FERMENTATION, UTILIZATION AND PALATABILITY OF BROILER LITTER ENSILED AT DIFFERENT MOISTURE LEVELS AND WITH HIGH MOISTURE CORN GRAIN

by

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INTRODUCTION

According to economic studies, the plant nutrient value of the 48 million tons of poultry wastes produced in the United States annually is not sufficient to justify disposing of these by land fertilization (Wadleigh, 1968). This situation has resulted from the rapidly increasing costs of labor and equipment necessary for the application of manure to land. The development of large-scale broiler operations, many of which are near metropolitan areas or located on small tracts of land away from major crop producing areas, has created additional problems with respect to disposal of broiler litter. These problems focus on the vast quantity of litter generated under such systems of production, the distribution of the human population and the availability of land suitable for fertilization with litter.

The fact that litter, when used as a feed for ruminants, has the potential to increase farm income, in addition to relieving the problem of disposal, is not a new concept. When incorporated into rations for cattle and sheep it contributes appreciable amounts of nitrogen, available energy and certain essential minerals. The attractiveness of litter as a feed can probably be attributed to the fact that it is an economical source of nitrogen and energy.

Presently, the use of poultry litter as an animal feed is not sanctioned by the Food and Drug Administration. Two specific problems confronting the approval of litter for use as a livestock feed are

pathogenic organisms and medicinal drugs that may be present in the litter. Research over the past several years has shown that litter can be rendered free of pathogens by a number of processing methods. The effect of processing methods on medicinal drug residues in litter is not well documented. Certain processing methods may increase dustiness and impart an undesirable odor in litter. Some processing methods add expense, in terms of labor, material and energy requirements. Also a decrease in nutritive value of litter may accompany processing methods which employ dry heat.

A biological method of processing litter, such as fermentation, may provide an inexpensive means of preparing the material for incorporation into rations for livestock. Furthermore, ensiling of litter as it comes from the house, with additional water or as part of a mixture with forages or grains may make it a more desirable product in one or more of the following ways: (1) drugs and pathogens may be reduced or eliminated; (2) nutritive value may be improved or at least maintained; (3) palatability may be enhanced; (4) the product may be less obnoxious to handle after ensiling; (5) silage feeding equipment may be advantageously used; (6) aspects of ensiling litter only during certain seasons may be eliminated; and (7) a final product that would approach a complete food may be produced.

The studies reported herein were conducted to evaluate the feasibility of ensiling broiler litter alone, with added water or with high moisture corn grain as measured by certain characteristics of

fermentation and by nitrogen utilization, ration digestibility and palatability when fed to ruminants.

REVIEW OF LITERATURE

Approval of poultry litter by the Food and Drug Administration (FDA) for use as an animal feed is presently pending the collection of additional data on the potential effects of disease organisms and medicinal drug residues in litter on human and animal health (Kirk, 1967, and Taylor, 1971).

Potentially Infections Microorganisms in Animal Wastes

According to Burrows (1968), coliform bacteria are facultative anaerobes, show optimal growth at 37 C and thrive in the presence of bile. Consequently, they are numerous in the intestinal tract of animals and can cause a number of disorders such as cholera, accumulation of intralumenal fluid, cystitis of the urogenital tract, local infections such as abscesses and conjunctivitis, scours in young animals, gallstones, and occasionally mastitis. Coliforms do not form spores and, therefore, are easily destroyed.

Classical members of the coliform group are *Escherichia coli* and *Aerobacter aerogenes* (Pelczar and Reid, 1965). *Aerobacter* coliforms are found most commonly on plant materials (Kroulik *et al.*, 1955). In the family of *Enterobacteriaceae*, Burrows (1968) has included *Salmonella*, *Shigella* and *Proteus spp*. A wide variety of disorders including bone infections, infections of the central nervous system, gastroenteritis and abortion have been attributed to these organisms.

Turkeys and broilers acquire Salmonella and Proteus spp congenitally and from nondomesticated infected fowl. Shigella spp are rarely found in domesticated fowl (Smith et al., 1964).

In 44 samples of poultry litter examined by Alexander et al. (1968), results were positive for Clostridium, Corynebacterium, Salmonella, Actinobacilli, Mycobacterium and Enterobacteriaceae (other than Salmonella) spp. Of the 44 field samples collected in this study, 26 were from operations in which the litter was being fed to livestock. Bacillus spp, Proteus spp, E. coli and other members of the Enterobacteriaceae family were found in 40% of fresh poultry fecal samples collected by Zindel (1970). Coliforms as a group were present in 60% of the samples.

Halbrook et al. (1951) reported fewer coliforms in litter which had built up for over 1 year than in litter changed weekly or between groups of broilers. Lactobacilli and coliform counts ranged from 1,000 to 200,000 per gram in new, unused litter to 600,000 to 3 million per gram for litter used 1 to 8 weeks.

Lovett et al. (1971) found approximately 10% of the total bacteria population of litter to be coliforms, following 1 week of use. Of this number, approximately one-third were E. coli. All litter samples tested negative for salmonella. Storing the litter in open, unprotected heaps for 1 to 34 months did not affect bacteria numbers.

A salmonella species introduced into litter through oral inoculation of day-old chicks was destroyed within 8 weeks in litter containing 44% moisture, whereas the same organism was recovered after 19 weeks in litter containing 21.6% moisture (Tucker, 1967). Survival

time was found to be independent of temperature and ammonia concentration.

In processing studies by Fontenot et al. (1971a) autoclaving at 116 C under steam pressure of 1.06 kg/cm^2 for 30 to 120 min., dry heating at 100 C for up to 48 hr, or fumigation with beta-propiolactone or ethylene oxide was ineffective for complete sterilization of broiler litter. Dry heating litter at 150 C for at least 3 hr resulted in sterilization. The impracticability of setting sterilization as the goal for litter processing methods prompted these workers to adopt the standards for pasteurized milk (Anonymous, 1967) as suitable criteria for determining the effectiveness of processing methods. Simply stated, these criteria are less than 10 coliforms and less than 20,000 total bacteria per gram by plate count. Under these standards, broiler litter was pasteurized by dry heating at a temperature of 150 C and depths of 0.6 or 1.2 cm for 15 or 30 min., respectively (Fontenot et al., 1971a).

In an experiment to extend the processing studies described above, Caswell et al. (1975) pasteurized highly contaminated litter by: dry heating at 150 C for 20 min. at a litter thickness of 0.6 cm; autoclaving for 10 min. or longer; dry heating at 150 C at depths of 0.6 or 2.5 cm, following addition of 1, 2 or 4 g of paraformaldehyde to 100 g of litter; and ethylene oxide fumigation for a minimum of 30 min. Coliforms were completely eliminated by all processing methods except fumigation with ethylene oxide for 30 min. All samples were negative for salmonella, shigella and proteus.

Methyl bromide fumigation of poultry litter was found to be most

effective when the moisture content of litter was high (Harry et al., 1973). E. coli was more resistant to methyl bromide fumigation than was a salmonella species.

Will et al. (1973) seeded a model oxidation ditch containing liquid cattle manure with salmonella. Dissolved oxygen, pH and temperature of the ditch contents were closely monitored. Salmonella survived 17 days post-seeding at 20 C. At 2 C, survival time was extended to 47 days.

Strauch et al. (1969) inoculated samples of semi-liquid hen manure with salmonella. Composition of the manure mixtures were: (1) feces, urine, water and straw; (2) feces, urine and water; (3) feces, urine, water and 10% sewage sludge; and (4) feces, urine, water and 0.2% superphosphate. Mixtures were stored at 8 or 17 C. Salmonella survived longer in mixtures 1 and 4 than in 2 and 3. Survival times ranged from 5 to 25 days with the longer survivals being characteristic of organisms in mixtures stored at 8 C.

Creger et al. (1973) enumerated the bacterial content of fermented broiler litter. The plate count for total bacteria provided an estimate of 165 million organisms per gram. The silage was found to be free of salmonella, staphlococcus (coagulase positive) and coliforms. High temperatures and high acidity levels created by the fermentation process can probably be credited with the absence of potentially pathogenic organisms in the final product. This has been shown by Barnett (1954).

In a laboratory experiment conducted by Harmon et al. (1975a), total bacteria and coliform counts were performed on silages consisting

of corn forage ensiled alone (control), with 0.5% urea or with broiler litter calculated to contribute 15, 30 or 45% of the total dry matter. Silages containing litter had significantly greater bacterial densities than corn forage ensiled alone. Total counts for silages containing the two highest levels of litter ranged from 265 million to 837 million per gram. In all silages except one control, coliform numbers did not exceed 171 per gram and were not significantly different among treatments. Larger silos stored in an open barn alleyway remained sealed longer and were subjected to greater temperature fluctuations. Total bacteria and coliform counts of these silages were 100,000 and 0 per gram, respectively.

The potential for the transmission of disease by feeding litter should be recognized. Versatility does exist, however, among the numerous physical, chemical and biological methods that can be used to eliminate pathogenic bacteria.

Studies of Medicinal Drug Residues in Animal Wastes and Tissues from Animals Fed Wastes

Brugman *et al*. (1964) analyzed laying house litter for arsanilic acid, zoalene, unistat, nicarbazin, furans and sulfaquinoxaline. Arsanilic acid was present at a level of 0.0048%. Residues of the other drugs were not detected. Arsenic ranged from 15 to 30 ppm in litter from houses where roxarsone was fed (Morrison, 1969). Alfalfa and clover from fields which had been fertilized with arsenic-containing litter for 0, 2 or 20 years contained less than 0.2 ppm arsenic regardless of

the extent of fertilization with litter.

Messer et al. (1971) analyzed poultry litter for arsenic, furazolidone and nitrofurazone. Arsenic in the litter from the five operations sampled ranged from 0.2 to 76.3 ppm (mean, 14.2 ppm). Litter from three of the farms contained less than 2 ppm. The mean furazolidone level was 14.0 ppm. Nitrofurazone varied from 4.5 to 26.7 ppm (mean, 12.7 ppm).

In an experiment conducted by El-Sabban et al. (1970), liver samples from steers fed diets supplemented with hydrolyzed poultry waste, dried poultry waste, soybean meal or urea were assayed for arsenic. Mean arsenic levels were 0.23, 0.38, 0.12 and 0.28 ppm, respectively. The value for steers fed dried poultry waste was significantly higher than for the other three rations, but, due to the very low liver arsenic levels for all treatments, this appears to be of little importance.

Smith et al. (1973) found total arsenic excretion as a percentage of intake to be 83.2 and 90.8% for lambs fed rations containing 7 or 14% dried poultry manure, respectively. Corresponding arsenic levels in the two rations were 3.42 and 4.95 ppm (dry basis). In another trial, arsenic levels in blood, liver, kidney and muscle of wethers fed graded levels of arsanilic acid for 28 days indicated that the amount of arsenic accumulated by these tissues was proportional to the amount ingested. Depletion of arsenic in the same tissues and excretion via urine and feces occurred quite rapidly when arsanilic acid was removed from the sheep rations. Extrapolation of depletion data indicated that arsenic in fresh liver could be reduced below the present

FDA tolerance level of 1 ppm (swine and poultry livers) if arsenic-containing litter was withdrawn from the diet of sheep 9 days prior to slaughter.

Poultry litter containing different levels of Amprol-Plus (amprolium plus ethopabate) and 3-nitro-4-hydroxyphenylarsonic acid was fed to lambs by Brugman et al. (1968). Even when additional levels were fed, amprolium and arsenic (as a measure of 3-nitro-4-hydroxyphenylarsonic acid) were not detected in heart, spleen, 12th rib, kidney, kidney fat, liver and brain tissues.

