels of estrogen in the excreta from laying than non-laying hens.

Mineral Residues. Bruhn et al. (1977) found no increase in copper levels of milk from cows receiving 10 to 26% poultry waste in the diets. The poultry waste contained 51.1 ppm copper. Similar results were seen by Calvert and King (1977).

Varghese and Flegal (1974) found no significant increase in levels of copper, mercury and zinc in muscle tissue, eggs and excreta after recycling dehydrated poultry waste through laying hens 33 times. The dehydrated poultry waste was incorporated into the hen rations at 12.5 and 25 percent. Arsenic was found in the liver of steers fed a 50% broiler litter ration, after a 5-day withdrawal, although it was below 1 ppm on a dry basis (Webb and Fontenot, 1975).

Westing (1978) found that liver copper levels of heifers fed corn-litter silage in which 30% broiler litter, dry basis, had been incorporated at ensiling time, were significantly higher than for the control heifers fed regular corn silage. Arsenic in the kidney and fat was higher in heifers fed silage containing broiler litter. Bromine was significantly lower in liver, kidney, muscle and fat of heifers fed silage containing broiler litter. Copper and arsenic levels were higher in broiler litter than the other ruminant feeds.

Westing (1978) compared a 16% cattle waste ration to a conventional feedlot ration in two successive trials. In the first trial, selenium was significantly higher in the livers of steers fed the ration containing waste. In the second trial lead content was significantly higher in the fat of cattle fed the ration containing waste; however, liver copper levels were higher in animals receiving the control ration.

The levels of various minerals in the liver of beef cows wintered for a six-year period on 1) hay; 2) 80% broiler litter, 20% ground shelled corn; 3) 80% broiler litter, 20% ground shelled corn and 160 ppm supplemental copper were assessed by taking liver biopsies at the beginning and end of the wintering period (Westing, 1978). Average copper levels in the wintering rations were 15.9, 412.6, and 595.6 ppm, dry basis, respectively. Liver copper levels from cows fed rations containing litter were significantly higher than from cows fed hay at both the beginning and end of the wintering period. Liver arsenic levels were similar for all treatments at the beginning of each wintering period but the liver arsenic level of the cows fed rations containing litter significantly increased over the wintering period. The health of the animals receiving the broiler litter was not affected.

OBJECTIVES

Experiments were conducted to determine the feasibility of ensiling swine waste with ground orchardgrass hay and with ground corn grain, and to evaluate the best combinations as feedstuffs for both ruminants and nonruminants. The specific objectives were to:

1) Determine the optimum levels of swine waste and ground orchardgrass hay for desirable fermentation and the effect of ensiling on bacteria numbers, especially fecal coliforms.
2) Determine the optimum levels of swine waste and ground corn grain for desirable fermentation and the effect of ensiling on bacteria numbers, especially fecal coliforms.
3) Study nitrogen utilization, digestibility of proximate components, and palatability of swine waste-ground orchardgrass hay silages and swine waste-ground corn grain silages fed to ruminants and nonruminants.
4) Study blood and ruminal parameters in ruminants fed swine waste silages.

EXPERIMENTAL PROCEDURE

Ensiling Swine Waste with Ground Orchardgrass Hay

Small Silo Study. A small silo study was conducted to determine fermentation characteristics and microbial parameters in ensiled swine waste and ground orchardgrass hay in the following proportions: 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80, wet basis. Swine waste refers primarily to fecal material and also includes wasted feed, urine, and wasted drinking water collected under slotted floors in a pit with a sloped floor and open drains. Leaving the pit drains open maintained the swine waste as a slurry instead of a liquid.

Swine waste was collected from growing-finishing swine fed a 16% crude protein corn-soybean meal diet fortified with minerals and vitamins. Three days prior to ensiling, the slotted floor and pits from which the swine waste was to be collected were washed down thoroughly. The manure that collected on top of the slats over the next 3-day period was scraped into the pits. All waste was removed from the pit, put directly into a horizontal mixer and allowed to mix for 15 minutes. The orchardgrass hay (full bloom, sun cured, ref. no. 1-03-427) was from a single harvest from one field. The hay was ground through a 2.5 cm screen. Composition of the orchardgrass hay and swine waste used is presented in table 1.

Twenty kilograms of each mixture were prepared by slowly adding the ground hay to the swine waste in a horizontal mixer to insure

TABLE 1. COMPOSITION OF SWINE WASTE AND GROUND ORCHARDGRASS HAY IN THE SMALL SILO SWINE WASTE-ORCHARDGRASS HAY STUDY[a]

Item	Swine waste	Orchard-grass hay
Dry matter, %	24.8	89.3
Composition of dry matter, %		
Crude protein	26.4	8.2
Ether extract	10.3	2.2
Crude fiber	14.6	33.8
NFE	32.1	50.3
Ash	16.6	5.5
Total nitrogen, %, dry basis	4.2	-
Protein nitrogen, % of total nitrogen	62.6	-

[a]Each value represents the mean of seven samples.

uniform mixing. Eight 2 kg samples of the hay and feces mixture were taken. Six samples were allowed to ensile, while two samples were aseptically sampled for microbial analysis. The initial microbial samples were refrigerated until analyzed 24 hours after being taken. Dry matter samples were also taken and the remaining parts of the two samples were frozen for later analysis. The samples for ensiling were tightly packed into cardboard food containers lined with double thickness 3.8 l polyethylene bags, which were twisted tightly to expel the air, and individually sealed. All silos were weighed prior to and after addition of the mixtures. All silos were stored in the laboratory at 22 Centigrade.

After a fermentation period of 42 days, one silo of each mixture was weighed and opened for observations on appearance and odor. The top 5 cm of material in each silo was discarded prior to subsequent sampling. Water extracts of the initial mixtures and fermented mixtures were prepared for microbial analysis by homogenizing 25 g wet material with 225 ml of sterile distilled water in a sterile Waring blender cup at full speed for 2 minutes. The homogenate was filtered through four layers of sterile cheesecloth and the filtrate was used for measurement of pH (electrometrically), volatile fatty acid preparation (Erwin et al., 1961), lactic acid (Barker and Summerson, 1941, as modified by Pennington and Sutherland, 1956) and water-soluble carbohydrate content (Dubois et al., 1956, as adapted to corn plants by Johnson et al., 1966). The water extracts of the initial and final mixtures were immediately subjected to quantitative tests for total bacteria, total coliforms (Anonymous, 1967), and fecal coliforms (Millipore, 1973).

Total and protein nitrogen were determined on the swine waste, initial mixtures, and silages after precipitation with tungstic acid (A.O.A.C., 1970). Dry matter of the swine waste, initial mixtures, and silages was determined by drying duplicate 200 g samples in a forced-draft oven at a maximum of 60 C for 48 hours. These samples were allowed to air equilibrate, duplicates were then composited, and ground through a 1 mm screen and analyzed for dry matter, ether extract, (A.O.A.C., 1970) and crude fiber (Whitehouse et al., 1945).

Large Silo Study. This study was conducted to determine the apparent digestibility, nitrogen utilization, and palatability of the 60:40 and 40:60 swine waste-orchardgrass hay silages when fed to ruminants and nonruminants. The microbial parameters and fermentation characteristics were also determined. Ground orchardgrass hay was from the same source as in the small silo study. The swine waste used in this study was collected from sloped solid concrete floors at 3-day intervals from growing-finishing swine fed a typical 15% crude protein corn-soybean meal diet fortified with minerals and vitamins. Composition of the orchardgrass hay and swine waste used is presented in table 2. The waste was mixed thoroughly on the floor with shovels and screened through a sheet of flat rolled 12 mesh expanded metal to remove large fecal balls and foreign objects. The screened waste was collected in 208 l steel drums lined with 8 mil polyethylene bags and transferred to the horizontal

TABLE 2. COMPOSITION OF SWINE WASTE AND GROUND ORCHARDGRASS HAY IN THE LARGE SILO SWINE WASTE-ORCHARDGRASS HAY STUDY[a]

Item	Swine waste	Orchard-grass hay
Dry matter, %	22.8	98
Composition of dry matter, %		
Crude protein	28.9	8.4
Ether extract	10.7	2.1
Crude fiber	14.9	35.2
NFE	31.8	50.9
Ash	17.1	5.4
Total nitrogen, %, dry basis	4.6	-
Protein nitrogen, % of total nitrogen	54.5	-

[a]Each value represents the mean of 7 samples.

mixer for further mixing.

The two silage mixtures (approximately 270 kg of each) were prepared by adding the ground hay slowly to swine waste in the mixer and mixing until it appeared uniform. Several samples of the hay and swine waste were taken at various intervals. These samples were composited, subsampled, and frozen for future chemical analysis. After mixing was complete, it was augered in equal amounts into two steel drums. As each mixture was augered into the drums lined with polyethylene bags, five samples (approximately 500 g each) were collected, composited, sub-sampled and frozen, except for a microbial sample which was placed in a sterile .5 l jar and sealed for analysis within 48 hours. All mixtures were packed as they were augered into the silo to remove excess air. An attempt was made to remove as much of the air as possible above the silage before each polyethylene bag was twisted and sealed.

All silos were allowed to ensile for a minimum of 42 days. Upon opening a silo, the silage in the upper 5 cm of each silo was discarded. Samples were then aseptically taken from various areas on the surface of the silage, composited, then one subsample was frozen for future analyses and another was placed in a sterile .5 l jar for microbial analysis within 48 hours. This procedure was repeated each time a silo was opened. Procedures for proximate components, microbial parameters and fermentation characteristics were as presented for the small silo study.

<u>Metabolism Trial - Sheep</u>. Twelve crossbred wethers averaging 32

kg initially were used in two metabolism trials to study nitrogen utilization and digestibility of ensiled swine waste and ground orchardgrass hay in proportions of 60:40 and 40:60. The wethers were assigned to three blocks of four animals each, based on weight and breed. Sheep within each block were randomly allotted to the following four treatments: 1) orchardgrass hay alone (negative control); 2) ensiled swine waste and ground orchardgrass hay (40:60); 3) ensiled swine waste and ground orchardgrass hay (60:40); and 4) ground orchardgrass hay and soybean meal (positive control). The composition of the diets is given in table 3. Dry matter intake was equalized among treatments.

The lambs were treated for internal parasites prior to being placed in the metabolism stalls. The metabolism stalls were similar to those described by Briggs and Gallup (1949). Initially, the lambs were fed twice daily 350 g of a ration consisting of 61.4% mixed grass hay, 28.8% corn, 9.6% soybean meal, and 2000 I.U. Vitamin A per pound. Iodized salt was fed at the rate of 5 g per feeding.

There was a 2-day adaptation period to the stalls followed by a 4-day transition period to the experimental diets during which the diets were introduced at the rate of 12.5% of the dry matter at each feeding. The sheep were then fed the experimental rations for a 10-day preliminary period followed by a 10-day collection period during which feces and urine were collected.

Fecal collections were made once daily and dried in a forced-draft oven at a maximum of 60 Centigrade. Following drying daily

TABLE 3. INGREDIENT AND PROXIMATE COMPOSITION OF EXPERIMENTAL DIETS FED IN SHEEP METABOLISM AND PALATABILITY TRIALS USING SWINE WASTE-ORCHARDGRASS HAY SILAGES

Item	Diets			
	Ground orchardgrass hay	40:60 silage[a]	60:40 silage[a]	Ground orchardgrass hay + soybean meal
Ingredient composition, %, dry basis				
Orchardgrass hay, sun cured, full bloom, grnd; Ref. no. 1-03-427	100.0	-	-	87.6
Waste-orchardgrass hay silages				
40:60 silage[a]	-	100.0	-	-
60:40 silage[a]	-	-	100.0	-
Soybean seed, solvt. extnd. grnd; Ref. no. 5-20-637	-	-	-	12.4
Iodized salt	+	+	+	+
Chemical composition				
Dry matter, %	88.0	66.5	50.5	92.9
Composition of dry matter, %				
Crude protein	8.2	9.8	13.0	14.8
Ether extract	2.2	3.6	4.9	2.1
Crude fiber	33.8	30.6	27.5	32.3
Ash	5.5	7.3	9.2	5.4
NFE	50.3	48.7	45.4	45.4

[a]Values refer to proportions of swine waste and orchardgrass hay.

fecal collections were composited by animal in metal cans with loose fitting lids, and allowed to air equilibrate. At the end of the trial all fecal composites were weighed, mixed, and subsampled.

Urine was collected in plastic jars which contained 15 ml of a 1:1 (w/w) mixture of concentrated sulfuric acid and water, and approximately 500 ml of water. At each 24 hour collection, the urine was diluted with water to a constant weight and a 2% sample by volume was taken and placed in an airtight plastic bottle and refrigerated. At the end of the trial, the urine was subsampled for chemical analysis and the remainder was frozen.

The ration ingredients were sampled at each feeding, beginning 2 days prior to the beginning and ending 2 days prior to the end of the collection period. Silage samples were frozen daily and composited at the end of the trial. Water was provided *ad libitum* except during the 2-hr feeding periods which began at 6:30 A.M. and 6:30 P.M.

Samples of silages, feeds, feces, and premixes were dried at a maximum of 60 C for dry matter determination, allowed to air equilibrate then ground in a Wiley mill through a 1 mm screen. Proximate analysis and nitrogen analysis were performed by the methods described for the small silo study. Nitrogen determination on all silages was on wet samples.

At the end of the collection period, rumen samples were obtained *via* stomach tube 2 hr after feeding. The rumen samples were strained through four layers of cheesecloth and the pH of the strained rumen fluid was determined electrometrically. Analysis of ruminal ammonia nitrogen (Conway, 1958) was performed on the strained ruminal fluid. Ruminal fluid was prepared for volatile fatty acid analysis (Erwin et al., 1961) and analyzed on a Perkin-Elmer 881 with a 1.83 m glass column with an internal diameter of .3175 cm. Liquid phase was SP-1200/H_3PO_4 and support media was Chromasorb WAW.

Blood samples were taken 6 hr after feeding the same day the ruminal fluid was obtained. Samples were obtained via jugular vein puncture. The blood samples were analyzed for blood urea nitrogen by the method of Coulombe and Favreau (1963).

Metabolism Trial - Swine. Three metabolism trials were conducted with 12 crossbred gilts with an average weight of 91 kilograms. These animals were blocked by weight, and the six animals within each block were randomly allotted to the following six treatments: 1) basal (14% protein corn-soybean meal ration); 2) 75% basal and 25% of the ground orchardgrass hay; 3) 75% basal and 25% of the 40:60 silage; 4) 75% basal and 25% of the 60:40 silage; 5) 50% basal and 50% of the 40:60 silage; and 6) 50% basal and 50% of the 60:40 silage, dry basis (table 4).