Litter samples from different parts of Virginia contained 12.5 units penicillin per gram, 10.9 ppm oxytetracycline, 12.5 ppm (0.8 ppm in samples from houses where use was not continuous) chlortetracycline, 0 ppm neomycin, 7.2 units zinc bacitracin per gram, 81.2 ppm nicarbazin and 27.3 ppm amprolium (Webb and Fontenot, 1975). No amprolium was found in kidney fat, muscle or liver of beef cattle fed 0, 25 or 50% litter in two feeding trials. One animal fed 25% litter and two fed 50% litter containing 12.5 ppm chlortetracycline had levels of the drug in kidney fat amounting to 0.034 and 0.041 ppm (average of both animals), respectively. In the second trial, litter containing 0.8 ppm chlortetracycline was fed with no deposition of the drug in any tissues sampled.

In a study by Creger et al. (1973), samples of the broiler litter silage analyzed for zinc bacitracin and 3-nitro-4-hydroxyphenylarsonic acid showed levels of 1.5 and 68.5 ppm, respectively. The broiler chicks reared on the litter also had been fed amprolium and ethopabate, but these drugs were not detected in the fermented material. None of the four drugs were found in muscle, liver or fat tissues of

heifers fed the silage for 120 days, indicating that the drugs were either altered or destroyed by ensiling or were not absorbed and deposited by the animals in detectable quantities.

Elmund et al. (1971) determined chlortetracycline half-life values to be greater than 20 days in cattle manure incubated at 4 or 28 C but only 7 days at 37 C. Their data showed 75% of dietary chlortetracycline to be excreted by cattle fed 70 mg/head/day.

Westing and Brandenburg (1974) fed beef steers a ration containing 14% beef feedlot waste obtained from a pile composted for 60 days. Carcass samples analyzed for antibiotics gave similar levels for both the control and the waste-fed groups. Furthermore, tissue levels were below the limits permissible by FDA, indicating no substantial accumulation as a result of feeding the composted waste.

Available data on the negligible extent to which arsenic and drugs are deposited in the tissues of animals are somewhat conclusive and lend strength to the possibility of litter being approved.

Effects of Feeding Poultry Wastes on Animal Health and Performance

There have been only two reports of deleterious effects of feeding poultry litter to livestock. Fontenot et al. (1971b) reported that ewes readily accepted rations containing 0, 25 or 50% litter, and daily gain and carcass measurements of lambs produced by the ewes were not significantly affected by treatment. After 137 days of feeding, one ewe in the group fed 50% litter died from copper toxicity. It was then determined that litter fed in this study contained an average of

195 ppm copper. Of the ewes fed 25 or 50% litter, 64% and 55%, respectively, had succumbed to copper toxicity by the 254th day. Liver copper levels (dry basis) of the three lots of ewes at death or slaughter were 648, 1,993 and 2,671 ppm respectively. Liver copper levels of lambs from the three groups of ewes were 572, 891 and 961 ppm, respectively. A number of blood and urine parameters measured on the ewes were not affected by treatment. Cattle are less sensitive to high dietary copper than sheep. Webb et al. (1974) wintered beef cows and heifers on hay or a corn-litter mixture alone, or with 160 ppm supplemental copper. The added copper was calculated to double the copper supplied by litter. In the cow experiment, liver copper levels were increased to 403 to 537 ppm by feeding litter alone or with added copper. In hay-fed cows, liver copper was 34 to 60 ppm. During the summer grazing period, however, liver copper levels in cows wintered on litter dropped to 153 to 179 ppm. Heifers responded similarly. Over two calvings, performance of the brood cows was similar among treatments.

Griel et al. (1969) reported a high incidence of abortion in brood cows fed litter. These investigators suggested hormone imbalance as a plausible cause, since the birds reared on the litter had been fed a dienestrol-treated feed.

Numerous studies have been reported in which litter has been successfully fed without affecting health. Noland et al. (1955) were the first to report satisfactory performance in gestating-lactating ewes fed chicken litter. No digestive disturbances or excessive feed refusals were observed over 157 days of feeding litter to ewes or

during a 56-day feeding trial in which steers were fed a ration containing 25% litter.

In comparing a conventional hay-corn-soybean meal diet to cattle fattening rations containing 25% peanut hull or wood shaving litter, Fontenot et al. (1966) found it necessary to incorporate long hay into the rations to alleviate diarrhea which had developed in the cattle. Performance for the litter-fed cattle was similar to that of the controls. In a second trial, eight lots of steers received 25 or 40% litter having base materials of peanut hulls, corn cobs, chopped grass hay or soybean hulls. Gains in the litter-fed lots were satisfactory and were similar among types of litter. Steers fed 40% litter did not gain as rapidly or efficiently as those fed 25%. Carcass data showed no marked effect from feeding litter.

Bull and Reid (1971) reported consumption of air dried chicken manure by non-lactating dairy cows to be sufficient to meet protein requirements if the manure contained less than 20% moisture and was the only source of supplemental nitrogen in a low protein diet. Furthermore, the cows showed no evidence of health deterioration.

Poultry wastes apparently can be fed without adversely affecting animal health. If the product is intended for consumption by sheep, care should be taken in obtaining litter with a low level of copper. In order to obtain satisfactory performance in fattening cattle, it appears that litter in air-dried or artificially dried forms cannot exceed 25% of the ration.

Poultry Litter as a Source of Nutrients

Using the chromic oxide indicator method, Brugman *et al*. (1964) reported digestion coefficients for crude protein, ether extract, crude fiber and gross energy of laying house litter to be 77.8, 44.4, 91.0 and 59.2%, respectively, when fed to Hereford bulls.

Bhattacharya and Fontenot (1966) reported the nitrogen fractions, as a percentage of total nitrogen (4.89%, dry basis), in wood shaving litter to be: protein nitrogen, 44.38%; non-protein nitrogen, 55.62%; uric acid nitrogen, 28.80%; and ammonia nitrogen, 15.40%. Peanut hull litter showed similar levels. When fed to wethers as 25 or 50% of a conventional diet, digestible protein values for wood shaving litter were 22.5 and 21.6%, respectively. For peanut hull litter, these values were 23.4 and 23.4%. Calculated TDN values of wood shaving litter fed as 25 or 50% of the ration were 61.0 and 58.0%, respectively, as compared to 60.7 and 59.3%, respectively, for peanut hull litter. Digestible energy values for the wood shaving and peanut hull litters were 2,429 and 2,504 kcal/kg of dry matter, respectively, when fed as 25% of the ration. At 50% of the ration, these values were 2,385 and 2,440 kcal/kg.

Fontenot *et al*. (1971a) collected broiler litter samples from 13 houses located in three major broiler producing areas of Virginia. Chemical analysis of the samples indicated considerable variation in composition, substantiating the need for detailed analysis of litter before incorporation into rations. It was in this report that data were presented showing a loss of 19% of the nitrogen in litter as a

result of processing at 150 C for 3 hr. These results prompted Harmon et al. (1974) to study the nitrogen loss from dry heat processed litter. They found that acidification of litter to a pH of approximately 6 with sulfuric acid prior to heat treatment reduced nitrogen loss by about 50%. In subsequent metabolism trials with sheep, litters processed by autoclaving, dry heating or acidification followed by dry heating were equally well utilized.

In the study by Caswell et al. (1975), the effects of other physical and chemical litter pasteurization methods on nitrogen components were evaluated. Uric acid nitrogen was significantly lowered by dry heat, either alone or in combination with paraformaldehyde. Autoclaving and paraformaldehyde pasteurization lowered NPN. Ammonia nitrogen was significantly reduced by all pasteurizing treatments except autoclaving for 10 min. In a metabolism trial with wethers, nitrogen utilization and ration digestibility were not significantly affected by processing litter with dry heat, paraformaldehyde plus dry heat or fumigation with ethylene oxide.

Belasco (1954) and Jurtshuk et al. (1958) have shown that rumen bacteria will attack uric acid. In fact, Oltjen et al. (1968) reported more efficient NPN utilization by cattle from uric acid than urea. The ammonia in litter is also a potential source of nitrogen for ruminants (Looper and Stallcup, 1958; Bryant and Robinson, 1962, 1963).

Biological processing of litter may provide a means by which nitrogen loss can be eliminated. Harmon et al. (1975a) observed no substantial change in total nitrogen during fermentation of corn forage-litter mixtures. However, increases in ammonia nitrogen levels

during fermentation gave some indication that redistribution of nitrogen may occur as a result of ensiling. Schefferle (1965) found certain strains of bacteria in litter to be able to hydrolyze uric acid to ammonia. Her results offer at least a partial explanation for the results reported by Harmon et al. (1975a).

While it is obvious that poultry litter represents a valuable source of nutrients for livestock, it should be kept in mind that certain methods of processing result in a significant loss of some of these nutrients. Although processing appears to exert no profound effect on the utilization of litter, nutrient losses as a result of processing must be minimized in order for litter to attain a position as an economically important feedstuff in the livestock industry.

Fermentation Characteristics and Feeding Value of Ensiled High Moisture Corn Grain

Fermentation Characteristics

McLaren and Matsushima (1968) reconstituted ground, mature, shelled corn to a moisture content of 28%. The resultant material was ensiled in small, circular, metal silos. Temperatures in the silos increased from 24 C to 30 C within the first 3 days after ensiling, and declined slightly after 8 days. By day 3, pH had decreased from 6.2, initially, to 4.6, and during the same period, lactic acid increased approximately six-fold. Lactic acid levels reached a maximum by day 15. Within the first 3 days after ensiling, soluble sugars decreased from 1.45% initially, dry basis, to 0.68%.

In three digestion trials with steers, coefficients of digestibility for dry matter and crude protein were significantly higher for ensiled reconstituted corn than for dry ground corn.

Prigge et al. (1974) investigated the effects of storage time on levels of lactic and acetic acids in high moisture corn ensiled in the whole or ground form. Storage times ranged from 0 to 56 days. At 28 days, levels of lactic and acetic acids in whole corn were 0.05 and 0.18% of dry matter, respectively. Respective levels in the ground corn at 28 days were 1.20 and 0.19%. Acetic acid content of the high moisture corn ensiled whole had increased to 0.68% by 56 days whereas the lactic acid content was unchanged from that at 28 days.

Dry matter losses and changes in the carbohydrate fractions of corn harvested at 22% moisture and ensiled in small laboratory silos as untreated-ensiled, dried-reconstituted-ensiled or formic acid reconstituted (88% solution added at the rate of 0.5%)-ensiled were studied by Danley and Vetter (1974a). The fermentation period was 18 days at 32 C. Dry matter losses for the three types of ensiled corn were 3.50, 2.27 and 1.72%, respectively. Water-soluble carbohydrate levels were 4.7, 3.8, 2.6 and 5.8%, dry basis, for the corn analyzed as unaltered (control), untreated-ensiled, dried-reconstituted-ensiled or formic acid reconstituted-ensiled, respectively.

Using the same corn and fermentation treatments, Danley and Vetter (1974b), quantitated the changes in nitrogen fractions. In unaltered (control), untreated-ensiled, dried-reconstituted-ensiled and formic acid reconstituted-ensiled corn, water-soluble nitrogen

levels, as percentage of total nitrogen, were 10.2, 14.2, 16.2 and 19.6, respectively. Ammonia nitrogen levels, as percentage of water-soluble nitrogen, were 51.2, 61.4, 60.1 and 42.4, respectively. A corresponding decrease in insoluble nitrogen accompanied the increase in water-soluble nitrogen reflecting the metabolism of organisms present in the ensiled corn. This phenomenon has also been reported by Nagel and Semeniuk (1947), Burmeister and Hartman (1966) and Burmeister et al. (1966).