Gilts were kept in stainless steel metabolism stalls in an environmentally controlled building. A 5-day adaptation period to the stalls was followed by a 5-day transition period to the diets, a 7-day preliminary period, and a 5-day collection period. During the transition period, a 12% protein corn-soybean meal diet was replaced by the test diet at the rate of 10% per feeding, dry

TABLE 4. INGREDIENT AND PROXIMATE COMPOSITION OF EXPERIMENTAL DIETS FED IN SWINE METABOLISM AND PALATABILITY TRIALS USING SWINE WASTE-ORCHARDGRASS HAY SILAGES

Item	Basal alone	75% basal + mixed grass hay	75% basal + 25% (40:60) silage[a]	75% basal + 25% (60:40) silage[a]	50% basal + 50% (40:60) silage[a]	50% basal + 50% (60:40) silage[a]
Ingredient composition, %, dry basis						
Corn, grain, grnd, no. 2 Ref. no. 4-02-931	82.3	61.7	61.7	61.7	20.6	20.6
Mixed hay (red clover) grnd.	-	25.0	-	-	-	-
Swine waste-orchardgrass[a] hay (40:60) silage	-	-	25.0	-	50.0	-
Swine waste-orchardgrass hay (60:40) silage[a]	-	-	-	25.0	-	50.0
Soybean, seeds, solv-extrd grnd. Ref. no. 5-20-637	14.7	11.0	11.0	11.0	7.4	7.4
Limestone, grnd, min. 33% calcium, Ref.no. 6-02-632	0.7	0.5	0.5	0.5	0.4	0.4
Phosphate rock, defluorinated grnd 1.3 mix, 1 part fluorine per 100 parts phosphorus, Ref. no. 6-01-780	1.4	1.1	1.1	1.1	0.7	0.7
Swine trace mineral salt[b]	0.5	0.4	0.4	0.4	0.3	0.3
Vitamin premix[c]	0.4	0.3	0.3	0.3	0.2	0.2
Chemical composition, %						
Dry matter	88.0	89.0	82.3	78.5	76.5	69.0
Composition of dry matter						
Crude protein	14.2	14.5	14.1	14.3	14.0	14.5
Ether extract	2.5	2.4	2.7	2.9	3.0	3.4
Crude fiber	4.6	10.7	11.4	10.7	18.0	16.4
Ash	3.9	4.6	4.7	5.1	5.5	6.4
Organic matter	96.1	95.4	95.3	94.9	94.5	93.6
NFE	74.8	67.8	67.1	67.0	59.5	59.3

[a] The ratios 40:60 and 60:40 refer to the percentage of swine waste to ground orchardgrass hay (as is basis) in the initial mixture.

[b] Contained (%) .8 Mn, .4 Fe, .06 Cu, .01 Ca, .01 I, 1.02 n, and 95.9 NaCl.

[c] Supplied (per kg of premix): 1.3 g riboflavin, 6.8 g pantothenic acid, 6.8 g niacin, 10.6 mg Vitamin B_{12}, 220 g choline chloride, 13,200,000 I.U. Vitamin A, 220,000 I.U. Vitamin D, and 2,200 I.U. Vitamin E, 330 mg Vitamin K and 40 mg Se per gram of premix.

basis. Animals were fed twice daily at 6:00 A.M. and 6:00 P.M.

Feces were collected twice daily and frozen in double-thickness plastic bags. Urine was collected through a funnel containing glass wool into a 5 l container which contained 25% H_2SO_4 (v/v) for the entire 5-day collection period. The pH of the urine was checked twice daily to maintain the pH below 5.5.

Feed ingredients were sampled and frozen at each feeding period beginning 2 days prior to the start of the collection period and ending 2 days prior to the end of it. Since the test diets varied considerably in moisture, water was added and hand mixed at each feeding so that all diets contained about the same amount of moisture.

Water was placed in the feed box as soon as the feed was consumed or after an hour. Refusals were collected once daily and frozen.

At the end of the trial the total feces were composited by animal and dried at a maximum of 60 C in a forced-draft oven. Refusals were handled in a similar manner. Urine samples were weighed and a 500 ml sample was frozen for future analysis.

Samples of the silages, feed ingredients, feces, and refusals were dried at a maximum of 60 C in a forced-draft oven for dry matter determination, allowed to air equilibrate, then ground through a 1 mm screen. Analysis for nitrogen and other proximate components were performed by the methods described for the small silo study. Nitrogen was determined on wet silage samples. All animals were weighed at the beginning of the 7-day preliminary period and at the end of the collection period.

For the second and third trials, all animals were again randomly allotted to treatments with the stipulation that no animal receive the same treatment twice. Also in the second and third trials, the 5-day stall adaptation period was deleted.

Palatability Trial - Sheep. A palatability trial was conducted with 24 crossbred wether lambs with an average body weight of 33 kilograms. The following rations were tested (table 3): 1) ground orchardgrass hay alone (negative control); 2) ensiled swine waste and ground orchardgrass hay (40:60); 3) ensiled swine waste and ground orchardgrass hay (60:40); and 4) ground orchardgrass hay and soybean meal - positive control. The positive control contained sufficient soybean meal to equalize the crude protein level of the 60:40 silage, dry basis.

The lambs were blocked by breed and weight into six blocks of four animals each. Animals within each block were randomly allotted to the four treatments.

All sheep were housed in individual 1.3 m x 4 m stalls in a partially enclosed barn. Sheep had access to iodized salt, and water was provided *ad libitum*. Animals were presented with fresh feed every 12 hr and refusals were collected once daily. The trial consisted of a 5-day transition period during which the test rations were substituted at a rate of 10% of the dry matter at each feeding. The diet fed to the sheep prior to the adaptation period was the same one fed prior to the start of the adaptation period in the metabolism trial. A 10-day preliminary period was followed by a 10-day measurement period. During the measurement period, refusals were collected once daily and dried in cloth bags at 60 C in a forced-draft oven.

All sheep were weighed prior to and at the end of the measurement period. The average of these two weights was used to calculate metabolic size ($W_{kg}^{.75}$) upon which dry matter intake was calculated.

All diet components were sampled at the time of feeding during the measurement period. The hay and soybean meal samples were stored in double-thickness plastic bags in metal cans with loose fitting lids. The silage samples were frozen in double-thickness plastic bags after each feeding. At the end of the trial, diet components were composited by treatment and refusals were composited by animal. Each sample was thoroughly mixed and a sample was removed for dry matter determination. Proximate analysis of diet components was performed in the manner described for the sheep metabolism trial.

Palatability Trial - Swine. A palatability trial was conducted using the same diets as used in the swine metabolism trial (table 4). The diets were: 1) basal (14% protein corn-soybean meal diet); 2) 75% basal and 25% of the ground orchardgrass hay; 3) 75% basal and 25% of the 40:60 silage; 4) 75% basal and 25% of the 60:40 silage; 5) 50% basal and 50% of the 40:60 silage; and 6) 50% basal and 50% of the 60:40 silage, dry basis. Thirty-six crossbred gilts averaging 91 kg were blocked by weight into six blocks of six animals. Animals within each block were randomly assigned to six treatments.

Pigs allotted to each treatment were randomly assigned in groups of three to four 1.3 m x 3 m pens (total of 12 pens). All animals were fed twice daily at 12 hr intervals. Water was provided ad libitum. Refusals were collected in cloth bags every 24 hr and placed in a forced-draft oven at a maximum of 60 Centigrade. The trial consisted of a 5-day transition to the test rations at 10% increments (dry basis) per feeding, followed by a 10-day preliminary, and a 10-day measurement period. The diet fed to the gilts prior to the transition period was a typical 14% protein corn-soybean meal diet.

All gilts were weighed 1 day prior to the beginning and at the end of the collection period. The average of these two weights was used to calculate metabolic size ($W_{kg}^{.75}$) upon which dry matter intake was calculated.

All diets were sampled twice daily during the measurement period. Samples of the hay and basal diet were stored in metal cans with loose fitting lids. The silage samples were immediately frozen in double-thickness plastic bags. All diets were mixed by hand to insure uniformity.

At the end of the trial, feed ingredients and silages were composited by treatment and feed refusals by pen. Each sample was thoroughly mixed and a sample removed for dry matter determination. Proximate analysis of diet ingredients was performed in the same manner as described for the gilt metabolism trial.

Ensiling Swine Waste with Ground Corn Grain

Small Silo Study. A small silo study was conducted to determine fermentation characteristics and microbial parameters of ensiled mixtures of swine waste and ground corn in the following proportions: 80:20, 70:30, 60:40, 50:50, 40:60, 30:70 and 20:80. Swine waste consisted primarily of fecal material and also includes wasted feed, urine, and wasted drinking water remaining when waste was collected under slotted floors in a pit with a sloped floor and open drains.

Swine waste was collected from growing-finishing swine fed a 16% crude protein corn-soybean meal diet fortified with minerals and vitamins. The swine waste was collected, mixed, and sampled as in the previous small silo study. Proximate components, dry matter disappearance, fermentation characteristics and microbial parameters were determined as in the previous small silo study. Samples were also tested for the presence of salmonella, shigella, and proteus organisms (Lewis, 1964). Composition of the swine waste and corn ground through a 1.25 cm screen is presented in table 5.

Large Silo Study. This study was conducted to determine the apparent digestibility, nitrogen metabolism, and palatability of the 60:40 and 40:60 swine waste-ground corn silages when fed to ruminants and nonruminants. The fermentation characteristics and microbial parameters of mixtures were also determined. Ground corn grain was from the same batch as in the small silo study. The swine waste used in this study was collected from sloped solid concrete floors at 3-day intervals from growing-finishing swine fed a typical 16%

TABLE 5. COMPOSITION OF SWINE WASTE AND GROUND CORN GRAIN IN SMALL SILO SWINE WASTE-GROUND CORN STUDY

Item	Swine waste	Ground corn grain
Dry matter, %[a]	24.0	88.3
Composition of dry matter, %[a]		
Crude protein	29.3	8.6
Ether extract	10.6	1.1
Crude fiber	15.5	3.5
NFE	27.2	85.0
Ash	17.4	1.8
Total nitrogen, %, dry basis[b]	4.7	-
Protein nitrogen, % of total nitrogen	54.2	-

[a]Each value represents the mean of six samples.
[b]Each value represents the mean of three samples.

protein corn-soybean meal diet. Composition of the ground corn and swine waste are presented in table 6. The swine waste and ground corn were mixed, sampled, ensiled and stored as in the previous large silo study. Proximate analysis and microbial parameters were measured as described in the previous large silo study.

Metabolism Trial - Sheep. A metabolism study was conducted to determine the apparent digestibility and nitrogen utilization of the 60:40 and 40:60 swine waste-ground corn grain silages by ruminants.

The trial was conducted with 30 crossbred wether lambs weighing approximately 35 kilograms. These lambs were blocked by breed and weight into blocks of six animals each and randomly allotted within blocks to the following treatments: 1) basal diet consisting of 50% corn-soybean meal (14% protein) and 50% ground mixed hay; 2) 80% basal and 20% of the 40:60 swine waste-ground corn grain silage; 3) 80% basal and 20% of the 60:40 swine waste-ground corn grain silage; 4) 60% basal and 40% of the 40:60 silage; and 5) 60% basal and 40% of the 60:40 silage, dry basis (table 7).

All animals were treated for internal parasites prior to being placed in metabolism stalls. Other procedures in the metabolism trials including the treatment, collection and sampling of excreta and feed, and assays were as described under the experiment on ensiling swine waste and hay.

Metabolism Trial - Swine. Three metabolism trials were conducted with 10 crossbred gilts weighing approximately 95 kg to determine the apparent digestibility and nitrogen utilization of diets containing

TABLE 6. COMPOSITION OF SWINE WASTE AND GROUND CORN GRAIN IN LARGE SILO SWINE WASTE-GROUND CORN STUDY

Item	Swine waste	Corn grain
	%	%
Dry matter	22.6	90
Composition of dry matter, %[a]		
Crude protein	28.9	8.7
Ether extract	11.1	2.3
Crude fiber	15.2	33.4
Ash	16.5	5.7
NFE	28.3	49.9
Total nitrogen, %, dry basis[b]	4.6	-
Protein nitrogen, % of total nitrogen	57.3	-

[a]Each value is the mean of 8 samples.
[b]Each value is the mean of 4 samples.

TABLE 7. INGREDIENT AND PROXIMATE COMPOSITION OF EXPERIMENTAL DIETS FED IN SHEEP METABOLISM AND PALATABILITY TRIALS USING SWINE WASTE-GROUND CORN SILAGES

Item	Diets				
	Basal	80% basal + 20% (40:60)[a] silage	80% basal + 20% (60:40)[a] silage	60% basal + 40% (40:60)[a] silage	60% basal + 40% (60:40)[a] silage
Ingredient composition, %, dry basis					
Corn, grnd					
No. 2 yellow dent					
Ref. no. 4-02-931	45.5	36.4	36.4	27.3	27.3
Soybean, seed, solv.					
extrd, grnd,					
Ref. no. 5-20-637	2.9	2.3	2.3	1.7	1.7
Ensiled swine waste-grnd corn					
40:60 silage[a]	-	20.0	-	40.0	-
60:40 silage[a]	-	-	20.0	-	40.0
Orchardgrass hay					
grnd, sun cured full bloom					
Ref. no. 1-03-427	51.1	40.9	40.9	30.7	30.7
Limestone, grnd					
mn 33% calcium					
Ref. no. 6-02-632	0.5	0.4	0.4	0.3	0.3
Vitamin A & D premix[b]	+	+	+	+	+
Iodized salt[c]	+	+	+	+	+
Chemical composition, %					
Dry matter	92.0	85.9	83.5	79.4	75.0
Composition of dry matter, %					
Crude protein	10.2	10.6	10.9	11.0	11.6
Ether extract	2.9	3.2	3.6	3.6	4.4
Crude fiber	19.9	16.8	17.2	13.7	14.4
Ash	3.4	3.5	3.8	3.5	4.2
NFE	63.5	65.9	64.5	68.2	65.4

[a]Values refer to proportions of swine waste and ground corn.
[b]Supplied (per kg of concentrate): 12,760 I.U. of vitamin A and 126 I.C.U. of vitamin D_3.
[c]All animals received 10 g per head of iodized salt.

different levels of the 60:40 and 40:60 swine waste-ground corn silages. All animals were blocked by weight into two blocks of five animals each and randomly allotted to one of the five following treatments: 1) basal (14% protein corn-soybean meal diet); 2) 75% basal and 25% of the 40:60 silage; 3) 50% basal and 50% of the 40:60 silage; 4) 75% basal and 25% of the 40:60 silage; and 5) 50% basal and 50% of the 60:40 silage (table 8). Other procedures, collection of excreta, obtaining samples and assays were as previously described for the swine waste-orchardgrass hay silage study.

Palatability Trial - Sheep. A palatability trial was conducted with 30 crossbred wether lambs weighing approximately 35 kilograms. The lambs were blocked by weight and breed into six blocks of five lambs each and were randomly allotted within each block to the following diets: 1) diet consisting of 45.5% corn, 2.9% soybean meal, and 51.1% ground mixed hay (basal); 2) 80% basal and 20% of the 40:60 swine waste-ground corn silage; 3) 80% basal and 20% of the 60:40 silage; 4) 60% basal and 40% of the 40:60 silage; and 5) 60% basal and 40% of the 60:40 silage (all percentages refer to dry basis, table 7). Other procedures were as previously described for the waste-orchardgrass hay silage palatability study with sheep.

Palatability Trial - Swine. A swine palatability trial was conducted with the following diets: 1) basal (14% protein corn-soybean meal diet); 2) 75% basal and 25% of the 40:60 swine waste-ground corn silage; 3) 50% basal and 50% of the 40:60 silage; 4) 75% basal and 25% of the 60:40 silage; and 5) 50% basal and 50% of the

TABLE 8. INGREDIENT AND PROXIMATE COMPOSITION OF EXPERIMENTAL DIETS FED IN SWINE METABOLISM AND PALATABILITY TRIALS USING SWINE WASTE-GROUND CORN SILAGES

Item	Basal	Diets: 75% basal + 25% (40:60)[a]	75% basal + 25% (60:40)[a]	50% basal + 50% (40:60)[a]	50% basal + 50% (60:40)[a]
Ingredient composition, %, dry basis					
Corn, grain, grnd, No. 2					
Ref. no. 4-02-931	82.4	61.8	61.8	41.2	41.2
Soybean, seed, solv. extrd, grnd					
Ref. no. 5-20-637	14.7	11.0	11.0	7.4	7.4
Limestone, grnd, mn 33% calcium					
Ref. no. 6-02-632	.7	.5	.5	.4	.4
Phosphate rock, defluorinated, grnd, mx. 1 part fluorine per 100 parts phosphorus					
Ref. no. 6-01-780	1.3	1.0	1.0	.7	.7
Ensiled swine waste-grnd corn					
40:60 silage[a]	-	25.0	-	50.0	-
60:40 silage[a]	-	-	25.0	-	50.0
Swine trace mineral salt[b]	.5	.4	.4	.3	.3
Vitamin premix[c]	.4	.3	.3	.2	.2
Chemical composition, %					
Dry matter	88.3	81.8	78.3	75.3	69.0
Composition of dry matter, %					
Crude protein	17.1	16.4	15.4	15.8	14.5
Ether extract	3.3	3.6	3.8	4.3	4.2
Crude fiber	5.1	5.1	5.8	5.3	5.8
Ash	4.5	4.2	4.7	3.9	4.9
NFE	70.0	70.7	70.3	70.7	70.6

[a]Values in parentheses refer to proportions of swine waste and corn of ensiled mixture.
[b]Contained (%): .8 Mn, .4 Fe, .08 Cu, .01 Co, .01 I, 1.0 Zn, and 95.9 NaCl.
[c]Supplied (per kilogram of premix): 1.3 g riboflavin, 6.8 g pantothenic acid, 6.8 g niacin, 10.6 mg Vitamin B_{12}, 220 g choline chloride, 13,200,000 I.U. Vitamin A, 220,000 I.U. Vitamin D, 2,200 I.U. Vitamin E, 330 mg Vitamin K and 40 mg Se per gram of premix.

60:40 silage (table 8). All percentages are on a dry basis. Thirty crossbred gilts averaging 86 kg were blocked by weight into two groups of 15 animals each. Animals within each group were randomly allotted to 15 pens. Treatments were then randomly assigned to the pens, containing two animals per pen. Other procedures were as described for the swine palatability trial with ensiled swine waste-orchardgrass hay.

Statistical Analysis

The small silo studies were analyzed by use of the general linear model as described by Barr et al. (1976). Linear, quadratic, and cubic effects of increasing levels of waste were tested by orthogonal polynomials. No comparisons were made between initial and fermented materials.

The large silo studies data were analyzed for significance using the least squares analysis of variance in the general linear model described by Barr et al. (1976). Significance between means was tested using Duncan's (1955) multiple range test.

Data from the sheep digestion trial in which swine waste-orchardgrass hay silage was fed and data from the palatability trials were analyzed for significance by analyses of variance (Barr et al., 1976). Significance between means was tested using Duncan's (1955) multiple range test.

Data from the digestion trials where sheep and swine received swine waste-ground corn silages were analyzed using analysis of variance by the general linear model (Barr et al., 1976). Effects of increasing levels of swine waste were tested by linear and quadratic polynomials.

Examples of statistical analyses are given in the appendix tables 1 to 6.

RESULTS AND DISCUSSION

Ensiling Swine Waste with Ground Orchardgrass Hay

Small Silo Study. Composition of the swine waste and orchardgrass hay is shown in table 1. Dry matter of swine waste was 24.8% which is similar to values reported previously (Kornegay et al., 1977; Pearce, 1977; Overhults et al., 1978). The crude protein level (dry basis) of the swine waste, 26.4%, is slightly higher than those reported by Pearce (1977) and Hilliard (1977). Protein accounted for 62.6% of the nitrogen with NPN supplying the balance. Swine waste contained 10.3% ether extract, 16.6% ash and 14.6% crude fiber. The ether extract value was slightly higher than that previously reported while ash content was quite similar (Kornegay et al., 1977; Pearce, 1977; Hilliard, 1977; Orr, 1974). Crude fiber content was similar to that reported by Kornegay et al. (1977), but less than that reported by Hilliard (1977). The higher crude fiber level reported by Hilliard (1977) probably resulted from the use of barley in the ration as the main energy source, whereas Kornegay et al. (1977) fed corn. Orchardgrass hay contained 89.3% dry matter, 8.2% crude protein, 2.2% ether extract, 33.8% crude fiber, 50.3% NFE and 5.5% ash.

After ensiling, the appearance and odor of the 30:70 through 60:40 mixtures were altered. These mixtures had a very pleasing aroma similar to a good quality haylage, while the ensiled mixtures containing more than 60% swine waste were only slightly less offensive than upon the day of ensiling. Mold was present in one of the six silos containing the 20:80 mixture. Caswell _et al_. (1978) reported good ensiling for broiler litter ensiled alone containing a minimum of 40% moisture.

As the level of swine waste in the mixture decreased, the percentages of crude protein, non-protein nitrogen, ether extract, and ash linearly ($P < .01$) decreased (table 9). However, the levels of dry matter, protein nitrogen, crude fiber, and NFE showed a linear increase ($P < .01$) with decreasing levels of swine waste in the mixture.

The pH of the initial mixtures ranged from 6.8 to 7.8, water soluble carbohydrates were above 5.0% (dry basis), and lactic acid content approached zero (table 10). Following ensiling, there was a drop in pH and water soluble carbohydrate level, while lactic acid content in the mixtures increased. Harmon _et al_. (1975a) reported an increase in lactic acid production, a decrease in water soluble carbohydrates and decreased pH values following ensiling of corn forage and broiler litter. The quadratic effect ($P < .01$) was significant for pH, water soluble carbohydrates and lactic acid content of the ensiled mixtures. Similar trends have been reported by Barnett (1954).

Dry matter disappearance was high for all laboratory silos and displayed a quadratic effect ($P < .01$). The 60:40 through the 40:60 mixtures were the lowest but still higher than those reported in

TABLE 9. PROXIMATE COMPONENTS OF VARIOUS ENSILED PROPORTIONS OF SWINE WASTE AND ORCHARDGRASS HAY, SMALL SILO STUDY

Item	Proportions of swine waste and orchardgrass hay[a]							SEM[b]
	80:20	70:30	60:40	50:50	40:60	30:70	20:80	
Dry matter, %[c]	36.0	43.9	52.5	60.2	64.6	71.2	76.9	.18
Composition of dry matter, %								
Crude protein	20.0	16.3	13.8	11.9	11.7	10.7	10.5	.07
Ether extract[c]	7.8	6.4	5.3	5.2	4.6	4.3	3.3	.06
Crude fiber[c]	27.1	29.3	30.8	32.7	33.5	35.0	36.7	.29
Ash[c]	11.1	8.8	7.6	6.8	6.4	5.9	6.5	.14
NFE[c]	34.0	39.3	42.5	43.3	43.7	44.2	42.8	.31
Total nitrogen, %, dry basis	3.2	2.6	2.2	1.9	1.9	1.7	1.7	-
Protein nitrogen, % of total nitrogen	52.4	58.5	60.2	63.9	68.1	63.1	78.2	.62

[a]Each value represents the mean of six samples except values for true protein nitrogen and non-protein nitrogen, which represent the mean of four samples.
[b]Standard error of the mean.
[c]Significant linear effect of treatment ($P < .01$).

TABLE 10. EFFECT OF ENSILING VARIOUS PROPORTIONS OF SWINE WASTE AND ORCHARDGRASS HAY UPON pH, WATER SOLUBLE CARBOHYDRATES, LACTIC ACID, AND DRY MATTER DISAPPEARANCE, SMALL SILO STUDY

Item	Proportions of swine waste and orchardgrass hay[a]							SEM
	80:20	70:30	60:40	50:50	40:60	30:70	20:80	
Initial[a]								
pH[d]	7.1	7.0	7.0	6.8	6.8	6.7	6.0	.19
Water soluble carbohydrates, %, dry basis[d]	5.32	6.89	6.38	7.92	6.85	6.88	6.68	.295
Lactic acid, %, dry basis[d]	0.01	0.02	0.04	0.04	0.06	0.04	0.02	.010
Ensiled[b]								
pH[d]	5.1	4.8	4.6	4.5	4.6	5.1	6.6	.08
Water soluble carbohydrates, %, dry basis[d]	1.86	2.12	2.37	2.51	2.46	2.39	1.69	.037
Lactic acid, %, dry basis[d]	.61	2.47	5.64	5.84	5.44	3.99	2.91	.143
Dry matter disappearance, %[d]	8.54	7.76	6.32	5.88	5.36	6.66	9.62	.333

[a]Each value represents the mean of two samples.
[b]Each value represents the mean of six samples.
[c]Significant quadratic effect of treatment ($P < .01$).

laboratory studies with ensiled poultry litter and corn forage (Harmon et al., 1975a). Albert (1977) reported dry matter losses ranging from 9.0 to 11.1% for ensiled mixtures of corn forage and caged layer waste, which are slightly higher than the dry matter disappearance reported in this study.

Volatile fatty acids are shown in table 11. Acetic, propionic and butyric were the major acids produced. The content of these decreased linearly ($P < .01$) or quadratically ($P < .05$ or .01) as the amount of swine waste decreased. Only traces of isobutyric, isovaleric and valeric were present.

Acetic acid is formed early in the fermentation process; however, at high pH values, many long chain fatty acids are formed from protein breakdown. This breakdown does not usually occur if appreciable amounts of water soluble carbohydrates are available for fermentation (Barnett, 1954). Thus, the quadratic effect seen in the acetic acid, especially the lower levels in the 20:80 mixture, was probably a combination of pH, lactic acid content, and water soluble carbohydrate levels of the initial mixture. The quadratic effect ($P < .01$) associated with the molar percentage of the remaining volatile fatty acids is most likely due to the strict conditions under which each of the acids is produced.

Acetic acid and the total volatile fatty acids expressed as percent of dry matter show a linear ($P < .01$) relationship in which each decreased with decreasing amounts of waste in the mixture. This closely reflects the levels of water soluble carbohydrates,

TABLE 11. EFFECT OF ENSILING VARIOUS PROPORTIONS OF SWINE WASTE AND ORCHARDGRASS HAY UPON VOLATILE FATTY ACID PRODUCTION, SMALL SILO STUDY

Item	Proportions of swine waste and orchardgrass hay[a]							SEM
	80:20	70:30	60:40	50:50	40:60	30:70	20:80	
Volatile fatty acids, molar percentage								
Acetic[b]	76.3	89.1	92.3	90.5	95.6	98.4	83.3	2.43
Propionic[c]	11.3	6.0	4.8	6.7	3.8	1.3	0	.22
Isobutyric[d]	0.2	0.1	0	0	0	0	0	.01
Butyric[cd]	10.4	4.9	3.0	2.8	0.5	0.2	0	.10
Isovaleric	0.1	0	0	0	0	0	0	0
Valeric[cd]	2.0	0	0	0	0	0	0	.02
Volatile fatty acids, % of dry matter								
Acetic[c]	7.49	6.47	4.12	2.66	1.65	1.18	0.10	.079
Propionic[d]	1.36	0.53	0.26	0.25	0.08	0.02	0	.016
Isobutyric[d]	0.03	0.01	0	0	0	0	0	0
Butyric[d]	1.47	0.51	0.19	0.12	0.02	0.01	0	.015
Isovaleric	0.02	0	0	0	0	0	0	0
Valeric[d]	0.33	0	0	0	0	0	0	0
Total[c]	10.70	7.51	4.57	3.03	1.74	1.20	0.10	.109

[a] Each value represents the mean of six samples.
[b] Significant quadratic effect of treatment ($P < .05$).
[c] Significant linear effect of treatment ($P < .01$).
[d] Significant quadratic effect of treatment ($P < .01$).

and moisture levels, which also decreased with decreasing amounts of waste in the mixture. Moisture level has been reported to be very important in the ensiling process by facilitating the packing of the ensiled mass to prevent further anaerobic fermentation (Barnett, 1954).

Total bacteria counts prior to ensiling ranged from 20 to 861 million organisms per gram of mixture (table 12). Total coliform counts ranged from .1 to 9.6 million per gram of mixture. Both total bacteria and total coliform numbers decreased with decreasing amounts of waste in the mixture. Fecal coliforms ranged from .3 to 107 thousand in the initial samples. Following ensiling, total bacteria counts ranged from .6 to 26 million organisms per gram. The 20:80 mixture was higher ($P < .01$) in total bacteria, probably due to some degree of aerobic action which occurred when the plastic bag in which the mixture was contained ruptured during the ensiling process. Total coliforms were largely destroyed and fecal coliforms were completely destroyed during the ensiling process. Caswell et al. (1977) reported a large reduction of coliforms following ensiling of broiler litter with high moisture corn grain. Duque et al. (1978) reported similar results following ensiling of mixtures containing broiler litter with added water or whey.