Feedlot Performance and Digestibility

Beeson and Perry (1958) fed ensiled high moisture (32.2%) ground ear corn or regular (17.7% moisture) ground ear corn, supplemented with protein, as the sole sources of concentrate and roughage for steers. A typical, pleasing, fermentation aroma was noticeable in the ensiled corn, and no spoilage was observed. The cattle consumed both rations readily, and no problems were encountered in keeping the steers on feed. Steers fed the fermented corn tended to gain slightly, though not significantly, faster. On the same moisture basis, a 12 to 15% savings in feed resulted from the feeding of high moisture corn. In a second trial, heifer calves fed ensiled high moisture (32.5%) ground ear corn supplemented with protein and offered with free choice mixed hay required 10% less corn to produce a unit of gain than heifers fed regular corn (15.5% moisture) fed with hay and supplemental protein.

Heuberger et al. (1959) reported similar daily gains and feed efficiency in yearling heifers fed shelled corn containing 14.5%

moisture or ensiled high moisture shelled corn containing 24 or 29% moisture. Performance of a fourth group fed fermented corn containing 36% moisture was appreciably lower. Digestion coefficients for energy, dry matter, nitrogen, ether extract and crude fiber in cattle fed corn containing 14.5, 24 or 36% moisture did not differ substantially among treatments. In silos containing 24, 29 or 36% moisture corn, losses of dry matter were 2.16, 3.40 and 1.19%, respectively. In another experiment, 1 week was required to get yearling steers on a full feed of high moisture (33%) shelled corn as compared to 6 weeks for dry corn.

The nutritive value of dry corn has been compared to that of ensiled high moisture corn (harvested at 27 to 34% moisture), ensiled reconstituted high moisture corn or volatile fatty acid treated high moisture corn in five feeding trials and one digestion trial with beef cattle (Tonroy et al., 1974). Corn consumption was not restricted in all feeding trials. Daily gains in four of the trials ranged from 1.02 to 1.16 kg among all treatments. Daily gains of animals fed ensiled high moisture corn containing 34% moisture in the fifth trial were approximately 10% less than for cattle fed dry corn. Of particular importance is the fact that cattle required 3 to 13% less dry matter per unit of gain when fed high moisture corn, as compared to dry corn. In the digestion trial, only slight treatment differences were observed in nutrient digestibility.

Tolman and Guyer (1974) compared the value of dry corn to ground or whole high moisture shelled corn ensiled at 20 to 30% moisture in feeding trials conducted over a period of 6 years involving

1,460 finishing cattle. Five of six comparisons showed an average of 7% improvement in rate of gain and 4% less feed dry matter required per unit of gain for the high moisture corn fed whole.

In vitro dry matter digestibilities of: (1) dry corn; (2) ensiled high moisture [29.2%] corn; (3) ensiled reconstituted high moisture corn; and (4) VFA treated high moisture [27.0%] corn were determined by Tonroy and Perry (1974). Values were significantly higher for ensiled high moisture corn and VFA treated high moisture corn than for the other two treatments. The effects of corn on ruminal fluid pH and VFA concentrations were also studied using four steers. Ruminal fluid pH was not significantly affected by treatment. Propionic acid concentrations were highest in cattle fed dry or VFA treated corn, whereas acetic acid concentrations were highest in cattle fed ensiled high moisture corn or ensiled reconstituted corn. Butyric acid was not significantly affected by treatment.

In addition to the dry matter, carbohydrate and nitrogen data reported above, Danley and Vetter (1974c) determined the *in vitro* dry matter digestibility of unaltered (control), untreated-ensiled, dried-reconstituted-ensiled or formic acid reconstituted-ensiled corn grain harvested at 22% moisture. An incubation period of 24 hr gave coefficients of 76.6, 73.2, 76.1 and 79.5%, respectively.

Experiments with high moisture corn have shown that the grain readily undergoes fermentation when ensiled. When fed to livestock, digestibility of ensiled high moisture corn is comparable to that of dry corn and, in feeding trials with cattle, satisfactory performance has been obtained with a substantial savings in feed required per

unit of gain if the moisture content of the fermented grain is not excessively high.

Fermentation and Feeding Studies of Ensiled or Composted Animal Wastes

Creger *et al*. (1973) ensiled built-up broiler litter with water added to elevate the moisture content to 35 to 38%. The material was ensiled in an air-tight, upright silo for a fermentation period of 6 weeks. Over a feeding period of 120 days, 15 heifer calves fed the litter silage *ad libitum* plus a constant daily amount of a mixture of ground milo, dehydrated alfalfa meal, soybean meal, molasses and vitamins A and D, consumed an average of 5.45 kg of silage per head per day and had an average daily gain of 1.16 kg. All tissues received acceptable scores for juiciness, flavor and tenderness regardless of treatment.

Harmon *et al*. (1975a) conducted a laboratory study in which corn forage harvested at 26 or 38% dry matter was ensiled alone, with 0.5% urea or with broiler litter at levels contributing 15, 30 or 45% to total dry matter. After 65 days of fermentation, pH of all silages ranged from 3.6 to 4.7, with silages containing litter generally having significantly higher pH values than those of corn forage ensiled alone or with urea. Lactic and acetic acid levels in litter-containing silages were not significantly different from silages devoid of litter. Water-soluble carbohydrate fermentation, expressed as a percentage of initial, was 62 to 71% for the earlier maturity material as compared to 29 to 47% for the later maturity material. The addition of litter

caused no marked changes in the extent to which carbohydrate fermentation occurred. Dry matter loss in the earlier maturity silages ranged from 4.4 to 11.2% and was 1.2 to 3.0% in the more mature silages. Again, the inclusion of litter had no profound effect on dry matter loss. Litter increased the crude protein content of the silages from about 8% for corn forage ensiled alone to about 11, 15 and 18% for silages in which litter contributed 15, 30 or 45% to the total dry matter, respectively.

In a larger scale study, the treatment in which litter contributed 45% of total dry matter was omitted for both corn forage maturities. Fermentation characteristics of these materials were quite similar to corresponding materials ensiled in the laboratory study. Harmon et al. (1975b) reported dry matter digestibility to be similar for all silages when fed to sheep. Advancing maturity of the corn plant depressed the digestibility of crude protein, but within each maturity, crude protein digestibility was significantly increased by each level of litter. Litter nitrogen was well utilized. Forage maturity did not affect dry matter intake by sheep, but within each maturity, dry matter intake was significantly greater for silages containing litter than for the control or urea-containing silages.

Corn field residue or oat straw was ensiled alone or with poultry or cattle manure by Saylor and Long (1972). Crop waste was ensiled with animal waste in a 2:3 ratio. Silages containing poultry manure exhibited significantly higher crude protein levels and in vitro digestibility of organic matter than silages containing cattle manure.

In another laboratory study, Saylor and Long (1974) ensiled caged

layer waste (72% moisture) with ground mixed grass hay in ratios of 60:40, 70:30, 80:20, 90:10 and 100:0. An additional five treatments in which 5% of each of the above mixtures was replaced with ground shelled corn were also evaluated. The length of the fermentation period was 60 days. Upon opening the silos, silages containing 90 or 100% layer waste exhibited putrefaction. Values obtained for certain measurements on the silages containing 60, 70 or 80% caged-layer waste were as follows: pH, 5.2, 6.8, 7.1; total volatile fatty acids, 23.5, 39.5, 55.7 mg/g; lactic acid, 15.6, 0.7, 0.6 mg/g; and crude protein, 20.0, 17.7, 13.3%, respectively. All values were significantly different among treatments. The addition of ground shelled corn did not significantly affect the parameters reported above.

Anthony (1966) mixed manure from cattle fed a high energy ration with ground coastal Bermudagrass hay in a ratio of 57:43. The resultant mixture was ensiled in polyethylene lined steel drums. After fermentation, the "wastelage" contained 54.1% dry matter and 12.4% crude protein, dry basis. This material was fed to four steers in a balance trial. In a second balance trial, manure collected during the first trial and fermented with hay to make wastelage was fed. In both trials, wastelage made up approximately 63% of the diet. Digestion coefficients for the wastelage rations fed in both trials differed by very little and were within a normal range. In a subsequent experiment, 21 mature ewes were divided into two groups and fed either ground coastal Bermudagrass hay or wastelage over an extended period of time. Ewes consuming wastelage maintained a noticeably better physical condition than those consuming hay. The average daily savings in hay dry

matter per ewe for the watelage-fed group was 0.38 kg. The wastelage reportedly had a pleasing odor and was readily consumed by the sheep.

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 pen receiving wastelage was also fed a constant amount of liquid protein supplement daily. The wastelage-fed pen gained faster than the control, and all carcasses from both pens graded choice. Feeding wastelage to a group of Angus heifers for 332 days covering breeding, gestation and lactation resulted in similar performance as for a control group fed corn silage.

An additional study summarized by Anthony (1971) indicated that daily gains and feed efficiency by cattle fed wastelage mixed with corn in a 2:3 ratio and fed as such or with added cottonseed meal were not significantly different from the same parameters measured on cattle fed a conventional high energy (basal) ration or cattle fed a 2:3 mixture of fresh manure and basal ration. In another experiment, a mixture of wastelage and corn mixed in a 2:3 ratio was compared to the same mixture supplemented with soybean meal or a urea-soybean meal mixture. Performance and carcass characteristics of the three groups of steers were similar. Performance of three groups of cattle fed a 2:3 mixture of wastelage and corn, a 2:3 mixture of fresh manure and corn or a complete ensiled mixture of 19.49% manure, 50.85% ground corn, 14.41% hay and 15.25% water was studied. Daily gain for the animals fed the fresh manure-corn mixture was lower than for those fed the other rations. Feed efficiency tended to be lower for the groups fed the fresh

manure-corn mixture or the ensiled manure-corn-hay-water mixture. The cattle fed the wastelage-corn mixture were easier to start and keep on feed than those fed the fresh manure-corn mixture. The pH values of the wastelage that was mixed with corn and of the fermented manure-corn-hay-water mixture were 5.1 and 4.3, respectively. Lactic acid levels (dry basis) of the same two ensiled materials were 2.3 and 3.7%, respectively.

Small laboratory silos were used by Anthony et al. (1973) to test the feasibility of ensiling corn silage, sorghum silage, green chopped rye forage, ground corn, cottonseed hulls, peanut hulls, rice hulls and almond hulls with manure from cattle fed a concentrate ration. Mixtures were allowed to ferment for at least 2 weeks. Corn and sorghum silage were each ensiled with manure in a 2:3 ratio. After fermenting, the lactic acid content of the sorghum silage-manure mixture was 10 times that of the corn silage-manure mixture. The green chopped rye forage was mixed with manure and ground corn in the following proportions: (1) 33% forage, 33% manure and 34% corn; (2) 44% forage, 44% manure and 12% corn; (3) 50% forage and 50% manure; (4) 25% forage and 75% manure; and (5) 75% forage and 25% manure. Final pH values for the five silages ranged from 4.0 to 4.1. Lactic acid concentrations were 5.13, 9.60, 7.52, 5.69 and 7.64% for mixtures 1, 2, 3, 4, and 5, respectively. All fermented mixtures of hulls and manure exhibited less desirable chemical and physical properties than the other fermented mixtures.