Large Silo Study. The dry matter content of the swine waste was lower (22.8 vs 24.8%) and orchardgrass hay was higher (93.0 vs 89.3%) than for the ingredients used in the small silo study (tables 1 and 2). Protein nitrogen accounted for 54.5% of the total

TABLE 12. THE EFFECT OF ENSILING VARIOUS PROPORTIONS OF SWINE WASTE AND ORCHARDGRASS HAY UPON THE NUMBER OF TOTAL BACTERIA, TOTAL COLIFORMS, AND TOTAL FECAL COLIFORMS, SMALL SILO STUDY

Item	Proportions of swine waste and orchardgrass hay							SEM
	80:20	70:30	60:40	50:50	40:60	30:70	20:80	
Initial[a]								
Total bacteria (10^6/g)	651	861	238	172	338	56	20	27.4
Total coliforms (10^5/g)	18	96	15	10	10	21	1	6.7
Total fecal coliforms (10^3/g)	47	107	4	4	4	3	5	3.8
Ensiled[b]								
Total bacteria (10^5/g)	12.1[c]	9.3	23.2[c]	6.0[c]	18.3[c]	23.7[c]	260[d]	17.03
Total coliforms (10^1/g)	1.3	2.5	3.9	1.4	15.2	22.3	37.8	12.95
Total fecal coliforms (-)	0	0	0	0	0	0	0	

[a]Each value represents the mean of two samples.
[b]Each value represents the mean of six samples.
[cd]Means in the same column with different superscripts are different ($P < .01$).

nitrogen in the swine waste used in the large silo study, compared to 72.6% in the small silo study. Crude protein content was higher (28.9 vs 26.4%) while other proximate components were similar to the waste used in the small silo study. Initial samples were lost due to malfunctioning of the refrigeration unit and, therefore, are not presented for this study.

As the level of waste in the ensiled mixture increased, there was an increase ($P < .05$) in crude protein, ether extract, and ash; however, there was a decrease ($P < .05$) in dry matter, protein nitrogen, crude fiber, and NFE (table 13).

The proportions of various volatile fatty acids produced during the ensiling period are shown in table 14. Isobutyric, isovaleric, and valeric acids were not present in either of the ensiled mixtures. When measured as a molar percentage, there were no differences in volatile fatty acids between silages. Acetic acid, expressed as a percent of the dry matter, was different ($P < .01$) between the 40:60 and 60:40 silages (.89 vs 1.17). Total volatile fatty acid production, as percent of dry matter, was lower ($P < .05$) for the 40:60 mixture than the 60:40 mixture (1.30 vs 1.63%).

The pH of the ensiled 40:60 mixture was 4.6, compared to 4.9 for the 60:40 mixture ($P < .01$). There were no significant differences between the two silages in levels of water soluble carbohydrates and lactic acid.

There was a treatment effect on the total number of bacteria in the silage samples ($P < .05$). The lower number for the 40:60

TABLE 13. PROXIMATE COMPONENTS OF SWINE WASTE-ORCHARDGRASS HAY SILAGES, LARGE SILO STUDY

Item	Proportion of swine waste and orchardgrass hay[ab]	
	40:60[c] silage	60:40[d] silage
Dry matter, %	65.5 ± .50[e]	51.2 ± .42[f]
Composition of dry matter, %		
Crude protein	11.0 ± .11[e]	15.1 ± .10[f]
Ether extract	3.4 ± .10[e]	4.0 ± .08[f]
Crude fiber	32.0 ± .15[e]	27.9 ± .13[f]
Ash	7.3 ± .06[e]	8.8 ± .05[f]
NFE	46.3 ± .22[e]	44.2 ± .19[f]
Total nitrogen, %, dry basis	1.76	2.42
Protein nitrogen, % of total nitrogen	80.9 ± 2.81[e]	67.3 ± 2.40[f]

[a]Values refer to proportions of swine waste and orchardgrass hay.
[b]Data presented as least squares means ± standard error of the mean.
[c]Each value represents the mean of 8 samples.
[d]Each value represents the mean of 11 samples.
[ef]Means in the same row with different superscripts differ ($P < .05$).

TABLE 14. EFFECTS OF ENSILING VARIOUS PROPORTIONS OF SWINE WASTE AND ORCHARDGRASS HAY UPON VOLATILE FATTY ACID PRODUCTION, pH, WATER SOLUBLE CARBOHYDRATES, LACTIC ACID LEVELS, AND MICROBIAL PARAMETERS, LARGE SILO STUDY

Item	Proportions of swine waste and orchardgrass hay[ab] 40:60[c] silage	Proportions of swine waste and orchardgrass hay[ab] 60:40[d] silage
Volatile fatty acids, molar percentage		
Acetic	76.8 ± 2.87	77.9 ± 2.45
Propionic	6.5 ± .69	6.7 ± .59
Isobutyric	0	0
Butyric	16.7 ± 2.47	14.4 ± 2.11
Isovaleric	0	0
Valeric	0	0
Volatile fatty acids, % of dry matter		
Acetic	.89 ± .033[e]	1.17 ± .027[f]
Propionic	.10 ± .015	.13 ± .013
Isobutyric	0	0
Butyric	.31 ± .066	.33 ± .057
Isovaleric	0	0
Valeric	0	0
Total	1.30 ± .100[e]	1.63 ± .085
pH	4.6 ± .02[e]	4.9 ± .02[f]
Water soluble carbohydrate, % of dry matter	2.91 ± .262	2.75 ± .224
Lactic acid, % of dry matter	4.93 ± .360	4.84 ± .307
Total bacteria, per gram	27.0 ± 4.15[e]	54.8 ± 3.54[f]
Total coliforms, per gram	0	0
Fecal coliforms, per gram	0	0

[a]Values refer to the proportion of swine waste and ground orchardgrass hay.
[b]Data presented as least squares means ± standard error of the mean.
[c]Each value represents the mean of 8 samples.
[d]Each value represents the mean of 11 samples.
[ef]Means in the same row with different superscripts differ ($P < .05$).

silage agrees with the trend between the ensiled 40:60 and 60:40 mixtures reported for the small silo study (table 12). Harmon et al. (1975a) reported an increase in total bacteria numbers with increasing levels of litter in corn forage-litter silages. Total and fecal coliforms were not present in the ensiled mixtures. This is similar to results reported by Duque et al. (1978) with ensiled broiler litter and water.

Sheep Metabolism and Palatability Trials. The test diets, 40:60 and 60:40 swine waste-orchardgrass hay silages, were intermediate in crude protein content, compared to the negative and positive control diets. However, the ether extract and ash contents of the test diets were higher than those of the controls. The higher ether extract and ash contents of the test diets resulted from increased levels of swine waste, which were higher than orchardgrass hay in both components.

Organic matter digestibility was similar for swine waste-orchardgrass hay silages and orchardgrass hay fed alone, but was lower ($P < .05$) than for the orchardgrass hay plus soybean meal diet (table 15). Crude protein digestibility was highest ($P < .05$) in the orchardgrass hay plus soybean meal diet, compared to the other diets and was lower ($P < .05$) for the 40:60 silage compared to the 60:40 silage. There were no significant differences in digestion coefficients of ether extract, crude fiber and NFE among the sheep fed the four diets.

Nitrogen intakes were different ($P < .01$) for the various diets

TABLE 15. APPARENT DIGESTIBILITY OF PROXIMATE COMPONENTS AND NITROGEN UTILIZATION OF GROUND ORCHARDGRASS HAY, SWINE WASTE-ORCHARDGRASS HAY SILAGES AND GROUND ORCHARDGRASS HAY PLUS SOYBEAN MEAL BY SHEEP

	Diets[a]				
Item	Ground orchard-grass hay alone	40:60 silage[b]	60:40 silage[b]	Ground orchard-grass hay + soybean meal	SEM
Apparent digestibility, %					
Organic matter	53.8[c]	56.4[c]	56.4[c]	61.2[d]	.48
Crude protein	52.7[cd]	48.7[c]	56.5[d]	72.0[e]	.48
Ether extract	28.5	54.1	80.1	32.4	2.59
Crude fiber	53.7	58.4	59.6	61.2	.65
NFE	54.8	55.9	55.2	57.9	.50
Nitrogen utilization					
Nitrogen intake, g/day	8.17[c]	9.79[d]	13.09[e]	14.63[f]	.100
Nitrogen excretion					
Fecal	3.88[c]	5.03[d]	5.49[e]	4.09[f]	.051
Urinary	4.20[c]	6.26[d]	8.83[e]	8.28[e]	.160
Total	8.08[c]	11.29[d]	14.32[e]	12.37[f]	.166
Nitrogen retention					
Grams per day	0.09[c]	- 1.50[d]	- 1.23[d]	2.27[e]	.147
Percent of intake	1.10[c]	-15.3[d]	- 9.4[d]	15.5[e]	1.213
Percent of absorbed	2.09[c]	-31.51[d]	-16.18[d]	21.49[e]	2.235

[a]Each value represents a mean of six animals.
[b]Values refer to proportions of swine waste and orchardgrass hay.
[cdef]Means in the same row with different superscripts are different ($P < .05$).

which were directly related to nitrogen content of the diets, as the dry matter intake was similar among diets (table 15). Expressed as grams per day, nitrogen intakes were 8.17, 9.79, 13.09, and 14.63 for the diets containing orchardgrass hay alone, 40:60 silage, 60:40 silage, and orchardgrass hay + soybean meal, respectively.

Fecal nitrogen excretion was higher ($P < .01$) for sheep fed the waste containing silages than for those fed either the orchardgrass hay alone or orchardgrass hay plus soybean meal. Urinary nitrogen excretion was higher ($P < .01$) for sheep fed the 60:40 silage and orchardgrass hay plus soybean meal diets, compared to the 40:60 silage or orchardgrass hay alone. Total nitrogen excretion was higher ($P < .01$) for the sheep fed the 60:40 silage than for sheep fed any of the other three diets.

Nitrogen retention was negative and lower ($P < .05$) for the sheep receiving the 40:60 and 60:40 silages, which is primarily a reflection of poor retention of absorbed nitrogen. In contrast, nitrogen retention of sheep receiving the orchardgrass hay plus soybean meal diet was positive and higher ($P < .05$) than for sheep fed the other three diets.

Ruminal fluid pH, ammonia nitrogen and blood urea nitrogen data are shown in table 16. Ruminal fluid pH was not different among sheep fed the different diets. Ruminal ammonia nitrogen level was highest ($P < .01$) for sheep receiving the 60:40 silage, intermediate for sheep receiving the 40:60 silage and the orchard-

TABLE 16. RUMINAL FLUID pH AND AMMONIA AND BLOOD UREA NITROGEN LEVELS OF SHEEP FED GROUND ORCHARDGRASS HAY, SWINE WASTE-ORCHARDGRASS HAY SILAGES AND GROUND ORCHARDGRASS HAY PLUS SOYBEAN MEAL

	Diets[a]				
Item	Ground orchard-grass hay	40:60 silage[b]	60:40 silage[b]	Ground orchard-grass hay + soy-bean meal	SEM
Ruminal fluid pH	6.84	6.75	6.81	6.67	.027
NH_3-N, mg/100 ml	9.92[c]	20.42[d]	27.11[e]	17.73[d]	.336
Blood urea, mg/100 ml	6.79[c]	13.04[d]	17.24[e]	16.80[de]	.466

[a]Each value represents the mean of six animals.
[b]Values refer to proportions of swine waste and orchardgrass hay.
[cde]Means in the same row with different superscripts are different ($P < .01$).

grass hay plus soybean meal, and lowest for sheep receiving orchardgrass hay alone. The high levels of ruminal ammonia nitrogen in sheep fed the 40:60 and 60:40 swine waste-orchardgrass hay silages was probably due to the NPN in the waste containing silages. Harmon _et al_. (1974) reported higher ruminal ammonia levels in sheep with the inclusion of broiler litter in the diet. Blood urea nitrogen levels of sheep fed orchardgrass hay were lower ($P < .01$) than the blood urea nitrogen levels of sheep fed the other diets. Blood urea nitrogen levels were higher ($P < .01$) for sheep consuming the 60:40 silage than those consuming the 40:60 silage. Levels of blood urea nitrogen were lowest ($P < .01$) for sheep receiving the orchardgrass hay diet than all other diets.

Ruminal volatile fatty acid concentrations are shown in table 17. When expressed as μmoles/ml, acetic acid was higher ($P < .01$) in sheep fed the orchardgrass hay plus soybean meal diet than either the orchardgrass hay or the 40:60 silage. Propionic acid was higher ($P < .05$) in sheep receiving the 60:40 silage and orchardgrass hay plus soybean meal diet than in those fed the other two diets. Isobutyric and isovaleric acids were higher ($P < .01$) in sheep fed the 60:40 silage and orchardgrass hay plus soybean meal diets than for the sheep fed the other two diets. The sheep fed the orchardgrass hay plus soybean meal diet had higher ($P < .05$) levels of butyric acid than sheep fed orchardgrass hay alone. The levels of butyric acid were intermediate and not different for sheep

TABLE 17. RUMINAL FLUID VOLATILE FATTY ACID CONCENTRATIONS OF SHEEP FED GROUND ORCHARDGRASS HAY, SWINE WASTE-ORCHARDGRASS HAY SILAGES, AND GROUND ORCHARDGRASS HAY PLUS SOYBEAN MEAL

	Diets[a]				
Item	Ground orchard-grass hay	40:60 silage[b]	60:40 silage[b]	Ground orchard-grass hay + soybean meal	SEM
Volatile fatty acids, μmole/ml					
Acetic	64.80^{c}	66.35^{c}	76.45^{cd}	84.79^{d}	3.400
Propionic	16.82^{f}	22.52^{g}	28.19^{h}	26.93^{h}	.651
Isobutyric	0.39^{c}	0.47^{c}	0.78^{d}	0.88^{d}	.027
Butyric	6.31^{f}	8.36^{fg}	7.53^{fg}	8.92^{g}	.401
Isovaleric	0.44^{c}	0.52^{c}	0.89^{d}	1.13^{d}	.035
Valeric	0.23^{f}	0.76^{g}	0.91^{g}	0.68^{g}	.037
Total	89.02^{c}	98.98^{cd}	114.75^{de}	123.33^{f}	2.478
Volatile fatty acids, moles/100 moles					
Acetic	72.74^{f}	67.10^{g}	66.74^{g}	68.76^{g}	.384
Propionic	19.04^{c}	22.71^{d}	24.47^{d}	21.76^{cd}	.409
Isobutyric	0.43^{c}	0.47^{c}	0.67^{d}	0.71^{d}	.020
Butyric	7.06	8.44	6.55	7.30	.362
Isovaleric	0.47^{c}	0.52^{cd}	0.78^{de}	0.92^{e}	.031
Valeric	0.25^{c}	0.76^{d}	0.80^{d}	0.55^{d}	.031

[a]Each value represents the mean of six animals.
[b]Values refer to proportions of swine waste and orchardgrass hay.
[cde]Means in the same row with different superscript letters are significantly different ($P < .01$).
[fgh]Means in the same row with different superscript letters are significantly different ($P < .05$).

fed the 40:60 and 60:40 silages. The sheep receiving the orchardgrass hay diet had a lower ($P < .05$) level of valeric acid than any of the other diets.

When expressed as moles/100 moles, sheep receiving only orchardgrass hay had higher ($P < .05$) levels of acetic than sheep receiving the other diets. Sheep fed the 40:60 and 60:40 swine waste silages had higher ($P < .01$) propionic acid levels than those fed the orchardgrass hay alone, with the level intermediate for sheep fed orchardgrass hay plus soybean meal. Isobutyric acid was higher ($P < .01$) for animals receiving the 60:40 silage and orchardgrass hay plus soybean meal diets than for animals fed the other two diets. Sheep fed orchardgrass hay had lower levels of isovaleric acid than animals receiving either the 60:40 silage or orchardgrass hay plus soybean meal diets ($P < .01$). Valeric was lowest ($P < .01$) for sheep fed the orchardgrass hay than for those fed any of the other diets.

The apparent digestion coefficients of the swine waste by sheep, calculated by the difference method (Crampton and Harris, 1969), are shown in table 18. Crude protein digestibility was lower ($P < .01$) in the 40:60 silage than in the 60:40 silage. Harmon _et al._ (1975b) reported a decrease in crude protein digestibility with an increase of broiler litter in the ensiled mixture. Lucas (1976) reported crude protein digestibility of dried cattle waste from steers fed a 50% roughage diet to be 32.1%, which is lower than the 67.0% reported for the swine waste in the 60:40 silage. Ether extract tended to be higher in the 60:40 than the 40:60 silage. The ether

TABLE 18. APPARENT DIGESTION COEFFICIENTS[a] OF SWINE WASTE IN SWINE WASTE-GROUND ORCHARDGRASS HAY SILAGES WHEN FED TO SHEEP

Item	40:60 silage[bc]	60:40 silage[bc]	SEM
Crude protein	31.1[d]	67.0[e]	4.81
Ether extract	170.7	189.8	10.92
Crude fiber	80.0	62.5	9.02
Ash	10.5	8.0	3.83
Organic matter	67.8	63.6	5.75
NFE	60.5	57.3	2.50

[a]Calculated by difference, using value for ensiled mixtures and orchardgrass hay.
[b]Values refer to proportions of swine waste and ground orchardgrass hay.
[c]Each value represents the mean of six animals.
[de]Means in the same row with different superscripts are different ($P<.01$).

extract digestibilities in excess of 100% may be the result of errors since ether extract accounted for small percentages of the dry matter. Digestion coefficients for crude fiber, ash, organic matter and NFE digestion coefficient of swine waste all tended to be lower in the 60:40 silage than the 40:60 silage.

Results of the palatability trial in which the same diets as fed in the digestion trial were fed are given in table 19. There were no significant differences in dry matter intake between the four diets. The 40:60 silage tended to be consumed at slightly higher levels than the 60:40 silage, when calculated as grams per $W_{kg}^{0.75}$ per day. Anthony (1966) found no differences in feed intake and palatability of the test diets and the basal when wastelage was fed as 63% of the test diet. Fontenot et al. (1966) reported similar performance for steers fed a fattening diet containing 25% broiler litter and those fed a conventional fattening diet plus a limited amount of long hay.

Swine Metabolism and Palatability Trials. Composition of proximate components of diets fed in the gilt metabolism and palatability trials are shown in table 4. The results from the metabolism trials were inconclusive due to inconsistent flow of digesta resulting from the high levels of hay and swine waste-orchardgrass hay silage in the diets and those will not be presented. Future studies with high fiber diet would warrant the use of digesta markers.

There was a decrease in dry majter intake with the increasing

TABLE 19. DAILY DRY MATTER INTAKE BY SHEEP FED GROUND ORCHARDGRASS HAY, SWINE WASTE-ORCHARDGRASS HAY SILAGES, AND GROUND ORCHARDGRASS HAY PLUS SOYBEAN MEAL

Item	Diets[a]				SEM
	Ground orchardgrass hay alone	40:60[b] silage	60:40[b] silage	Ground orchardgrass hay + soybean meal	
Grams per day	788	760	679	870	65.11
Grams per $W_{kg}^{0.75}$ per day	56.9	56.3	50.4	62.2	4.53

[a] Each value represents the mean of six animals.
[b] Values refer to proportions of swine waste and orchardgrass hay.

levels of silage in the diet (table 20). Intake was lower ($P < .01$) for diets containing 50% of the 40:60 or 60:40 silages compared to the basal alone or to the 75% basal plus 25% mixed hay diets. This may have been due to the increased levels of crude fiber in the diets containing swine waste-orchardgrass hay silages. Intake for the 75% basal plus 25% mixed hay ration tended to be lower than for the basal alone.

Ensiling Swine Waste with Ground Corn Grain

Small Silo Study. The composition of the swine waste and ground corn grain used in the small silo study is shown in table 5. Dry matter of the swine waste was 24%, which is in close agreement with previous work (Overhults *et al*., 1978; Kornegay *et al*., 1977; Pearce, 1977; and Orr, 1974). Swine waste averaged 29.3% crude protein (dry basis) which is higher than the swine waste used in the previous small silo study (26.4%), but similar to that used in the previous large silo study (28.9%). The protein nitrogen fraction of the total nitrogen in the swine waste was 54.2%, which is similar to the value of 54.5% reported in the previous large silo study. In general, the levels of the other components of the swine waste were similar to that used in the previous small and large silo studies.

The mixtures containing 70% or more swine waste were similar to a sludge and very difficult to handle before and after ensiling. Mixtures containing 60% or more swine waste had a very offensive odor before and after ensiling. Ensiled mixtures containing 50% waste or less were quite easy to handle and had an acetic aroma.

TABLE 20. DAILY DRY MATTER INTAKE BY SWINE FED A BASAL DIET AND DIETS CONTAINING SWINE WASTE-ORCHARDGRASS HAY SILAGES

	Diets[a]						
Item	Basal	75% basal + 25% mixed grass hay	75% basal + 25% (40:60)[b] silage	75% basal + 25% (60:40)[b] silage	50% basal + 50% (40:60)[b] silage	50% basal + 50% (60:40) silage	SEM
Kilograms per day	6.75[c]	5.70[cd]	4.89[de]	6.12[cd]	3.51[e]	3.49[e]	.252
Grams per $W_{kg}^{0.75}$ per day	72.82[c]	64.91[cd]	55.00[de]	67.64[cd]	41.15[f]	44.31[ef]	3.601

[a]Each value represents the mean of six animals.
[b]Values in parentheses refer to proportions of swine waste and orchardgrass hay.
[cdef]Means in the same row with different superscripts are significantly different ($P < .01$).

All bags containing the 80:20 mixture ruptured during the first 3 days of the ensiling period and were resealed. No further ruptures were encountered.

Dry matter, protein nitrogen and NFE increased linearly ($P < .01$) with decreasing amounts of swine waste in the mixture (table 21). Crude protein, ether extract, crude fiber and ash all decreased linearly with decreasing amounts of waste in the mixture ($P < .01$). This was a direct reflection of the decrease in the level of waste in the mixture which is higher than corn in the aforementioned components.

In the initial samples, the pH and water soluble carbohydrate content were similar for all mixtures while the lactic acid content tended to decrease with decreasing levels of swine waste in the mixture (table 22).

The pH values of all ensiled mixtures were below 4.4. There was a linear ($P < .01$) decrease in water soluble carbohydrate and lactic acid levels of the ensiled material with decreasing amounts of waste in the mixture. Lactic acid content of the ensiled mixtures ranged from 15.0% in the 80:20 mixture to 1.9% in the 20:80 mixture. The decrease in pH and water soluble carbohydrates, and the marked increase in lactic acid over the ensiling period are good indications that ensiling did occur.

Dry matter disappearance was linear ($P < .01$) across all mixtures ranging from 6.33% for the 80:20 mixture to .10% for the 20:80 mixture.

TABLE 21. PROXIMATE COMPONENTS OF VARIOUS ENSILED PROPORTIONS OF SWINE WASTE AND GROUND CORN, SMALL SILO STUDY

Item	Proportions of swine waste and ground corn grain[a]							SEM
	80:20	70:30	60:40	50:50	40:60	30:70	20:80	
Dry matter, %[b]	34.9	42.0	49.0	55.9	63.4	70.3	76.9	.15
Composition of dry matter, %								
Crude protein[b]	21.4	18.0	15.4	13.7	12.1	11.2	10.5	.07
Ether extract[b]	10.0	8.9	7.7	6.4	5.7	4.7	4.3	.74
Crude fiber[b]	8.7	8.0	6.2	5.2	4.4	4.0	3.8	.12
Ash[b]	10.3	7.2	5.7	4.6	3.6	2.9	2.6	.19
NFE[b]	49.6	47.9	65.2	70.1	74.2	77.2	78.6	.29
Total nitrogen, % dry basis[b]	3.4	2.9	2.5	2.2	1.9	1.8	1.7	-
Protein nitrogen, % of total nitrogen	49.0	50.9	56.1	58.6	64.1	69.0	68.8	.43

[a]Each value is the mean of six samples.
[b]Significant linear effect of treatment ($P < .01$).

TABLE 22. EFFECT OF ENSILING VARIOUS PROPORTIONS OF SWINE WASTE AND GROUND CORN GRAIN UPON pH, WATER SOLUBLE CARBOHYDRATES, LACTIC ACID, AND DRY MATTER DISAPPEARANCE, SMALL SILO STUDY

Item	Proportions of swine waste and ground corn grain							SEM
	80:20	70:30	60:40	50:50	40:60	30:70	20:80	
Initial mixture[a]								
pH	6.9	6.8	6.4	6.8	6.9	6.8	6.6	.01
Water soluble carbohydrates, % dry basis	3.5	4.3	4.3	4.6	4.6	3.5	2.9	.12
Lactic acid, % dry basis	2.4	3.1	1.8	0.7	0.9	0.7	0.1	.15
Ensiled mixture[a]								
pH[c]	4.4	4.3	4.2	4.3	4.3	4.2	4.4	.02
Water soluble carbohydrates, % dry basis[c]	1.8	1.6	1.3	1.6	1.7	1.2	0.8	.19
Lactic acid, % dry basis[c]	15.0	13.4	11.1	7.6	5.5	4.4	1.9	.15
Dry matter disappearance, %[bc]	6.33	3.53	1.00	2.48	0.15	3.37	0.10	.066

[a]Each value represents the mean of two samples.
[b]Each value represents the mean of six samples.
[c]Significant linear effect of treatment ($P < .01$).

TABLE 23. EFFECT OF ENSILING VARIOUS PROPORTIONS OF SWINE WASTE AND GROUND CORN UPON VOLATILE FATTY ACID PRODUCTION, SMALL SILO STUDY

Item	Proportions of swine waste and corn grain[a]							SEM
	80:20	70:30	60:40	50:50	40:60	30:70	20:80	
Volatile fatty acids, molar percentage								
Acetic[b]	47.1	58.1	65.4	75.1	81.8	87.4	93.6	2.12
Propionic[c]	16.9	16.0	15.2	12.4	10.0	7.0	3.7	.03
Isobutyric[d]	1.0	0.9	0.8	0.8	0.1	0	0	.01
Butyric[d]	29.1	21.4	18.0	11.8	8.2	5.6	2.5	0
Isovaleric	1.3	0.8	0	0	0	0	0	.02
Valeric[d]	4.4	2.6	0.5	0	0	0	0	0
Volatile fatty acids, % of dry matter								
Acetic[c]	2.35	2.15	1.65	1.33	1.12	0.98	0.96	.277
Propionic[d]	1.02	0.74	0.47	0.27	0.16	0.09	0.04	.095
Isobutyric[d]	0.07	0.05	0.03	0.02	0	0	0	.033
Butyric[d]	2.08	1.17	0.67	0.30	0.15	0.09	0.03	.144
Isovaleric	0.11	0.05	0	0	0	0	0	.045
Valeric[d]	0.37	0.16	0.02	0	0	0	0	.063
Total[c]	5.71	4.33	2.79	1.93	1.44	1.16	1.03	.398

[a]Each value represents the mean of six samples.
[b]Significant quadratic effect of treatment ($P < .05$).
[c]Significant linear effect of treatment ($P < .01$).
[d]Significant quadratic effect of treatment ($P < .01$).

When expressed as a molar percentage, acetic acid was observed to increase quadratically ($P < .05$) as the level of waste in the mixture increased (table 23). In all mixtures acetic was the most prominent volatile fatty acid. Propionic acid decreased ($P < .01$) linearly and butyric acid quadratically ($P < .01$) as the level of waste decreased in the mixture. Isobutyric and valeric acids exhibited a quadratic ($P < .01$) effect, approaching zero as the level of waste in the mixture decreased. Expressed as a percent of the dry matter, propionic, isobutyric, butyric, and valeric acids decreased quadratically ($P < .01$) with decreasing levels of waste in the mixture. Acetic and total VFA's (volatile fatty acids) decreased ($P < .01$) linearly as the level of waste decreased in the mixture. On a dry matter basis, percentage of volatile fatty acids was highest for the 80:20 mixture (5.71%) and lowest for the 20:80 mixture (1.03%). There was a linear decrease ($P < .01$) in volatile fatty acids with decreasing levels of swine waste in the mixture.

The microbial parameters of the initial and ensiled mixtures are shown in table 24. Total bacteria, total coliforms and fecal coliforms tended to decrease with decreasing levels of waste in the initial mixture. Proteus were found in all the initial mixtures, but salmonella and shigella were not present. Harmon et al. (1975a) reported decreasing levels of bacteria in initial mixtures of corn forage-broiler litter with decreasing amounts of litter in the mixture.