The feeding value of a fermented mixture of wilted barley and cattle manure in a 3:2 ratio was compared to ensiled direct cut barley

or ensiled wilted barley (Gonzalez, 1973). Addition of manure to the wilted barley at ensiling had no significant effect on the fermentation process. Final silage pH values ranged from 3.8 to 4.1. For the barley-manure mixture, pH had dropped from 5.4, initially, to a final value of 4.1 at 35 days. Performance of dairy heifers fed this material was similar to that of heifers fed direct cut barley silage, but somewhat inferior to those fed wilted barley silage. In a second experiment, corn forage was ensiled alone or with 20 or 40% cattle manure. The addition of manure to the forage resulted in no appreciable modification of the extent to which fermentation took place. Heifers fed the 40% manure silage had significantly lower daily gain than those fed the 20% manure silage. Feed efficiency followed the same pattern. Intakes of the two manure-containing silages were similar. Intake and performance of animals fed the 40% manure mixture were similar to those fed corn forage ensiled alone. When fed to dairy heifers in rations containing equal levels of protein and fiber, wilted barley ensiled alone or with 17 or 24% manure provided similar performance among treatments. No marked treatment effects were observed in the fermentation process.

McClure et al. (1973) observed adequate consumption for maintenance in 363-kg steers offered fermented manure from cattle fed an all-concentrate ration and bedded with straw. During fermentation, pH of the manure dropped from 7.5 to 5.0 and total VFA concentration was increased 10-fold. In another study, manure from cattle bedded with corn stover was fermented in a polyethylene covered stack. During an 80-day period, feeding manure silage, alone or with corn added to

equal the grain in corn silage resulted in daily gain, feed efficiency and dry matter intake per $W_{kg}^{0.75}$ similar to those obtained with cattle fed corn silage plus corn added to equal 1.0% of body weight. In a digestion trial with sheep, coefficients of dry matter digestibility for manure silage ensiled with and without 10% corn were 60.9 and 50.5%, respectively. Dry matter intake per $W_{kg}^{0.75}$ for the manure fermented alone was approximately 60% of that for manure fermented with 10% corn.

Ward and Beede (1973) investigated the digestibility of Cerola by lambs. Cerola was prepared by chemical and mechanical separation of beef feedlot manure into a washed solid fraction and a residual fraction. The solid fraction was then washed, screened, pressed and ensiled after the addition of 5% dried molasses. The fermentation period was at least 3 weeks. The fermented feed contained 54.2% dry matter and, on a dry basis, 11.0% crude protein and 66.5% NFE. For the sake of simplicity, additional supplementation was excluded from the ration fed. Under this system, crude protein intake was approximately 91 g which probably would not support weight gains under field conditions. Digestibility coefficients for dry matter, crude protein, ether extract, crude fiber and NFE were 75.7, 63.9, 85.3, 49.7 and 89.0%, respectively. Calculated TDN of the Cerola was 77%, dry basis. The lambs maintained generally good health and appearance throughout.

Ward _et al_. (1974) reported the digestibility and acceptability of Cereco silage, a fermented feed obtained from the manure of finishing cattle, when fed to growing-finishing beef steers. Apparent

digestibility of Cereco silage was quite similar to that of corn silage. Consumption of the ration containing Cereco silage was equal to that of the corn silage ration when Cereco silage did not exceed 25 to 50% of the total ration.

"Cornury" was prepared by Williams et al. (1974) by fermenting a 1:3 mixture of fresh manure (from a dairy confinement herd) and shelled corn. On an as fed basis, cornury contained 28% moisture and 10% crude protein. Crossbred beef steers fed cornury alone, with a fixed amount of corn silage daily, with fixed daily amounts of corn silage and soybean meal or a typical 14% crude protein finishing diet (with a constant daily allowance of corn silage) had average daily gains of 1.52, 1.34, 1.49 and 1.60 kg, respectively.

The performance of steers fed a typical finishing ration was compared to that of steers fed a ration containing 14% beef feedlot waste that had composted for 60 days (Westing and Brandenburg, 1974). Crude protein levels of the rations were 9.22 and 11.47%, respectively. Average daily gain, feed efficiency, intake, carcass measurements and organoleptic comparisons were similar between the two groups of cattle.

Cooper et al. (1972) reported an ensiled 1:1 mixture of whole corn plant and feces from ewes fed an all-roughage ration to be somewhat unacceptable when offered to ewes. However, when diluted with sufficient corn silage and soybean meal to make rations containing 0, 6.25, 12.5, 18.75 or 25% feces, intake was adequate for maintenance. The apparent digestion coefficients for dry matter and nitrogen were lower for corn plant-feces silage than for corn silage plus soybean meal, when fed to lambs. Nevertheless, positive nitrogen balance was maintained.

Fecal wastes from broilers, laying hens, cattle and sheep have been ensiled or composted alone or with water, forages, grain, bedding or other materials of plant origin. As measured by chemical parameters, the ensiled materials have readily undergone fermentation in most cases. In addition, feeding and digestibility studies have shown ensiling of animal wastes to be an effective method of preserving nutritive value and enhancing palatability of the materials.

OBJECTIVES

Experiments were conducted to ascertain the feasibility of ensiling broiler litter alone, with additional water or with high moisture corn grain. The specific objectives were to:

1. Determine the level of moisture necessary for optimum fermentation of ensiled broiler litter and to evaluate the effect of ensiling on bacteria numbers and medicinal drug residues.
2. Determine the extent of fermentation and the effects of ensiling litter on a large scale at two moisture levels on bacteria numbers and levels of medicinal drugs.
3. Study nitrogen utilization, ration digestibility, ruminal and blood parameters and palatability in ruminants fed ensiled broiler litter with different moisture levels.
4. Compare the fermentation characteristics of ensiled high moisture corn grain to an ensiled high moisture corn grain-broiler litter mixture and to investigate the effects of ensiling litter with corn on bacteria numbers and medicinal drug residues.
5. Study nitrogen utilization, ration digestibility, ruminal and blood parameters and palatability in ruminants as affected by ensiling broiler litter with high moisture corn grain.

EXPERIMENTAL PROCEDURES

Experiment 1--Ensiling Broiler Litter with Different Levels of Moisture

Small Silo Study.

This study was conducted to investigate the bacterial destruction and fermentation characteristics of broiler litter ensiled with moisture levels of 15.6, 20, 30, 40 and 50%. Approximately 115 kg of wood shaving based broiler litter was obtained from one humidity controlled, insulated, commercial broiler house.[1] One group of broilers had been reared on the litter. Medicinal drugs fed to the birds included amprolium, ethopabate, monensin sodium and zinc bacitracin. The litter was screened through 2.5 x 2.5 cm hardware cloth to remove compacted material and was bagged in synthetic fiber bags with approximately 10 kg per bag. Each bag was tied near the top and placed on a pallet in the bed of the truck with the litter spread out as much as possible within the bag and with space between the bags to facilitate ventilation. Upon arrival at Blacksburg, the litter was thoroughly mixed in a horizontal mixer and similarly rebagged and spread out on a pallet until ensiling the following day.

Samples of the litter were dried approximately 20 hr. at 100 C,

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[1]Obtained from Rocco Feeds, Inc., Harrisonburg, Virginia

and the moisture content thus determined was used to calculate the amount of distilled water to be added to the litter to prepare materials containing 15.6 (no water added), 20, 30, 40 and 50% moisture. Twenty kilograms of each material were prepared either by mixing in a Hobart mixer for 10 min. (two batches of 10 kg each for each of the 15.6 and 20% moisture levels) or by turning the litter on a concrete floor with shovels while the water was slowly added (one 20-kg batch for each of the 30, 40 and 50% moisture levels). The sticky consistency of the materials containing 30, 40 or 50% moisture prevented the use of the Hobart mixer for preparation of those mixtures. As the litter for each mixture was weighed, a composite sample of approximately 1 kg was accumulated, representing the litter used to prepare that mixture. These five samples were frozen for subsequent analyses and characterization of the litter used in this study.

The 20 kg of each mixture were used to prepare: (1) eight silos, each containing 2 kg of mixed material; and (2) two initial mixture samples of approximately 1 kg each. The mixtures with different moisture levels were subsampled for microbial tests, with the remaining portion frozen for subsequent chemical analyses. After weighing the 2 kg of mixed material to be placed in each silo, one double handful of the mixture was removed from the remaining mass of material. These double-handful samples were composited over four silos, so that one initial mixture sample represented the first four silos prepared from a given mixture. Similarly, the other initial mixture sample represented the remaining four silos prepared from the same mixture. The silos were prepared by firmly packing the mixed material into double-thickness

polyethylene bags of 3.8 liter capacity, supported by cardboard food containers of the same capacity. Two of the eight silos per moisture level were equipped with thermistor probes inserted into the approximate center of the packed material with both polyethylene bags tightly twisted and individually sealed around the thermistor lead. Similarly, both bags were individually sealed for the remaining six silos, being careful to expel the air above the packed material before sealing. Initial temperature and initial silo weight measurements were made. All silos were stored in the laboratory for daily silo and ambient temperature measurements.

After an average fermentation of 47 days, each silo, except those subjected to temperature measurement, was weighed and opened. Approximately 5 cm of the top material in each silo was discarded, and samples were aseptically removed and immediately subjected to total bacteria and coliform counts (Anonymous, 1967). A qualitative test for the presence of the enteric bacteria genera of salmonella, shigella and proteus (Lewis, 1964) was performed on each sample. After removing samples for microbial tests, the bags were immediately resealed and frozen for later chemical analysis.

Nitrogen componets were determined on the initial litter, initial mixtures and silages by the following methods: total nitrogen, (A.O.A.C., 1970); protein nitrogen, precipitation of protein with tungstic acid followed by nitrogen determination (A.O.A.C., 1970); uric acid nitrogen (Buys and Potgieter, 1959); and ammonia nitrogen, magnesium oxide method for ammonia in fertilizer (A.O.A.C., 1970). Non-protein nitrogen was calculated by difference between values obtained

for total and protein nitrogen. Dry matter of initial litter, initial mixtures and silages was determined by drying duplicate 200 g samples in a forced-draft oven at 80 C for 48 hr. Following equilibration with atmospheric moisture the duplicate dried samples were composited, ground through a 1 mm mesh screen and subjected to analysis for crude fiber (Whitehouse et al., 1945), dry matter, ether extract and ash (A.O.A.C., 1970).

Water extracts of the initial litter, initial mixtures and silages were prepared by homogenizing 25 g wet material with 100 ml water in a Waring blender at full speed for 2 min. The homogenate was filtered through four layers of cheesecloth, and the filtrate was used for measurement of pH (electrometrically), volatile fatty acids (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).

Initial and final silo weights and initial and final dry matter determinations provided a basis for estimating dry matter loss of the silages during fermentation.

Samples of initial mixtures and silages were freeze-dried and allowed to air equilibrate before being ground through a 20-mesh screen. Portions of the ground samples were composited according to: type of sample (initial mixture or silage) and moisture level (15.6, 20, 30, 40 or 50%). The ten composites were then analyzed for amprolium (fluorometric), ethopabate, monensin sodium and zinc bacitracin accordint to A.O.A.C. (1970) procedures. Individual samples were subjected

to drug analysis if data from the composite samples suggested a treatment effect.

Large Silo Study.

This study was conducted to investigate the apparent digestibility, nitrogen utilization and palatability by ruminants of rations containing 22 and 40% moisture ensiled broiler litter. Bacterial survival and fermentation characteristics in the ensiled materials were also measured. For this study, approximately 3.3 metric tons of wood shaving based broiler litter were obtained from one humidity controlled, insulated, commercial broiler house. One group of broilers had been reared on the litter. Medicinal drugs fed to the birds included clopidol, monensin sodium and roxarsone.