After ensiling, there was a decrease in total bacteria which

TABLE 24. EFFECT OF ENSILING VARIOUS PROPORTIONS OF SWINE WASTE AND GROUND CORN UPON THE NUMBER OF TOTAL BACTERIA, TOTAL COLIFORMS, TOTAL FECAL COLIFORMS, AND QUALITATIVE TESTS FOR SALMONELLA, SHIGELLA, AND PROTEUS ORGANISMS, SMALL SILO STUDY

Item	Proportions of swine waste and ground corn grain							SEM
	80:20	70:30	60:40	50:50	40:60	30:70	20:80	
Initial mixtures[a]								
Total bacteria (10^6/g)	112.0	100.0	28.5	5.2	5.8	8.7	9.3	47.09
Total coliforms (10^3/g)	6.0	8.0	17.0	42.0	174.0	193.0	47.0	15.20
Total fecal coliforms (10^3/g)	1.0	1.5	6.6	11.2	29.8	13.5	50.0	9.48
Salmonella	-	-	-	-	-	-	-	
Shigella	-	-	-	-	-	-	-	
Proteus	+	+	+	+	+	+	+	
Ensiled mixtures[b]								
Total bacteria (10^3/g)[c]	84.5	62.6	58.2	37.0	18.9	13.1	10.8	.043
Total coliforms (-)	0	0	0	0	0	0	0	0
Total fecal coliforms (-)	0	0	0	0	0	0	0	0
Salmonella	-	-	-	-	-	-	-	
Shigella	-	-	-	-	-	-	-	
Proteus	-	-	-	-	-	-	-	

[a]Each value represents the mean of two samples.
[b]Each value represents the mean of six samples.
[c]Significant linear effect of treatment ($P < .01$).

exhibited a linear decrease ($P < .01$) with decreasing amounts of waste in the mixture. Reductions in total bacteria and total coliform numbers following ensiling of broiler litter with water have been reported by Caswell et al. (1978). Harmon et al. (1975a) reported similar results for broiler litter ensiled with corn forage. Coliforms, both total and fecal, were completely destroyed by the ensiling, which is in agreement with results of the large silo study with swine waste-orchardgrass hay silage. However, in the small silo study with swine waste-orchardgrass hay silage, total coliforms were reduced but not completely destroyed. Duque et al. (1978) reported complete destruction of fecal coliforms with the ensiling of mixtures of broiler litter and water or liquid whey. This was probably due to the rapid drop in pH associated with the ensiling process. Lactic acid increased rapidly during the fermentation process (table 22) and rapidly lowered the pH of the ensiled material. Salmonella and shigella organisms were not found in the initial or ensiled material. Proteus, which was present in the initial mixtures, was destroyed by ensiling. Similar results were reported by Caswell et al. (1978) from ensiling broiler litter with added moisture.

Results of the study indicate that good ensiling, as measured by pH and lactic acid content of the ensiled mixtures, occurred in all ratios of swine waste-ground corn except the 20:80 mixture. The 60:40 and 40:60 mixtures were used in a large silo study since mixtures above the 60:40 ratio were impractical because of a poor consistency and offensive odor.

Large Silo Study. Composition of the swine waste (table 6) was in close agreement with the values reported for previous studies in this dissertation and those reported by Orr (1974), Kornegay *et al.* (1977), Pearce (1977) and Overhults *et al.* (1978). Protein nitrogen accounted for 57.3% of the total nitrogen in swine waste.

Dry matter, protein nitrogen and NFE values were higher for the 40:60 silage, compared to the 60:40 silage (table 25). The 60:40 silage was higher in crude protein, ether extract, crude fiber and ash than the 40:60 silage because of the higher levels of waste in the 60:40 silage. Similar trends were observed in the swine waste-ground corn small silo study. Protein nitrogen appeared to decrease during the ensiling period. The decrease in protein nitrogen during ensiling may be due to a breakdown or utilization of protein nitrogen sources by microorganisms in the fermenting silage.

Acetic, propionic, isobutyric, and butyric acids, expressed as a molar percentage, were different ($P < .01$) between the initial and ensiled mixtures (table 26). Levels of acetic acid in the ensiled mixtures were higher ($P < .01$) than in the initial mixtures. Acetic acid is formed most readily during the first few days of ensiling and rapidly utilizes many of the available water soluble carbohydrates. The decreased ($P < .01$) molar percentage of propionic acid during the ensiling process is most likely due to the further breakdown of lactic acid to acetic. Acetic made up the largest molar percentage of volatile fatty acids in each ensiled treatment, being

TABLE 25. PROXIMATE COMPONENTS OF SWINE WASTE-GROUND CORN SILAGES, LARGE SILO STUDY

Item	40:60[ab] silage		60:40[ab] silage	
	Initial[c]	Ensiled[d]	Initial[e]	Ensiled[f]
Dry matter, %				
Composition of dry matter, %	63.2 ± .29[g]	60.7 ± .17[h]	49.0 ± .25[i]	50.0 ± .18[j]
Crude protein	11.4 ± .13[g]	12.1 ± .08[h]	15.4 ± .11[i]	14.0 ± .08[j]
Ether extract	4.6 ± .09[g]	4.5 ± .05[g]	6.7 ± .08[h]	6.7 ± .06[h]
Crude fiber	4.4 ± .10[g]	4.4 ± .06[g]	5.8 ± .09[h]	5.8 ± .06[h]
Ash	3.3 ± .11[g]	3.4 ± .07[g]	5.4 ± .10[h]	5.5 ± .07[h]
NFE	76.3 ± .26[g]	75.5 ± .15[g]	66.7 ± .16[h]	68.0 ± .22[h]
Total nitrogen, % dry basis	1.8	1.9	2.5	2.2
Protein nitrogen, % of total nitrogen	79.6 ± 2.82[g]	67.0 ± 1.63[h]	73.5 ± 2.44[g]	54.5 ± 1.73[i]

[a]Values refer to proportions of swine waste and ground corn grain.
[b]Data presented as least squares means ± standard error of the mean.
[c]Each value represents the mean of 3 samples.
[d]Each value represents the mean of 9 samples.
[e]Each value represents the mean of 4 samples.
[f]Each value represents the mean of 8 samples.
[ghij]Means in the same row with different superscripts are different ($P < .05$).

TABLE 26. EFFECT OF ENSILING VARIOUS PROPORTIONS OF SWINE WASTE AND GROUND CORN ON VOLATILE FATTY ACIDS, pH, WATER SOLUBLE CARBOHYDRATES, AND LACTIC ACID LEVELS, LARGE SILO STUDY

	Proportions of swine waste and corn grain[a]			
	40:60 silage		60:40 silage	
Item[b]	Initial[c]	Ensiled[d]	Initial[e]	Ensiled[f]
Volatile fatty acids, molar percentage[f]				
Acetic	70.0 ± 1.04^{g}	85.5 ± .77^{h}	75.2 ± 1.16^{i}	79.7 ± .32^{j}
Propionic	17.6 ± .57^{g}	8.3 ± .43^{h}	13.9 ± .64^{i}	11.5 ± .45^{j}
Isobutyric	0	0	0	0
Butyric	12.4 ± .41^{g}	6.2 ± .30^{h}	9.5 ± .45^{i}	8.5 ± .32^{i}
Isovaleric	0	0	0	0
Valeric	0	0	0	0
Volatile fatty acids, % of dry matter				
Acetic	.65 ± .078^{g}	.81 ± .058^{g}	1.10 ± .087^{h}	1.76 ± .062^{i}
Propionic	.15 ± .017^{g}	.10 ± .013^{h}	.34 ± .019^{i}	.31 ± .014^{i}
Isobutyric	0	0	0	0
Butyric	.12 ± .014^{g}	.08 ± .010^{h}	.28 ± .015^{i}	.28 ± .011^{i}
Isovaleric	0	0	0	0
Valeric	0	0	0	0
Total	.93 ± .101^{g}	.98 ± .075^{g}	1.72 ± .113^{h}	2.35 ± .080^{i}
pH	5.422 ± .0598^{g}	4.162 ± .0446^{h}	5.362 ± .0669^{g}	4.326 ± .0473^{i}
Water soluble carbohydrates, % of dry matter	.98 ± .092^{gi}	.79 ± .061^{g}	2.94 ± .082^{h}	1.15 ± .065^{i}
Lactic acid, % of dry matter	2.70 ± .205^{g}	4.54 ± .137^{h}	1.53 ± .183^{i}	5.63 ± .145^{j}

[a] Values refer to proportions of swine waste and ground corn grain.
[b] Data presented as least squares means ± standard error of the mean.
[c] Each value represents the mean of 3 samples.
[d] Each value represents the mean of 9 samples.
[e] Each value represents the mean of 4 samples.
[f] Each value represents the mean of 8 samples.
[g,h,i,j] Means in the same row with different superscripts are different ($P < .05$).

85.5% in the 40:60 silage and 79.7% in the 60:40 treatment (table 26). Acetic was reported to be the major volatile fatty acid in corn silage (Barnett, 1954).

When expressed as a percent of the dry matter, acetic, propionic, and butyric acids were higher ($P < .01$) for the 60:40 silage than the 40:60 silage. Total volatile fatty acids, as a percent of the dry matter, for the 40:60 and 60:40 silages were .98 and 2.35%, respectively.

The pH decreased ($P < .01$) during ensiling for both mixtures. The ensiled mixtures were all below pH 4.4, which indicates ensiling has occurred. Harmon et al. (1975a) reported pH values for ensiled corn forage-litter ranged from 3.7 to 4.4.

Water soluble carbohydrate levels decreased ($P < .01$) during ensiling in both mixtures. Water soluble carbohydrate levels were higher ($P < .01$) for the 40:60 mixture compared to 60:40 mixture before and after ensiling. Lactic acid levels increased ($P < .01$) during ensiling to 5.63% in the 60:40 silage and 4.54% in the 40:60 silage.

The drop in pH is related to the increase in lactic acid. The further breakdown of lactic acid or limited appearance of it in the ensiled mass is usually an indication of poor ensiling (Barnett, 1954). The decrease in water soluble carbohydrates during the ensiling process is reflective of the increased levels of volatile fatty acids being produced.

As reported for the small silo study, there was a decrease

($P < .01$) in total bacteria numbers for both mixtures following ensiling and total fecal coliforms were completely destroyed in the ensiling process (table 27). Proteus organisms were present in the initial mixtures but not after ensiling. Similar findings were reported by Caswell _et al_. (1978) from ensiling broiler litter and added moisture.

Caswell _et al_. (1978) reported the complete destruction of all coliforms in ensiled broiler litter when the ensiled material contained over 20% moisture. Albert (1977) ensiled various proportions of caged layer waste and corn forage and reported reduction of total bacteria numbers and complete elimination of coliforms after ensiling. Duque _et al_. (1978) reported complete elimination of fecal coliforms after ensiling with various proportions of broiler litter and water or whey. McCaskey and Anthony (1975) reported that pH values of 4.0 to 4.5 were successful in eliminating 27 cultures of salmonella in 3 to 4 days in laboratory silos containing 45% corn, 15% corn forage, and 40% cattle manure. Therefore, had any salmonella or shigella organisms been present in the initial mixtures, the pH of the ensiled material would have been sufficient for their destruction.

Sheep Metabolism and Palatability Trials. The composition of the diets fed in the sheep digestion trial is presented in table 7. No palatability problems or digestive disturbances were observed during the digestion trial for animals fed the diets containing swine waste-ground corn silages.

The apparent digestion coefficients for dry matter, crude protein,

TABLE 27. THE EFFECT OF ENSILING VARIOUS PROPORTIONS OF SWINE WASTE AND GROUND CORN ON THE NUMBER OF TOTAL BACTERIA, TOTAL COLIFORMS, TOTAL FECAL COLIFORMS AND QUALITATIVE TESTS FOR SALMONELLA, SHIGELLA, AND PROTEUS ORGANISMS, LARGE SILO STUDY[a]

Item	40:60 silage[b]		60:40 silage[b]	
	Initial	Ensiled	Initial	Ensiled
Total bacteria, per gram[cd]	$3766^{d} \pm 588.5$	$33.2^{e} \pm 339.77$	$3625^{d} \pm 509.7$	$41.5^{e} \pm 360.38$
Total coliforms, per gram[cd]	$53.7^{d} \pm 6.3$	0^{d}	$59.7^{d} \pm 5.47$	0^{d}
Total fecal coliforms, per gram[bc]	$24^{d} \pm 3.4$	0^{d}	$26.5^{d} \pm 3.01$	0^{d}
Salmonella	-	-	-	-
Shigella	-	-	-	-
Proteus	+	-	+	-

[a]Data presented as least squares means ± standard error of the mean.
[b]Values refer to proportions of swine waste and ground corn grain.
[c]Per gram on an as is basis.
[de]Means in the same row with different superscripts are different ($P < .05$).

organic matter, and NFE increased linearly ($P < .01$) as the 40:60 and 60:40 silages were added at a level of 20 and 40% in the diet (table 28). Ether extract digestibility also increased linearly for the sheep fed the 40:60 ($P < .01$) and 60:40 ($P < .05$) silages. Crude fiber and ash digestibility coefficients were not different.

Nitrogen intakes, expressed as grams per day, increased when the higher level of the silages was substituted for the basal diet. Fecal nitrogen excretion was not significantly different among treatments. Urinary nitrogen increased linearly ($P < .01$) with increasing levels of the 40:60 and 60:40 silages in the diet. Total nitrogen excreted was only increased ($P < .01$) for the sheep fed the 60:40 silage.

Nitrogen retention, expressed as grams per day or as a percent of intake, was not different ($P > .10$) between the diets. Nitrogen retention expressed as a percent of absorbed nitrogen linearly decreased ($P < .05$) for diets containing the 60:40 silage. The same trend was observed in the 40:60 corn silage but the differences were not significant.

Digestion coefficients, calculated by difference (Crampton and Harris, 1969), for dry matter, crude protein, ether extract, crude fiber, organic matter and NFE were high for the 40:60 and 60:40 swine waste-ground corn silages, but appeared to decrease when the higher level (40%) was added in the diet (table 29). Digestion coefficients varied widely among sheep within treatment resulting in no significant differences between levels fed or treatment.

TABLE 28. APPARENT DIGESTIBILITY OF PROXIMATE COMPONENTS AND NITROGEN UTILIZATION OF A BASAL DIET AND DIETS CONTAINING[a] SWINE WASTE-GROUND CORN SILAGES BY SHEEP

Item	Diets					
		Level of 40:60 silage[b]		Level of 60:40 silage[b]		
	Basal	20%	40%	20%	40%	SEM
Apparent digestibility[c]						
Dry matter[de]	67.6	73.2	76.5	73.3	74.8	.43
Crude protein[de]	56.2	60.4	63.0	63.5	62.6	.77
Ether extract[df]	64.0	69.6	72.8	70.6	76.1	.70
Crude fiber	55.9	62.9	58.7	60.8	59.9	.78
Ash	48.0	37.8	42.3	40.0	38.4	2.31
Organic matter[de]	68.2	74.4	77.7	74.6	76.4	.41
NFE[de]	74.2	80.0	84.1	80.5	83.2	.36
Nitrogen utilization[c]						
Nitrogen intake, g/day	12.06	12.40	12.73	12.75	13.45	0
Nitrogen excretion, g/day						
Fecal	5.28	4.91	4.71	4.64	5.03	.096
Urinary[de]	4.83	5.36	6.15	6.47	7.09	.110
Total[e]	10.11	10.27	10.86	11.11	12.12	.142
Nitrogen retention						
Grams per day	1.94	2.12	1.88	1.64	1.32	.142
Percent of intake	16.1	17.2	14.7	12.8	9.8	1.145
Percent of absorbed[f]	27.8	27.9	22.9	20.3	14.8	1.702

[a]Each value represents the mean of six animals.
[b]Values refer to the proportions of swine waste and ground corn grain.
[c]Diets containing the 40:60 silage were analyzed with the basal and diets containing the 60:40 silage were analyzed with the basal.
[d]Significant linear effect for diets containing 40:60 silage ($P < .01$).
[e]Significant linear effect for diets containing 60:40 silage ($P < .01$).
[f]Significant linear effect for diets containing 60:40 silage ($P < .05$).

TABLE 29. APPARENT DIGESTIBILITY OF SWINE WASTE-GROUND CORN SILAGES BY SHEEP[a]

	Diets[b]				
	Level of 40:60 silage[c]		Level of 60:40 silage[c]		
Item	20%	40%	20%	40%	SEM
Dry matter	95.7	89.8	96.5	85.7	2.99
Crude protein	77.3	72.2	92.7	72.1	4.72
Ether extract	91.9	88.6	98.1	94.2	4.77
Crude fiber	90.8	62.8	80.3	65.9	4.86
Ash	- 2.8	33.7	7.9	24.2	15.72
Organic matter	99.2	91.9	100.2	88.6	2.75
NFE	102.5	98.9	105.3	96.7	2.33

[a]Calculated by difference using value for ensiled mixture plus basal and basal diet.
[b]Each value represents the mean of six animals.
[c]Values refer to the proportions of swine waste and ground corn grain.

The increases in the apparent digestibility of the diet with increasing levels of silage is due to the decrease of the orchardgrass hay in the diet from 51.1% in the basal to 30.7% in the diets containing 40% of either the 40:60 or 60:40 swine waste-ground corn silage. On a dry matter basis, the ratio of swine feces to ground corn in the 60:40 swine waste-ground corn silage is approximately 1:3. Hence, by increasing the level of the 60:40 swine waste-ground corn silage, the amount of corn was increased, which has an apparent digestibility of 91% in sheep and decreasing the amount of orchardgrass hay, with an apparent digestibility of 60 percent.

Ruminal fluid pH values decreased linearly ($P < .01$) and ammonia nitrogen levels increased linearly ($P < .01$) with increasing levels of the swine waste-ground corn silages in the diet (table 30). There was a trend for sheep fed the diet containing the 60:40 silage to have higher ruminal ammonia nitrogen levels than those fed the 40:60 silage. Harmon _et al_. (1974) reported increasing levels of ruminal ammonia nitrogen in sheep fed silages containing broiler litter. The increase in ruminal ammonia nitrogen levels in sheep fed the diets containing swine waste-ground corn silages tends to follow the increased levels of non-protein nitrogen present in the silage mixtures.

Blood urea nitrogen levels increased linearly ($P < .05$) with increasing amounts of 40:60 swine waste-ground corn silages in the diet, but there were no differences between the sheep fed the 20 and

TABLE 30. RUMINAL FLUID pH AND AMMONIA AND BLOOD UREA NITROGEN LEVELS OF SHEEP FED A BASAL DIET AND DIETS CONTAINING SWINE WASTE-GROUND CORN SILAGES

Item	Diets					SEM
		Level of 40:60 silage[bc]		Level of 60:40 silage[bc]		
	Basal	20%	40%	20%	40%	
Ruminal fluid pH[de]	6.12	5.98	5.63	5.97	5.66	.030
NH_3-N, mg/100 ml[de]	6.8	9.5	15.7	11.7	18.3	.69
Blood urea nitrogen mg/100 ml[fg]	4.5	6.0	7.0	7.4	6.8	.27

[a]Each value represents the mean of six animals.
[b]Value refers to the proportions of swine waste and ground corn grain.
[c]Diets containing the 40:60 silage were analyzed with the basal. Diets containing the 60:40 silage were analyzed with the basal.
[d]Significant linear effect for diets containing 40:60 silage ($P < .01$).
[e]Significant linear effect for diets containing 60:40 silage ($P < .01$).
[f]Significant linear effect for diets containing 40:60 silage ($P < .05$).
[g]Significant linear effect for diets containing 60:40 silage ($P < .05$).

40% level of the 60:40 silage.

Ruminal fluid volatile fatty acid (VFA) data are shown in table 31. Acetic acid, expressed as μmoles/ml showed a quadratic effect ($P < .05$). The other VFA's and total VFA's linearly increased ($P < .01$ and $P < .05$) with increasing levels of each swine waste-ground corn silage in the ration.

Acetic acid, expressed as moles/100 moles linearly decreased ($P < .05$) with increasing levels of the silages in the diet. The proportion of propionic acid linearly increased ($P < .01$) with increasing amounts of the 60:40 silage in the diet; the effect was similar but nonsignificant for the 40:60 silage. The proportion of butyric acid linearly increased ($P < .01$) with increasing amounts of the 40:60 silage in the diet; the effect was similar but nonsignificant for the 60:40 silage. The proportion of valeric acid linearly increased ($P < .05$ and $P < .01$) with increasing levels of the silages in the diet.

The dry matter intakes from the palatability trial are presented in table 32. Lambs fed the basal plus 20% of the 60:40 silage and the basal plus 40% of the 40:60 silage consumed ($P < .01$) more feed on an actual and metabolic size base than lambs fed the basal diet. The consumption of the other two diets was intermediate. Harmon et al. (1975b) attributed the higher intake of corn forage-broiler litter silage compared to corn silage alone to the increased bulk density of the ensiled material. This may well explain the results observed in this study using swine waste-ground corn silage.

TABLE 31. RUMINAL FLUID VOLATILE FATTY ACID CONCENTRATIONS OF SHEEP FED A BASAL DIET AND DIETS CONTAINING SWINE WASTE-GROUND CORN SILAGES[a]

Item	Basal	Diets: Level of 40:60 silage[bc] 20%	40%	Level of 60:40 silage[bc] 20%	40%	SEM
Volatile fatty acids, µmoles/ml						
Acetic[d]	55.9	48.9	63.9	55.1	67.0	1.75
Propionic[ef]	14.2	15.7	21.6	15.5	25.4	1.01
Isobutyric[eh]	0.5	0.5	0.7	0.6	0.7	.02
Butyric[e]	9.4	9.2	13.6	11.6	12.6	.52
Isovaleric[fg]	0.7	0.7	1.2	0.9	1.2	.05
Valeric[fg]	0.5	0.7	1.3	1.0	1.5	.04
Total[ef]	81.3	75.7	102.3	84.7	108.4	2.68
Volatile fatty acids, µmoles/100 moles						
Acetic[ef]	68.6	64.8	62.8	65.2	61.5	.57
Propionic[h]	17.5	20.5	20.9	18.3	22.9	.58
Isobutyric	.6	.6	.7	.7	.7	.02
Butyric[g]	11.6	12.2	13.2	13.6	12.4	.57
Isovaleric	.9	.9	1.1	1.0	1.1	.05
Valeric[eh]	.7	1.0	1.3	1.2	1.4	.05

[a]Each value represents the mean of six animals.
[b]Value refers to the proportions of swine waste and ground corn grain.
[c]Diets containing the 40:60 silage were analyzed with the basal.
Diets containing the 60:40 silage were analyzed with the basal.
[d]Significant quadratic effect for diets containing 40:60 silage ($P < .05$).
[e]Significant linear effect for diets containing 40:60 silage ($P < .05$).
[f]Significant linear effect for diets containing 60:40 silage ($P < .05$).
[g]Significant linear effect for diets containing 40:60 silage ($P < .01$).
[h]Significant linear effect for diets containing 60:40 silage ($P < .01$).

TABLE 32. DRY MATTER INTAKE OF SHEEP FED A BASAL DIET AND DIETS CONTAINING SWINE WASTE-GROUND CORN SILAGES

	Diets[a] (dry basis)					
Item	Basal	80% basal + 20% (40:60)[b] silage	80% basal + 20% (60:40)[b] silage	60% basal + 40% (40:60)[b] silage	60% basal + 40% (60:40)[b] silage	SEM
Kilograms per day	1.24[c]	1.30[cd]	1.60[e]	1.53[de]	1.41[cde]	.062
Grams per $W_{kg}^{0.75}$ per day	88.02[c]	91.68[cd]	113.63[e]	111.03[de]	97.63[cde]	4.745

[a]Each value represents the mean of six animals.
[b]Value refers to the proportions of swine waste and ground corn grain.
[cde]Means in the same row with different superscripts are significantly different.

Swine Digestion and Palatability Trials. The composition and proximate components of the diets fed in the gilt metabolism trial are shown in table 8. Although the ensiled rations were only fed as 25% and 50% of the diet in the swine metabolism trials, all diets were normally consumed within 30 minutes. No refusals or palatability problems were noticed in the metabolism trials. Dry matter and crude protein decreased with each increment of the swine waste-ground corn silages in the diet. Diets containing the 60:40 swine waste-ground corn silage tended to have lower crude protein values than those containing the 40:60 silage. Ether extract, crude fiber, ash and NFE were slightly higher in diets containing the 60:40 silage.

In general, the digestibility of all components except NFE and ether extract decreased with increasing levels of silages in the diet (table 33). Dry matter, crude protein, and organic matter digestion coefficients decreased ($P < .01$ and $P < .05$) with increasing levels of the 40:60 and 60:40 silages in the diet.

Nitrogen intake (g/day) decreased linearly ($P < .01$) with increasing levels of swine waste-ground corn silage in the diet. Fecal nitrogen excretion was higher ($P < .01$) for gilts fed diets containing the silages. Kornegay et al. (1977) reported higher fecal nitrogen excretion in diets containing swine feces than in a typical basal diet composed of corn-soybean meal. Total nitrogen excretion, although not significantly different, appeared to be less for gilts fed the diets containing the silages.

TABLE 33. APPARENT DIGESTIBILITY OF PROXIMATE COMPONENTS AND NITROGEN UTILIZATION OF A BASAL DIET AND DIETS CONTAINING SWINE WASTE-GROUND CORN SILAGES BY SWINE

Item	Diets					
		Level of 40:60 silage		Level of 60:40 silage		
	Basal	25%	50%	25%	50%	SEM
Apparent digestibility, %						
Dry matter[de]	90.0	90.6	86.9	89.2	86.3	.33
Crude protein[fd]	89.0	88.6	82.8	86.0	81.3	.43
Ether extract	83.0	84.5	81.1	82.2	78.9	.64
Crude fiber[g]	71.2	74.0	67.2	72.5	61.2	1.10
Organic matter[de]	91.7	92.2	88.9	91.1	88.3	.27
Ash[h]	44.5	55.3	34.5	49.4	48.3	2.32
NFE[i]	94.3	94.7	93.3	94.4	92.4	.32
Nitrogen utilization						
Nitrogen intake, g/day[de]	44.4	42.9	41.5	40.1	37.8	.15
Nitrogen excretion, g/day						
Fecal[df]	4.9	4.9	7.1	5.6	6.9	.18
Urinary	26.9	21.3	22.8	20.6	22.9	1.06
Total	31.8	25.2	29.9	26.2	29.8	1.09
Nitrogen retention						
Grams per day	12.6	16.7	11.5	13.9	8.0	1.16
Percent of intake	28.0	39.1	27.8	34.6	21.1	2.76
Percent of absorbed	31.1	44.0	33.6	40.1	25.9	3.25

[a] Each value represents the mean of six animals.
[b] Value refers to proportion of swine waste and ground corn grain.
[c] Diets containing the 40:60 silage were analyzed with the basal. Diets containing the 60:40 silage were analyzed with the basal.
[d] Linear effect for diets containing 60:40 silage ($P < .01$).
[e] Linear effect for diets containing 40:60 silage ($P < .05$).
[f] Linear effect for diets containing 40:60 silage ($P < .01$).
[g] Linear effect for diets containing 60:40 silage ($P < .05$).
[h] Quadratic effect for diets containing 60:40 silage ($P < .05$).
[i] Quadratic effect for diets containing 40:60 silage ($P < .05$).

Nitrogen retention, expressed as g/day, percent of intake and percent absorbed, tended to be higher for gilts fed diets containing 25% of either the 40:60 or 60:40 silage and lower for gilts fed diets containing 50% of either the 40:60 or 60:40 silage, than for those fed the basal.

The lower nitrogen retention in swine fed diets containing 50% of the dry matter from the silages was probably due to the higher levels of non-protein nitrogen in the ration which is poorly utilized by the pig (Lee and Blair, 1972).

Crude fiber digestion coefficients were not different for the diets with 25% of the 40:60 and 60:40 silages but were less ($P < .05$) for the diets with 50% of the 60:40 silage. There was little difference in the digestion coefficients of NFE although the quadratic effect was significant for the 40:60 silage, indicating a lower digestibility of the 50% level.

Digestibility coefficients for all of the proximate components of the silages, calculated by difference (Crampton and Harris, 1969), appeared to decrease as the level of swine waste increased in the diet, although the linear effect was significant only for crude fiber (table 34). Kornegay _et al_. (1977) reported similar results.

Dry matter intakes from the palatability trial are presented in table 35. There were no significant differences, whether expressed on an actual or grams/$W_{kg}^{.75}$/day basis. However, gilts receiving the basal and the basal plus 25% of the 40:60 silage diet tended to consume about the same amount of diet and more than those receiving the

TABLE 34. APPARENT DIGESTIBILITY OF SWINE WASTE-GROUND CORN SILAGES BY SWINE

Component	Level of 40:60 silage[bcd]		Level of 60:40 silage[bcd]		SEM
	25%	50%	25%	50%	
Dry matter	92.3	83.8	86.6	82.6	1.58
Crude protein	87.5	76.7	77.0	74.6	1.96
Ether extract	89.1	79.1	79.7	74.8	3.09
Crude fiber[e]	83.7	63.7	77.7	51.7	4.35
Organic matter	87.8	24.5	63.9	52.2	11.67
Ash	93.6	86.1	89.4	84.9	1.36
NFE	95.8	92.2	94.5	90.4	1.33

[a] Each value represents the mean of six animals.
[b] Value refers to proportion of swine waste and ground corn grain.
[c] Diets containing the 40:60 silage were analyzed together. Diets containing the 60:40 silage were analyzed together.
[d] Calculated by difference, using value for basal and ensiled materials.
[e] Significant linear effect for diets containing 60:40 silage ($P < .05$).