The litter was transported from the broiler house to Blacksburg in burlap bags with approximately 30 kg per bag. The next day the litter was ground through a 0.6 cm mesh screen, rebagged and spread out on the floor to facilitate ventilation. Ensiling occurred the following day.

One batch of 545.4 kg of the litter (containing 22.3% moisture) was thoroughly mixed for 10 min. in a horizontal mixer and augered into each of two silos. As the litter was weighed into the mixer, 12 double-handful samples (approximately one per 50 kg of litter) were accumulated, composited, subsampled and frozen for subsequent chemical analyses for characterization of the litter used in this study. Similarly, as the mixed litter was augered into the silo, 12 double-handful samples were again accumulated, composited, subsampled and

frozen. The remainder of the sample was returned to the silo after subsampling. Hereafter, these samples of mixed litter will be referred to as initial mixture samples. All initial mixture samples were further subsampled for microbial tests prior to freezing, and all microbial tests were performed as soon as possible.

Two silos were filled with litter containing 40% moisture. Each of these silos contained the same absolute amount of dry matter as the two silos described above. However, the procedure for mixing this litter, to which tap water was added, was slightly different. In the small silo study problems were encountered when an attempt was made to use a Hobart mixer to prepare litter mixtures containing 30% or more moisture. In an attempt to avoid similar problems in the present study, only 272.7 kg of litter were weighed into the horizontal mixer at one time instead of weighing in 545.4 kg, as was done for the first two silos filled. To this was slowly added a weighed quantity of tap water to increase the moisture content of the litter from 22.3% to 40%. The litter was mixed during the addition of the water and for 10 min. after all of the water had been added. The mixed material was then augured into a silo and the procedure repeated to give the same absolute amount of dry matter in that silo, as in each of the silos to which litter containing 22.3% moisture had been added. Sampling of the litter as it was weighed into the mixer and as the litter-water mixture was augered into the silo was the same as the method used for the 22.3% moisture treatment. Samples accumulated for each 272.7 kg batch were composited to represent the entire 545.4 kg of litter added to each silo.

Each silo consisted of a plywood box with cubic dimensions of

1.2 m lined with doubled 0.004 mm polyethylene bags. After filling, a thermistor probe was inserted into the litter to a depth of 0.3 m, and both polyethylene bags were individually twisted around the thermistor probe lead and sealed with plastic-coated electrical wire. An attempt was made to expel as much of the air above the ensiled mass as possible before sealing the bags. The silos were equipped with a polyethylene covered, waterproof, plywood lid elevated approximately 2.5 cm above the top of the silo walls. Thermistor probe leads were exteriorized through this 2.5 cm vent to permit daily silo temperature measurement without opening the silo. An initial silo temperature measurement was made 5 min. after sealing.

One 22% moisture silo and one 40% moisture silo were opened after 159 days. The litters from these silos were fed concurrently in a metabolism trial with sheep and in the first of two palatability trials with cattle. The remaining two silos were opened for feeding at the beginning of the second palatability trial, 212 days after ensiling.

Upon opening the first two silos, approximately 5 cm of the top material were removed from two diagonally opposed corners of each silo at a distance of approximately 0.3 m from the silo corner. Separate samples of the litter silage were then aseptically obtained from each area. This procedure was repeated on the last day of the first palatability trial. Upon opening the remaining two silos on the first day of the second palatability trial, two samples per silo were again aseptically obtained, and the procedure was likewise repeated on the last day of the second palatability trial. This method gave a total

of eight samples per silo, each of which was subjected to the microbial tests as performed in the small silo study. All microbial tests were initiated the day the samples were obtained.

During the entire 50 days that the litter silages were being fed, each silo was sampled daily at feeding. Daily silo samples were accumulated and frozen in a sealed glass container. Every 8 days, these composites were thawed, thoroughly mixed and subsampled. This gave a total of six samples of each silage. Subsamples obtained from each 8-day composite included: (1) a wet sample immediately frozen for subsequent determinations of nitrogen components; (2) duplicate 200 g samples immediately subjected to drying in a forced-draft oven at 80 C for 48 hr.; and (3) a 25 g sample immediately subjected to water extraction for determinations of pH, volatile fatty acids, lactic acid and water-soluble carbohydrates. Handling of samples and analytical procedures used to determine nitrogen components, proximate constituents and fermentation characteristics were the same as described for the small silo study.

Samples of initial mixtures and silages were prepared and composited for drug analyses as were samples in the small silo study. The four composites thus obtained were analyzed for arsenic (as a measure of clopidol and roxarsone) after wet ashing, and monensin sodium according to A.O.A.C. (1970) procedures. In the arsenic analysis, samples of litter were wet ashed by the procedure of Sandell (1950) instead of being dry ashed as specified by the A.O.A.C. (1970) procedure. Individual samples were subjected to drug analysis if data from

the composite samples suggested a treatment effect.

Metabolism Trial. Twenty-four crossbred wethers, averaging 36.5 kg initially, were used in a metabolism trial to study the relative effects of ensiling broiler litter at moisture levels of 22.3% and 40% on nitrogen utilization, ration digestibility and blood and ruminal parameters. Internal parasites were controlled by drenching all sheep with thiabendazole prior to initiation of the metabolism trial. The sheep were assigned to six outcome groups (blocks) of four on the basis of weight and breeding, and the sheep within each outcome group were randomly allotted to four rations. The composition of the rations used in the experiment is presented in table 1. The following four supplements supplied 50% of the dietary nitrogen for the four respective rations: (1) dry heat processed litter; (2) 22% moisture ensiled litter; (3) 40% moisture ensiled litter; and (4) soybean meal. Proximate analysis and calcium and phosphorus determinations were performed on the ground shelled corn, ground corn cobs, processed litter, litter silages and soybean meal before formulation of the experimental rations. Levels of ingredients were varied in an attempt to equalize crude protein and TDN among rations. Vitamins A and D were supplemented in the rations at levels to supply 770 IU and 200 IU per animal per day, respectively.

The dry heat processed litter consisted of the portion of litter remaining after filling the silos, which was dry heat processed in a forced-draft oven at 260 C for 30 min., with the litter at a depth of 1.3 cm. The litter was allowed to air equilibrate before being thoroughly mixed in a vertical mixer and rebagged for later incorporation

TABLE 1. COMPOSITION OF EXPERIMENTAL RATIONS FED IN METABOLISM TRIAL, EXPERIMENT 1

Item	Nitrogen supplements			
	Processed litter	Litter silage, 22% moisture	Litter silage, 40% moisture	Soybean meal
Ingredient composition, %				
Corn, cobs, grnd, (1) ref. no. 1-02-782	34.6	37.1	35.4	43.2
Corn, grain, grnd, (4) ref. no. 4-02-879	48.9	46.4	44.3	45.6
Processed litter	16.5	----	----	----
Litter silage, 22% moisture	----	14.4	----	----
Litter silage, 40% moisture	----	----	18.4	----
Soybean, seeds, solv-extd, grnd, (5) ref. no. 5-04-604	----	----	----	10.3
Corn, sugar[a], (4) ref. no. 4-02-891	----	2.1	1.9	0.5
Limestone, grnd, mn 33% calcium, (6) ref. no. 6-02-632	----	----	----	0.4
Vitamin A palmitate[b], (7) ref. no. 7-05-143	++	++	++	++
Vitamin D_3 supplement[c], (7) ref. no. 7-05-149	++	++	++	++
Chemical composition				
Dry matter, %	91.8	89.7	86.0	91.8
Composition of dry matter, %				
Crude protein	10.3	10.4	10.9	10.4
Ether extract	2.2	2.1	2.3	1.8
Crude fiber	19.5	20.3	20.2	20.9
Ash	3.9	3.5	3.6	2.5
NFE	64.1	63.7	63.0	64.4

[a]Cerelose, Corn Products Refining Co., New York, N.Y.
[b]Contained 325,000 IU per gram and was fed to supply 770 IU per animal daily.
[c]Contained 200,000 IU per gram and was fed to supply 200 IU per animal daily.

into the experimental ration. After processing, this litter contained 404 total bacteria and no coliforms per gram and tested negative for salmonella, shigella and proteus. The chemical composition of the processed litter was as follows: 92.3% dry matter; 30.0% crude protein; 2.5% ether extract; 19.7% crude fiber; 13.7% ash; and 34.1% NFE (dry basis, except for dry matter). Nitrogen loss as a result of processing was 25%.

The shelled corn and corn cobs were ground through a 0.6 cm mesh screen. Ground shelled corn, corn sugar, ground limestone and vitamins A and D were mixed into premixes for the respective rations. An adequate amount of each litter silage was removed from the silos each day to supply the evening feeding of that day and the morning feeding of the next day. The litter silages were stored overnight under refrigeration in sealed metal cans. The premixes, ground corn cobs and supplements (processed litter, 22% moisture litter silage, 40% moisture litter silage or soybean meal) were mixed by hand at each feeding to insure uniform intake. Ration ingredients were sampled at each feeding, starting 2 days prior to the beginning and ending 2 days prior to the end of the collection period. Litter silage samples were stored below 0 C in sealed glass containers.

In an attempt to equalize dry matter intake the sheep were fed 400, 411, 430 and 403 g of the processed litter, 22% moisture litter silage, 40% moisture litter silage and soybean meal rations, respectively, plus 5 g of trace mineralized salt at 8:00 am and 8:00 pm (total of 800, 822, 860 and 806 g/day, respectively). Water was available *ad libitum* except during the 2-hour feeding periods.

Before the trial, the sheep were maintained on a ration consisting of 46.3% ground shelled corn, 40.0% ground corn cobs, 12.8% soybean meal, 0.4% ground limestone and 0.5% trace mineralized salt. Transition to the experimental rations was accomplished over a 5-day period with the test rations being introduced at the rate of 10% per feeding. The metabolism trial consisted of a 10-day preliminary period followed by a 10-day period during which total fecal and urinary collections were made. The sheep were maintained in metabolism stalls similar to those of Briggs and Gallup (1949), facilitating separate collection of urine and feces. Urine was collected in glass jars to which had been added approximately 500 ml of water and 15 ml of a 1:1 (w/w) mixture of concentrated sulfuric acid and water. Each 24-hour urine sample was diluted to a constant weight, and a 2% sample by volume was taken and stored under refrigeration in air-tight, 1-liter plastic bottles. The total fecal excretion was collected daily and dried for 24 hr. or until dry in a forced-draft oven at a maximum temperature of 60 C. Daily collections were composited by animal in metal cans with loosely fitting lids and allowed to equilibrate with atmospheric moisture after being dried. The composites were weighed and sampled at the end of the collection period.

Samples of litters, feeds, premixes and air equilibrated feces were finely ground through a 1 mm mesh screen. Crude fiber in these samples was determined by the method of Whitehouse et al. (1945). Determination of moisture, nitrogen, ether extract and ash was according to A.O.A.C. (1970) procedures. Nitrogen determination of litter silages was performed on wet samples. Calcium analysis of litters and feeds was by Perkin-Elmer 403 atomic absorption spectro-

photometric methods and phosphorus analysis by the method of Fiske and Subbarow (1925) after wet ashing by the procedure of Sandell (1950).

At the end of the collection period rumen samples were taken *via* stomach tube 2 hr. after the morning feeding. The rumen contents were strained through four layers of cheesecloth, and pH of the strained fluid was determined electrometrically. Analyses for ammonia nitrogen (Conway, 1958) and volatile fatty acids (Erwin *et al.*, 1961) were performed on the strained rumen fluid.