TABLE 35. DRY MATTER INTAKE OF SWINE FED DIETS CONTAINING SWINE WASTE-GROUND CORN SILAGES

Item	Diets[ab]					
		Level of 40:60 silage		Level of 60:40 silage		
	Basal	25%	50%	25%	50%	SEM
Kilograms per day	4.7	4.5	3.9	3.8	3.1	.37
Grans per $W_{kg}^{0.75}$ per day	83.6	80.3	70.0	68.0	63.3	6.01

[a]Each value represents a mean of six animals.
[b]Value refers to proportion of swine waste and ground corn grain.

other diets. Similar results were reported by Overhults *et al.* (1978) when various levels of ensiled swine waste were mixed with a corn-soybean meal basal diet. Geri (1968) and Perez-Aleman *et al.* (1968) found reduced feed efficiency when poultry manure was added to the diets of growing swine. The reduced consumption observed in the present study as the level of feces in the diet increased may be partly due to the higher levels of ash in the diet.

SUMMARY

Experiments were conducted to determine the feasibility of ensiling swine waste with orchardgrass hay or with ground corn grain. Swine waste was ensiled with either orchardgrass hay or ground corn grain in small laboratory silos in the following proportions, on an as is basis: 80:20, 70:30, 60:40, 50:50, 40:60, 30:70 and 20:80.

Good fermentation, as measured by pH and level of lactic acid, occurred in swine waste-orchardgrass hay ratios of 40:60, 50:50, and 60:40. Bacteria and total coliform numbers were decreased and fecal coliforms were completely destroyed by ensiling. Ensiled mixtures of swine waste and ground corn grain containing more than 30% ground corn exhibited good fermentation characteristics, however, mixtures containing 70% swine waste and above had an offensive odor and would be difficult to handle by conventional methods.

In a subsequent study swine waste and orchardgrass hay were ensiled in proportions of 40:60 and 60:40 in steel drums lined with plastic. Fermentation parameters were similar to those in the small silo study. Twelve wethers were used in a digestion study and 24 in a palatability study. The four diets fed were: 1) ground orchardgrass hay alone (negative control); 2) ensiled swine waste and ground orchardgrass hay (40:60); 3) ensiled swine waste and ground orchardgrass hay (60:40); and 4) ground orchardgrass hay plus soybean meal (positive control). Organic matter digestibility tended to be

higher for swine waste-orchardgrass hay silages than orchardgrass hay fed alone, and was highest ($P < .05$) for the orchardgrass hay plus soybean meal diet. Crude protein digestibility was higher ($P < .05$) in the orchardgrass hay plus soybean meal diet than any of the other diets. Nitrogen retention was negative ($P < .05$) for sheep receiving the swine waste containing silages, a reflection of the poor retention of absorbed nitrogen. The organic matter digestibility of the feces calculated by difference was over 60% for both silages. No significant differences in dry matter intake among diets were recorded in the sheep palatability trial.

A swine palatability trial was conducted with 36 crossbred gilts to measure the dry matter intake of the ensiled 40:60 and 60:40 swine waste-orchardgrass hay mixtures. Diets were: 1) basal (corn-SBM, 16.4% protein), 75% basal plus 25% of the 40:60 silage (an ensiled mixture of 40 parts swine waste and 60 parts ground orchardgrass hay), 75% basal plus 25% of the 60:40 silage (an ensiled mixture of 60 parts swine waste and 40 parts ground orchardgrass hay), 50% basal plus 50% of the 40:60 silage, 50% basal plus 50% of the 60:40 silage, and 75% basal plus 25% mixed hay, dry basis. Dry matter intake was lower for diets containing 25 and 50% of the swine waste-orchardgrass hay silages compared to the basal alone with a large decrease for diets containing 50% of the swine waste-orchardgrass hay silages.

Swine waste-ground corn was ensiled in ratios of 40:60 and 60:40 in steel drums lined with plastic. The lactic acid levels were lower in the large silos and the pH values were slightly higher than in the small silos.

Thirty crossbred wethers were used in a digestion trial and a subsequent palatability trial. The diets fed were: 1) basal diet consisting of 50% corn-soybean meal (14% protein) and 50% ground mixed hay; 2) 80% basal and 20% of the 40:60 swine waste-ground corn grain silage; 3) 80% basal and 20% of the 60:40 swine waste-ground corn grain silage; 4) 60% basal and 40% of the 40:60 silage; and 5) 60% basal and 40% of the 40:60 silage.

The digestion coefficients for dry matter, crude protein, organic matter, and NFE increased linearly ($P < .01$) as the level of 40:60 and 60:40 swine waste-ground corn silages increased in the diets. Nitrogen retention, expressed as a percent of absorbed nitrogen, decreased linearly for diets containing the 60:40 silage ($P < .05$). The same trend was recorded for the 40:60 silage but the difference was not significant. In a lamb palatability trial using the same five diets, lambs receiving the basal plus 20% of the 60:40 silage and the basal plus 40% of the 40:60 silage consumed ($P < .01$) more feed than lambs fed the basal when dry matter intake was expressed as grams/day or grams/$W_{kg}^{.75}$/day.

Three metabolism trials with 10 gilts and one palatability trial with 30 gilts were conducted using the following diets: 1) basal (14% protein corn-soybean meal diet); 2) 75% basal and 25% of the 40:60 silage; 3) 50% basal and 50% of the 40:60 silage; 4) 75% basal and 25% of the 60:40 silage; and 5) 50% basal and

50% of the 60:40 silage. The digestibilities of dry matter, organic matter, and crude protein decreased with increasing levels of 40:60 and 60:40 silages. Fecal nitrogen excretion was higher in gilts receiving the swine waste containing silages ($P < .01$). Nitrogen retention expressed as grams/day, percent of intake and percent absorbed tended to be higher for gilts fed diets containing 25% of either the 40:60 or 60:40 silages and lower for diets containing 50% of either the 40:60 or 60:40 silages.

In the gilt palatability trial, there were no significant differences in dry matter intake between treatments when expressed on an actual or grams/$W_{kg}^{.75}$/day basis.

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APPENDIX

TABLE 1. EXAMPLE OF ANALYSIS OF VARIANCE AND FITTING OF ORTHOGONAL POLYNOMIAL, SWINE WASTE-ORCHARDGRASS HAY SILAGES, SMALL 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	11	21.29859286	1.93623571	7.64	0.001	0.736949	9.9660
Error	30	7.60244762	0.25341492		Std Dev		pH mean
Corrected total	41	28.90104048			0.50340334		5.05119048

Source	DF		F value	PR < F[a]
Lin	1	6.30268810	24.87	0.0001
Quad	1	11.79446429	46.54	0.0001
Cub	1	1.64694444	6.50	0.0161
Quan	1	0.00133413	0.01	0.9426
Sext	1	0.00001623	0.00	0.9937
Rep	5	1.42266905	1.12	0.3696

[a] Level of significance.

TABLE 2. EXAMPLE OF ANALYSIS OF VARIANCE AND DUNCAN'S MEAN SEPARATION, SWINE WASTE-ORCHARDGRASS HAY SILAGE, LARGE SILO STUDY

General Linear Model Procedure

Dependent variable: EE

Source	DF	Sum of squares	Mean square	F value	PR > F[a]	R-square	C.V.
Model	1	1.71059234	1.71059234	22.03	0.0002	0.564475	7.4167
Error	17	1.31981818	0.07763636		STD DEV		EE mean
Corrected total	18	3.03041053			0.27863303		3.75684211

Source	DF	Type III SS	F value	PR > F[a]
TMT	1	1.71059234	22.03	0.0002

General Linear Models Procedure
Duncan's Multiple Range Test for Variable EE
Means with same letter are not significantly different
Alpha level = .05 DF = 17 MS = .0776364

Grouping	Mean	N	TMT
A	4.012727	11	2
B	3.405000	8	1

[a]Level of significance.

TABLE 3. EXAMPLE OF ANALYSIS OF VARIANCE, SWINE WASTE-ORCHARDGRASS HAY SILAGES, SHEEP DIGESTION TRIAL

Analysis of Variance Procedure

Dependent variable: Rum-AM

Source	DF	Sum of squares	Mean square	F value	PR > F[a]	R-square	
Model	6	916.58332500	152.76388750	56.14	0.0001	0.951954	8.7774
Error	17	46.26043750	2.72120221		STD DEV		Rum_AM mean
Corrected total	23	962.84376250			1.64960668		18.79375000

Source	DF	Anova SS	F value	PR > F[a]
TMT	3	910.87854583	111.58	0.0001
TRIAL	1	0.56120417	0.21	0.6555
BLOCK	2	5.14357500	0.95	0.4081

[a] Level of significance.

TABLE 4. EXAMPLE OF ANALYSIS OF VARIANCE AND DUNCAN'S MEAN SEPARATION, SWINE WASTE-GROUND CORN SILAGES, LARGE SILO STUDY

General Linear Models Procedure

Dependent variable: EE

Source	DF	Sum of squares	Mean square	F value	PR > F [a]	R-square	
Model	3	27.27539861	9.09179954	338.88	0.0001	.980707	2.9089
Error	20	0.53658472	0.02682924		STD DEV		EE mean
Corrected total	23	27.81198333			0.16379633		5.63083333

Source	DF	Type III SS	F value	PR > F [a]
TMT	3	27.27539861	338.88	0.0001

Duncan's Multiple Range Test for EE
Means with the same letter are not significantly different
Alpha level = .05 DF = 20 MS = .0268292

Grouping	Mean	N	TMT
A	6.707500	4	3
A	6.691250	8	2
B	4.616667	3	4
B	4.547778	9	1

[a] Level of significance.

TABLE 5. EXAMPLE OF ANALYSIS OF VARIANCE AND FITTING OF POLYNOMIAL, SWINE WASTE-GROUND CORN SILAGES, SHEEP DIGESTION TRIAL

General Linear Models Procedure

Dependent variable: OM

Source	DF	Sum of squares	Mean square	F value	PR > F[a]	R-square	C.V.
Model	7	255.30577222	36.47225317	14.45	0.0002	0.910042	2.1734
Error	10	25.23705556	2.52370556		STD DEV		OM mean
Corrected total	17	280.54282778			1.58861750		73.09388889

Source	DF	Type I SS	F value	PR > F[a]	DF	Type IV SS	F value	PR > F
Block	5	34.86122778	2.76	0.0805	5	34.86122778	2.76	0.0805
L2	1	199.02307500	78.86	0.0001	1	199.02307500	78.86	0.0001
Q2	1	21.42146944	8.49	0.0155	1	21.42146944	8.49	0.0155

[a]Level of significance.

TABLE 6. EXAMPLE OF ANALYSIS OF VARIANCE AND FITTING OF POLYNOMIAL, SWINE WASTE-GROUND CORN SILAGES, SWINE DIGESTION TRIALS

General Linear Models Procedure

Dependent variable: DM

Source	DF	Sum of squares	Mean square	F value	PR > F [a]	R-square	C.V.
Model	3	48.33323889	16.11107963	3.70	0.0377	0.442116	2.3399
Error	14	60.98921111	4.35637222		STD DEV		DM mean
Corrected total	17	109.32245000			2.08719243		89.20166667

Source	DF	Type I SS	F value	PR > F [a]	DF	Type IV SS	F value	PR > F
Block	1	1.33933889	0.31	0.5880	1	1.33933889	0.31	0.5880
L1	1	29.0163000	6.66	0.0218	1	29.01630000	6.66	0.0218
Q1	1	17.97760000	4.13	0.0616	1	17.97760000	4.13	0.0616

[a] Level of significance.

VITA

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Jerry Carl Albert Berger

FERMENTATION, UTILIZATION, AND PALATABILITY OF SWINE WASTE ENSILED WITH VARIOUS PROPORTIONS OF GROUND ORCHARDGRASS HAY OR GROUND CORN GRAIN

by

Jerry Carl Albert Berger

(ABSTRACT)

The feasibility of ensiling swine waste (primarily feces) with ground orchardgrass hay or with ground corn grain was determined by mixing and ensiling the following proportions of each (as is basis): 80:20, 70:30, 60:40, 50:50, 40:60, 30:70 and 20:80.

In the swine waste-orchardgrass hay trials, good fermentation occurred in the 40:60 through 60:40 mixtures as determined primarily by pH and lactic acid. Bacteria and total coliform numbers decreased and fecal coliforms were completely destroyed. In a sheep metabolism trial, organic matter digestibility was similar in 40:60 and 60:40 swine waste-orchardgrass hay silages and in orchardgrass hay fed alone, but was higher ($P < .05$) in an orchardgrass hay plus soybean meal diet. Crude protein digestibility was higher ($P < .05$) in the orchardgrass hay plus soybean meal diet than any of the other diets. Nitrogen retention was negative ($P < .05$) for sheep fed the silages. Organic matter digestibility of the swine waste calculated by difference was over 60 percent. In the sheep palatability trial,

dry matter intake was similar between the diets. In a swine palatability trial, dry matter intake decreased as swine waste-orchardgrass hay silages were substituted for the basal diet at levels of 25 and 50% of the dry matter.

In the swine waste-ground corn trials, mixtures containing more than 30% waste exhibited good fermentation characteristics. Ensiling reduced the total bacteria numbers and completely destroyed all coliform bacteria. In a sheep metabolism trial, digestibility of dry matter, crude protein, organic matter, and NFE increased linearly ($P < .01$) as 20 and 40% of the 40:60 and 60:40 silages were substituted for a basal diet composed of 50% of a 14% protein corn-soybean meal mixture and 50% mixed hay. Nitrogen retention (percent of absorbed) decreased linearly for diets containing the 60:40 silage ($P < .05$). In the sheep palatability trial dry matter intake was greatest ($P < .01$) for the basal with either 20% of the 60:40 silage or 40% of the 40:60 silage.

In the swine metabolism trial, digestibility of dry matter, organic matter, and crude protein decreased as 25 and 50% of the 40:60 and 60:40 swine waste-ground corn silages were substituted for a basal 14% crude protein corn-soybean meal diet. Fecal nitrogen excretion was higher ($P < .01$) and nitrogen retention lower in swine fed diets containing the silages. In the swine palatability trial, dry matter intake was not different between diets.

Swine waste was successfully ensiled with either orchardgrass hay or ground corn grain. Ensiling was an effective way to destroy many potential pathogens. Diets containing these silages were fed to both ruminants and nonruminants. The high levels of fiber in the swine waste-orchardgrass hay silages had an adverse effect on acceptability by nonruminants, but not ruminants. Ruminants and nonruminants both consumed adequate amounts of the swine waste-ground corn silages for maintenance.