Blood samples were taken on the same day as the rumen ingesta samples by jugular vein puncture 6 hr. after the morning feeding. The blood samples were analyzed for blood urea by the method of Coulombe and Favreau (1963).

Palatability Trials. The palatability of the litter silages was evaluated in two trials with 12 Shorthorn, Hereford and Angus yearling steers. Average initial weights of the steers for trials 1 and 2 were 332 and 339 kg, respectively. The steers were placed in three outcome groups (blocks) of four according to weight and breed. For trial 1, the steers within each group were randomly allotted to four rations. For trial 2, all steers remained in the original blocks and were reallotted to treatment, with the restriction that no steer would receive the same ration in both trials.

The composition of the experimental rations is shown in table 2. The four rations fed contained the same major ingredients as those used in the metabolism study with sheep. The rations were calculated to contain equal levels of TDN. For the three litter-containing rations, litter contributed 50% to the total ration dry matter. The steers had

TABLE 2. COMPOSITION OF EXPERIMENTAL RATIONS FED IN PALATABILITY TRIALS, EXPERIMENT 1

Item	Nitrogen supplements			
	Processed litter	Litter silage, 22% moisture	Litter silage, 40% moisture	Soybean meal
Ingredient composition, %				
Corn, cobs, grnd, (1) ref. no. 1-02-782	10.2	9.2	7.8	39.2
Corn, grain, grnd, (4) ref. no. 4-02-879	40.6	36.9	31.3	41.0
Processed liter	49.2	---	---	---
Litter silage, 22% moisture	---	53.9	---	---
Litter silage, 40% moisture	---	---	60.9	---
Soybean, seeds, solv-extd, grnd, (5) ref. no. 5-04-604	---	---	---	19.2
Limestone, grnd, mn 33% calcium, (6) ref. no. 6-02-632	---	---	---	0.6
Chemical composition				
Dry matter, %	90.6	84.5	71.9	90.9
Composition of dry matter, %				
Crude protein	18.9	24.0	24.5	14.3
Ether extract	2.9	2.6	2.8	2.0
Crude fiber	16.9	17.2	17.3	20.7
Ash	7.7	8.2	8.2	3.5
NFE	53.6	48.0	47.2	59.5

access to trace mineralized salt in block form while confined to individual stalls, and each animal was injected intramuscularly with 2,000,000 IU of vitamin A prior to the initiation of the first trial.

The shelled corn and corn cobs were ground through a 1.3 cm mesh screen and were mixed in appropriate ratios to make one premix for the three rations containing litter and another premix for the ration containing soybean meal. The ground limestone in the soybean meal-containing ration was mixed with the soybean meal. Sufficient litter silage was removed from each silo daily to supply the amount needed to feed that day. The premixes and supplements (processed litter, 22% moisture litter silage, 40% moisture litter silage or soybean meal plus limestone) were mixed by hand at each feeding to insure uniform intake of ingredients. Ration ingredients were sampled at each feeding starting the 11th day and ending the 25th day of each trial. Samples of litter silages were frozen and stored in sealed glass containers. Proximate analysis of ration ingredients was performed by the same procedures that were used to analyze feed samples in the metabolism trial with sheep. An attempt was made to feed approximately 5 to 10% in excess of consumption. From the 11th through the 25th day of each trial, 5% of the daily refusal from each animal was stored in individual polyethylene bags at a temperature below freezing. At the end of each trial these samples were composited by animal, thoroughly mixed and sampled for dry matter determination. The cattle were fed the respective rations once daily. They were put in individual stalls at approximately 3:00 pm and turned out the next morning at approximately 7:00 am. The cattle were kept as

a group in exercise lot the remainder of the time. Water was available in the exercise lot but not in the individual feeding stalls.

The cattle were weighed at the beginning and end of the intake measurement period which was the last 15 days of each trial. An average of these two weights was used to calculate metabolic size ($W_{kg}^{0.75}$) for each trial, upon which voluntary dry matter intake was based.

Prior to trial 1 a preliminary ration consisting of 52.5% ground shelled corn, 30.5% ground corn cobs, 15.9% soybean meal, 0.6% ground limestone and 0.5% trace mineralized salt was fed to the steers. Each trial consisted of a 5-day transition period during which the experimental rations were introduced at the rate of 20% per day, followed by a 20-day experimental period.

While in the stalls, eating patterns of the individual steers were measured during the last 15 days of each trial using photoelectric relays and operation recorder similar to those used by Putnam and Davis (1963). The parameter measured was the number of minutes spent in the feedbox per hour. In summarizing the eating pattern data, the daily measurements were subdivided into three periods: 0-3 hours; 3-6 hours; 6-16 hours. The total 15-day measurement period was divided into five periods of 3 consecutive days each.

Statistical Analyses. All data were analyzed by analysis of variance (Ostle, 1963) where possible (excluding drug analyses on composited samples). Significant differences among treatment means were tested using the multiple range test of Duncan (1955). In both fermentation studies, statistical analysis was performed between treatments (moisture levels) within either the initial mixtures or the

silages. In no case was a statistical comparison made between initial and fermented values within a given moisture level.

Experiment 2--Ensiling Broiler Litter with High Moisture Corn Grain

This experiment was conducted to study the fermentation characteristics of an ensiled mixture of broiler litter and high moisture corn grain and to assess the digestibility, nitrogen utilization and palatability of rations containing the ensiled mixture. High moisture corn grain, containing 26.3% moisture, was harvested and ensiled the same day, both alone and in a 2 to 1 (w/w) ratio with wood shaving based broiler litter, containing 18.7% moisture. One group of birds had been reared on the litter which was obtained from one commercial, insulated, humidity-controlled broiler house. The broilers had been fed amprolium, ethopabate, monensin sodium, roxarsone, sulfaquinoxaline and zinc bacitracin. The litter was transported to Blacksburg in burlap bags and stored, with the bags spread out on the floor to facilitate ventilation. Ensiling of the litter with the corn occurred the following day.

Approximately 1 metric ton of the corn grain was weighed, ground through a 0.6 cm mesh screen and mixed 10 min. in a vertical mixer before being ensiled in each of six silos. As the shelled corn for each silo was weighed, 22 double-handful samples (approximately one per 50 kg of corn) were accumulated, composited, subsampled and frozen for later analyses. Results of these analyses were used to characterize the corn. In a similar manner, the same number of double-handful samples

were again accumulated, composited and subsampled as the mixed corn grain was removed from the mixer. After subsampling, the remaining material was returned to the silo. These initial material samples were further subsampleo for microbial tests prior to freezing, and all microbial tests were initiated as soon as possible after obtaining samples.

Corn and litter were added in a 2 to 1 ratio to two silos. For each silo, 682 kg of the shelled corn and 341 kg of the litter were weighed, ground through a 0.6 cm mesh screen and mixed 10 min. before being placed in the silo. Sampling of this corn and the litter as they were weighed into the hammermill and sampling of the corn-litter mixture as it was removed from the mixer was performed by the same method used to sample corn alone, in that approximately one double-handful sample was obtained per 50 kg of unground ingredients or mixed material. As with the six batches of corn alone described in the previous paragraph, the samples of unground ingredients obtained from the two batches of the corn and litter treatment were used for chemical characterization of the corn and the litter. The samples of the mixed corn and the corn-litter mixtures obtained after grinding and mixing represented the materials ensiled and will hereafter be referred to as initial material samples.

The silos used were identical in construction and were equipped and sealed as those used in the large silo study of Experiment 1. Initial silo temperature was recorded 5 min. after sealing.

Three of the corn and one of the corn-litter silos were opened after 80 days. The fermented materials from these silos were fed

concurrently in a metabolism trial with sheep and in the first of two palatability trials with cattle. The second palatability trial was conducted using fermented materials from the remaining four silos which were opened 140 days after ensiling.

Samples for microbial tests were aseptically obtained from two diagonally opposed corners of each of the first four silos opened on day 80 and again on the last day of the first palatability trial by the method used for the large silo litter silage study described above. Samples were taken from the remaining four silos on the first and last days of the second palatability trial. All samples were subjected to microbial tests the day they were obtained.

Each silo was sampled daily at feeding time during the 50 days that the fermented materials were being fed. Samples were frozen and stored in sealed glass containers. The silo composites were thawed every 8 days and composited according to the type of ensiled material. Subsamples obtained were handled as described for the large silo litter silage study with respect to sample preparation and analysis for nitrogen components, proximate constituents and fermentation characteristics.

As in the other studies, drug analyses were performed on freeze dried composites of the initial and fermented corn-litter mixtures. Drug analyses included amprolium, ethopabate, monensin sodium, arsenic (as a measure of roxarsone), sulfaquinoxaline and zinc bacitracin. Drug analysis was performed on individual samples only if data from the composite samples indicated a possible effect of ensiling.

Metabolism Trial. A metabolism trial was conducted to determine the effect of ensiling litter with high moisture corn grain on nitrogen

utilization, ration digestibility and blood and ruminal parameters. Twenty-four crossbred wethers, averaging 34.4 kg initially, were placed in six outcome groups (blocks) of four based on weight and breeding. The sheep within each block were randomly allotted to four rations. All sheep were drenched with thiabendazole before the trial to control internal parasites.

The rations used were: (1) control, low protein; (2) ensiled corn-litter; (3) ensiled corn and processed litter; and (4) ensiled corn and soybean meal. The ingredient and chemical composition of the rations are shown in table 3. Prior to formulation of the rations, calcium and phosphorus determinations and proximate analyses were performed on the ensiled corn, ensiled corn-litter mixture, ground corn cobs, processed litter and soybean meal. The level of ground corn cobs was equal in all rations (50%). Calculated crude protein content was equalized among the ensiled corn-litter, ensiled corn and processed litter and ensiled corn and soybean meal rations. Contributions to total ration nitrogen from litter or soybean meal were 56.5%, 64.4%, and 58.6% for the ensiled corn-litter, ensiled corn and processed litter and ensiled corn and soybean meal rations, respectively. Vitamins A and D were mixed with iodized salt at levels of 770 IU and 200 IU, respectively, per 10 g of salt. Consequently, daily requirements of the animals for vitamins A and D were met by feeding 5 g of the iodized salt to each animal at each of the two feedings per day.

The processed litter consisted of the litter from the same house as the ensiled material. It was ground through a 0.6 cm mesh screen

TABLE 3. COMPOSITION OF EXPERIMENTAL RATIONS FED IN METABOLISM TRIAL, EXPERIMENT 2

Item	Ration designation			
	Ensiled corn	Ensiled corn-litter	Ensiled corn + proc. litter	Ensiled corn + soybean meal
Ingredient composition, %				
Corn, cobs, grnd, (1) ref. no. 1-02-782	50.0	50.0	50.0	50.0
Corn, grain, grnd, ensiled, (3) ref. no. 3-07-739	49.7	---	27.2	37.2
Ensiled corn-litter mixture	---	50.0	---	---
Processed litter	---	---	22.8	---
Soybean, seeds, solv-extd, grnd, (5) ref. no. 5-04-604	---	---	---	12.6
Limestone, grnd, mn 33% calcium, (6) ref. no. 6-02-632	0.1	---	---	0.2
Phosphate rock, defluorinated grnd, mx 1 part fluorine per 100 parts phosphorus, (6) ref. no. 6-01-780	0.2	---	---	---
Chemical composition				
Dry matter, %	83.5	86.2	87.9	85.8
Composition of dry matter, %				
Crude protein	6.3	10.8	11.1	11.7
Ether extract	1.6	1.3	1.3	1.3
Crude fiber	24.5	27.6	28.9	26.1
Ash	2.6	4.0	4.8	2.8
NFE	65.0	56.3	53.9	58.1

and dry heat processed as described for the litter silage study. The processed litter contained 554 total bacteria and no coliforms per gram and was free of salmonella, shigella and proteus. The chemical composition of the litter after processing was 93.8% dry matter; 29.9% crude protein; 2.1% ether extract; 21.5% crude fiber; 13.1% ash; and 33.4% NFE (dry basis, except for dry matter). Nitrogen loss as a result of processing was approximately 20%.

The corn cobs were ground through a 0.6 cm mesh screen. In the ensiled corn ration, the ground limestone and defluorinated phosphate were mixed together and a preweighed amount of the mixture was added to the feed of the animals on that treatment at each feeding. In the ensiled corn and soybean meal ration, the ground limestone was mixed with the soybean meal. Sufficient amounts of the corn and the corn-litter mixture were removed from the silos each day to supply enough of each to feed that evening and the following morning. The fermented materials were stored overnight under refrigeration in sealed metal cans. Ration ingredients were mixed by hand at each feeding to insure uniform intake. Sampling of ration ingredients and storage of the samples of fermented materials were as in the metabolism trial described for the large silo litter silage study.

An attempt was made to equalize dry matter intake by feeding the sheep 350, 342, 331 and 342 g of the ensiled corn, ensiled corn-litter, ensiled corn and processed litter and ensiled corn and soybean meal rations, respectively, plus 5 g of the iodized salt-vitamins A and D premix at 7:30 am and 7:30 pm (total of 700, 684, 662 and 684 g/day,

respectively). The sheep had access to water at all times except during the 2-hour feeding periods.

Palatability Trials. Two palatability trials were conducted with 12 Shorthorn, Hereford and Angus steer calves with average initial weights of 231 and 249 kg in trials 1 and 2, respectively. The animals were blocked into groups of four based on weight and breed. For trial 1, the steers within each group were randomly allotted to four rations. For trial 2, all steers remained in the original blocks and were re-allotted to treatment, with the restriction that no steer would receive the same ration in both trials.

The composition of the experimental rations fed is shown in table 4. The four rations contained the same major ingredients as those used in the metabolism study described above. Calculated crude fiber levels were equalized among the rations by varying the amounts of corn cobs. For the two rations containing litter, 27.5% of the total ration dry matter was contributed by litter. The calves had access to trace mineralized salt in block form while confined to individual stalls. An intramuscular injection of 2,000,000 IU of vitamin A was given to each animal prior to trial 1.

The corn cobs were ground through a 1.3 cm mesh screen. The ground limestone and defluorinated phosphate were mixed together for the ensiled corn ration, and a preweighed amount of the mixture was added to the daily feed allowance of the calves. Ground limestone and defluorinated phosphate were mixed with the soybean meal in the ensiled corn and soybean meal ration.

TABLE 4. COMPOSITION OF EXPERIMENTAL RATIONS FED IN PALATABILITY TRIALS, EXPERIMENT 2

Item	Ration designation			
	Ensiled corn	Ensiled corn-litter	Ensiled corn + proc. litter	Ensiled corn + soybean meal
Ingredient composition, %				
Corn, cobs, grnd, (1) ref. no. 1-02-782	30.0	20.0	20.0	28.4
Corn, grain, grnd, ensiled, (3) ref. no. 3-07-739	69.1	---	56.3	55.9
Ensiled corn-litter mixture	---	80.0	---	---
Processed litter	---	---	23.7	---
Soybean, seeds, solv-extd, grnd, (5) ref. no. 5-04-604	---	---	---	14.9
Limestone, grnd, mn 33% calcium, (6) ref. no. 6-02-632	0.3	---	---	0.6
Phosphate rock, defluorinated grnd, mx 1 part fluorine per 100 parts phosphorus, (6) ref. no. 6-01-780	0.6	---	---	0.2
Chemical composition				
Dry matter, %	79.9	81.6	82.5	81.9
Composition of dry matter, %				
Crude protein	6.9	16.0	13.5	13.5
Ether extract	2.1	2.2	2.2	1.9
Crude fiber	17.6	16.6	17.5	17.6
Ash	2.8	5.0	4.7	3.2
NFE	70.6	60.2	62.1	63.8

Adequate amounts of the fermented materials were obtained from the silos each day to supply the quantity needed to feed that day. Ration ingredients were mixed by hand at each feeding and were sampled, stored and analyzed according to the methods described for the palatability trials conducted in the large silo litter silage study.

Prior to trial 1, the calves were maintained on a diet consisting of 81.3% ground ear corn, 4.0 % ground corn cobs, 13.3% soybean meal, 0.9% ground limestone and 0.5% trace mineralized salt. Other aspects of conducting the two trials were the same as those described in the litter silage study.

Statistical Analyses. Data from the fermentation study, the metabolism trial and palatability trials were statistically handled the same as those obtained in Experiment 1. Examples of analysis of variance are shown in the appendix.

RESULTS AND DISCUSSION

Experiment 1--Ensiling Broiler Litter with Different Levels of Moisture

Small Silo Study

Composition of Litter. In table 5 is shown the composition of the broiler litter used in this study. Crude protein content averaged 31.5%, dry basis. With the exception of the relatively high ash content of 19.4%, this litter was typical of most litter obtained from commercial broiler operations in Virginia. Generally, ash constitutes 13 to 15% of litter dry matter. The value of 2.6% for water-soluble carbohydrates is substantially lower than the level of 4.40% reported by Harmon *et al*. (1975a). Levels of nitrogen components generally were within ranges established by Fontenot *et al*. (1971a), Caswell *et al*. (1975) and Harmon *et al*. (1975a) but agreed most nearly with those determined by Bhattacharya and Fontenot (1966).

Fermentation and Associated Effects. The ensiling process did not appear to appreciably affect the temperature of the silages. Ambient temperature was generally reflected in the daily temperatures of the silages. Temperature data are presented in tabular form in appendix table 37. If a temperature change did occur in the silages, the possibility of rapid dissipation of heat from the very small mass of

TABLE 5. COMPOSITION OF BROILER LITTER USED IN EXPERIMENT 1, SMALL SILO STUDY[a]

Item	Broiler litter
Dry matter, %	81.4
Composition of dry matter, %	
Crude protein	31.5
Ether extract	3.5
Crude fiber	19.5
Ash	19.4
NFE	26.1
Water-soluble carbohydrates	2.6
Total nitrogen	5.0
Composition of total nitrogen, %	
Protein nitrogen	48.5
Non-protein nitrogen	51.5
Uric acid nitrogen	26.0
Ammonia nitrogen	12.9

[a]Values represent an average of five samples of litter.

material ensiled could have prevented such a change from being recorded. Also, the quantity of heat produced, if any, by a 2-kg mass of fermenting silage may have been too small to measure, considering the limited sensitivity of the instrument used to monitor silo temperatures.

Upon opening the silos, a pleasing fermentation aroma was noticed in silages containing 30% or more moisture. No mold growth was observed in silages containing 15.6, 20 or 30% moisture. However, in the 40% moisture treatment, two to seven mold colonies having diameters of approximately 1 to 2.5 cm were observed on the surface of the silages. In silages of the 50% moisture level, a rather dense layer of mold covered the entire surface of the silage in all six silos and spots of subsurface mold were observed throughout the fermented mass despite the fact that this material was easy to pack firmly at ensiling.

In table 6 is shown the composition of the initial mixtures and silages. Values for initial mixtures represent an average of two replicates of each moisture level. In the lower portion of table 6, silage means represent six replicates of each treatment. The dry matter of the materials was, in all cases, slightly lower than desired. Apparently, drying of the samples before ensiling the litter was incomplete, resulting in an error in the calculation of the amount of distilled water to be added to the litter. For the initial mixtures, the actual moisture level was 1.6 to 2.8 percentage units higher than expected. Dry matter content of both the initial mixtures and the silages was, of course, significantly ($P<.01$) affected by treatment.

In the initial mixtures, ash was lower ($P<.01$) for the 20% than for the 40% moisture level. No apparent reason can be given for the

TABLE 6. COMPOSITION OF INITIAL MIXTURES AND SILAGES, EXPERIMENT 1, SMALL SILO STUDY

Type of material	Estimated moisture (%)	Dry matter (%)	Composition of dry matter				
			Crude protein (%)	Ether extract (%)	Crude fiber (%)	Ash (%)	NFE (%)
Initial mixtures	15.6	81.6[a]	31.2	3.50	18.5	19.4[a,b]	27.4
	20.0	77.5[b]	31.5	3.67	18.9	19.1[a]	26.8
	30.0	67.8[c]	32.6	3.10	19.5	19.6[a,b]	25.2
	40.0	57.9[d]	31.9	3.45	20.6	19.8[b]	24.3
	50.0	48.4[e]	30.4	3.66	19.9	19.6[a,b]	26.4
Silages	15.6	81.0[f]	31.8	3.68	18.4	19.3[f]	26.8
	20.0	77.2[g]	31.3	3.62	19.1	19.4[f]	26.6
	30.0	67.8[h]	30.3	3.27	18.9	19.6[f]	27.9
	40.0	57.3[i]	30.9	3.57	18.2	19.9[g]	27.4
	50.0	47.6[j]	32.3	3.50	19.3	20.1[g]	24.8

[a,b,c,d,e] Means for initial mixtures having different superscripts are significantly ($P<.01$) different.

[f,g,h,i,j] Means for silages having different superscripts are significantly ($P<.01$) different.

difference in ash content between these initial mixture moisture levels. Ash was significantly ($P < .01$) higher for silages containing 40 or 50% moisture than it was for the 15.6, 20 or 30% moisture treatments. Harmon et al. (1975a) observed a similar significant increase in ash content in corn forage ensiled with 0.5% urea as compared to corn forage ensiled alone. Other proximate components were not significantly affected by moisture level in initial mixtures or silages.

Data on fermentation characteristics are presented in table 7. The pH values for the initial mixtures were not significantly different, whereas pH of the silages decreased significantly ($P < .01$) with each added increment of water up to the 40% moisture level. Values for pH for the silages containing 15.6 or 20% moisture were quite similar to those for the corresponding initial mixtures, indicating limited fermentation with low moisture levels.

The initial mixtures were devoid of lactic acid. Lactic acid level in the silages was significantly ($P < .01$) increased with increasing moisture levels. The increase in lactic acid level between the 30 and 40% moisture levels was 107% as compared to an increase of only 12% between the 40 and 50% moisture levels, indicating that fermentation and, consequently, lactic acid production were approaching maximum in litter ensiled at 40% moisture. Of the volatile fatty acids normally found in measurable amounts in ruminal fluid, acetic acid was the only one found in measurable quantities in the initial mixtures and silages. In the initial mixtures, there was a trend toward elevation of acetic acid with increasing additions of water to litter. Since some time elapsed between preparation of initial mixtures and transportation of

TABLE 7. FERMENTATION CHARACTERISTICS OF INITIAL MIXTURES AND SILAGES, EXPERIMENT 1, SMALL SILO STUDY

Type of material	Estimated moisture (%)	pH	Level, % of dry matter		
			Lactic acid	Acetic acid	Water-soluble carbohydrates
Initial mixtures	15.6	7.78	0	0.83	2.65
	20.0	7.74	0	0.91	2.67
	30.0	7.77	0	1.01	2.70
	40.0	7.72	0	1.20	2.62
	50.0	7.68	0	1.28	2.60
Silages	15.6	7.81[a]	0[a]	0.99[a]	2.61[a]
	20.0	7.63[b]	0.24[b]	1.15[a]	2.66[a]
	30.0	6.12[c]	2.21[c]	2.33[b]	1.89[b]
	40.0	5.39[d]	4.58[d]	3.14[c]	1.75[b]
	50.0	5.43[d]	5.14[e]	4.17[d]	1.73[b]

[a,b,c,d,e] Means for silages having different superscripts are significantly ($P<.01$) different.

the samples to the freezer, this response may possibly have been an artifact of a minute level of fermentation that was initiated before these mixtures could be frozen. For the silages, acetic acid was significantly ($P < .01$) elevated by each additional increment of moisture beyond the 20% moisture level. Saylor and Long (1974) reported a pH of 5.2 for a fermented 60:40 caged layer manure-grass hay mixture containing 47% moisture. In the same mixture, lactic acid production was lower (1.56%) than the level reported here for silage of a comparable moisture level. Total VFA production in their study was also lower at 2.35%. However, another manure-hay mixture (70:30) containing 53% moisture had a total VFA level of 3.95% following fermentation. This value is quite similar to the 4.17% reported in the present study for litter silage containing 50% moisture.

The significant ($P < .01$) decrease in water-soluble carbohydrates for the 30, 40 and 50% moisture treatments is also indicative of fermentation of sugars in these silages. Supporting the statement made above that fermentation and lactic acid production approached maximum for the 40% moisture treatment is the fact that water-soluble carbohydrate levels in the 40 and 50% moisture silages were essentially equal and were lower than for the 30% moisture silage.

Data presented in table 8 concerning the extent of water-soluble carbohydrate fermentation and dry matter loss of silages were calculated using dry matter and water-soluble carbohydrate values, and initial and final silo weights. Carbohydrate fermented, expressed as grams per 100 g of dry matter, was significantly ($P < .01$) higher at 0.82 to 0.90 g

TABLE 8. EXTENT OF WATER-SOLUBLE CARBOHYDRATE FERMENTATION AND DRY MATTER LOSS OF SILAGES, EXPERIMENT 1, SMALL SILO STUDY

Estimated moisture, (%)	Carbohydrate fermented		Dry matter loss, (%)
	g/100 g DM	% of initial	
15.6	0.07[a]	2.4[a]	1.06[a]
20.0	0.02[a]	0.6[a]	0.76[a]
30.0	0.82[b]	30.6[b]	0.83[a]
40.0	0.89[b]	33.9[b]	2.18[b]
50.0	0.90[b]	34.5[b]	2.93[b]

[a,b]Means having different superscripts are significantly ($P<.01$) different.

for the 30, 40 and 50% than for the 15.6 and 20% moisture levels. As a percent of initial, carbohydrate fermentation followed the same pattern. For the 30, 40 and 50% moisture levels, values ranged from 30.6 to 34.5%. These values are within the range of 29 to 47% reported by Harmon et al. (1975a) for fermented corn forage-litter mixtures containing 50 to 60% moisture.

Dry matter loss was significantly ($P<.01$) greater for the 40 and 50% moisture treatments. However, values for 30, 40 and 50% moisture levels were similar to those reported under conventional ensiling of a larger mass of high moisture corn grain (Danley and Vetter, 1974a, and Heuberger et al., 1959). In laboratory studies, Harmon et al. (1975a) also reported dry matter losses of 1.2 to 3.0% in litter-containing silages having moisture levels comparable to the 50% moisture silage.

In table 9 are shown the levels of nitrogen components of the initial mixtures and silages. Total nitrogen was not significantly affected by moisture level. Furthermore, no large differences were observed between corresponding total nitrogen levels of initial mixtures and silages, which is in agreement with results reported by Harmon et al. (1975a). In the initial mixtures, no significant differences between treatments were observed for protein, non-protein or uric acid nitrogen. However, ammonia nitrogen was significantly ($P<.01$) higher for the 50% initial mixture than it was for the other four treatments, and was significantly ($P<.01$) higher for the 30 and 40% treatments than for the 15.6 and 20% moisture levels.

The only significant ($P<.01$) reduction in protein nitrogen among the ensiled treatments was observed for the 50% moisture silage.

TABLE 9. NITROGEN COMPONENTS OF INITIAL MIXTURES AND SILAGES, EXPERIMENT 1, SMALL SILO STUDY

Type of material	Estimated moisture (%)	Total nitrogen (% of DM)	Composition of total nitrogen			
			Protein nitrogen (%)	Non-protein nitrogen (%)	Uric acid nitrogen (%)	Ammonia nitrogen (%)
Initial mixtures	15.6	4.99	47.2	52.8	25.3	12.4[a]
	20.0	5.04	48.5	51.5	28.5	14.4[a]
	30.0	5.22	48.5	51.5	25.2	20.3[b]
	40.0	5.10	50.2	49.8	25.7	25.4[b]
	50.0	4.87	45.3	54.7	27.2	34.3[c]
Silages	15.6	5.08	46.2[d]	53.8[d]	24.6[d,e]	14.6[d]
	20.0	5.01	48.0[d]	52.0[d]	27.6[d]	15.9[d,e]
	30.0	4.85	46.9[d]	53.1[d]	22.3[e]	14.2[d]
	40.0	4.94	44.6[d]	55.4[d]	21.9[e]	17.2[e]
	50.0	5.17	36.5[e]	63.5[e]	22.0[e]	21.1[f]

[a,b,c]Means for initial mixtures having different superscripts are significantly ($P<.01$) different.
[d,e,f]Means for silages having different superscripts are significantly ($P<.01$) different.

Consequently, NPN was significantly ($P<.01$) higher in the 50% moisture silage than in the other four treatments. The significant ($P<.01$) decreases in uric acid nitrogen in the 30, 40 and 50% silages can be explained on the basis of the results of research by Schefferle (1965). She found certain strains of coryneform bacteria to be able to decompose uric acid to urea and eventually to ammonia if decomposition was permitted to proceed. Since coryneform bacteria are frequently found in litter, such decomposition could have taken place in these silages. Possibly, ammonia from the decomposition of protein and uric acid during fermentation along with other free ammonia molecules was incorporated into other non-protein nitrogenous compounds. Evidence of this is the higher ($P<.01$) NPN level for the 50% moisture silage and the lower ammonia nitrogen levels for the 30, 40 and 50% silages, relative to initial mixtures of the same moisture levels.

Bacterial data for the initial mixtures and silages are presented in table 10. Total bacterial counts of the initial mixtures ranged from 1.75 to 2.53 billion organisms per gram of litter. Coliform counts performed on the initial mixture samples provided estimates of 70,000 to 124,000 organisms per gram. Halbrook et al. (1951) reported similar coliform counts. All initial mixture samples gave negative tests for salmonella and shigella but were positive for proteus. Ensiling of all materials resulted in marked reductions in total bacteria. Counts obtained in the present studies for silages in which active fermentation took place were considerably lower than the total bacteria counts obtained for 35 to 38% moisture litter silage (Creger et al., 1973) and fermented mixtures of corn forage and litter (Harmon et al, 1975a).

TABLE 10. BACTERIA COUNTS OF INITIAL MIXTURES AND SILAGES, EXPERIMENT 1, SMALL SILO STUDY

Type of material	Estimated moisture	Total bacteria	Coliforms	Salmonella	Shigella	Proteus
	%	10^9 per gram	10^3 per gram			
Initial mixtures	15.6	1.75	124^a	-	-	+
	20.0	2.24	97^b	-	-	+
	30.0	2.00	$92^{b,c}$	-	-	+
	40.0	2.53	$84^{b,c}$	-	-	+
	50.0	2.33	70^c	-	-	+
Silages	15.6	0.209^d	0.010^d	-	-	-
	20.0	0.187^d	0^e	-	-	-
	30.0	0.024^e	0^e	-	-	-
	40.0	0.007^e	0^e	-	-	-
	50.0	0.024^e	0^e	-	-	-

[a,b,c] Means for initial mixtures having different superscripts are significantly ($P<.01$) different.

[d,e] Means for silages having different superscripts are significantly ($P<.01$) different.

The counts at the 30 to 50% moisture levels were only 3 to 14% of the counts for litter ensiled with no additional moisture. Coliforms were completely eliminated by ensiling the materials containing 20% or more moisture. Creger et al. (1973) reported similar results. Proteus found in the initial mixtures was destroyed by ensiling. This finding is of particular importance since proteus bacteria can cause gastrointestinal and/or urogenital tract infections in animals and man (Burrows, 1968).

The residues of medicinal drugs found in the initial mixtures and silages are presented in table 11. Values for amprolium ranged from 8.5 to 10.0 ppm in initial mixtures and from 8.4 to 10.1 ppm in silages, and showed no definite trends with respect to moisture level in either the initial mixtures or the silages. All levels of amprolium were within the range of 0 to 77 ppm reported for 29 samples analyzed by Webb and Fontenot (1975). Contrary to the results of Creger et al. (1973), amprolium was detected following fermentation of the broiler litter. Ethopabate and monensin sodium analyses revealed no detectable levels of these drugs in either the initial mixtures or the silages. Levels of zinc bacitracin in the initial mixtures ranged from 0.655 to 0.830 units per gram. Although levels of bacitracin in the silages indicated that the antibiotic was affected by ensiling and by the moisture level of ensiled litter, analysis for bacitracin was performed only on composited samples due to the complexity and time involvement in carrying out this procedure. Zinc bacitracin was markedly lowered by ensiling at 15.6, 20 and 30% moisture and was completely destroyed by ensiling at 40 and 50% moisture.

TABLE 11. MEDICINAL DRUG RESIDUES IN INITIAL MIXTURES AND SILAGES, EXPERIMENT 1, SMALL SILO STUDY[a]

Type of material	Estimated moisture	Concentration of drug, dry basis			
		Amprolium	Ethopabate	Monensin sodium	Zinc bacitracin
	%	ppm	ppm	ppm	units/g
Initial mixtures	15.6	10.0	0	0	0.780
	20.0	9.2	0	0	0.655
	30.0	8.5	0	0	0.830
	40.0	8.6	0	0	0.775
	50.0	8.7	0	0	0.675
Silages	15.6	8.4	0	0	0.215
	20.0	9.5	0	0	0.100
	30.0	10.1	0	0	0.050
	40.0	9.8	0	0	0
	50.0	9.3	0	0	0

[a]Analysis performed on composited samples only.

Data collected in this study indicate that broiler litter will sustain fermentation when ensiled if the moisture level is increased to at least 30%. Although levels of organic acids were maximal in the 50% moisture silage, physical characteristics of this material were such that it appeared that 40% moisture would be a more practical level at which to ensile the litter in the large silo study.

Large Silo Study

Composition of Litter. The composition of the litter ensiled in the large silo study is shown in table 12. The main differences between the litter described here and that used in the small silo study were higher moisture, crude protein and water-soluble carbohydrate levels in this litter. Fractionation of total nitrogen indicated that levels of nitrogen components in this litter were normal.

Fermentation and Associated Effects. Silo temperature data are presented in tabular form in appendix table 38. When plotted over the entire fermentation period, daily silo temperatures generally paralleled ambient temperature. However, sudden, severe changes in ambient temperature were not reflected in silo temperatures unless these ambient changes lasted for prolonged periods of time. Malfunctioning of the instrument used to measure silo temperatures prevented monitoring for a period of 35 days early in the fermentation period. Upon opening the silos, the aroma of the 40% moisture silage was quite pleasing and indicative of fermentation. No surface or subsurface mold was observed. The odor of the 22% moisture silage was not noticeably different from that observed the day of ensiling.

TABLE 12. COMPOSITION OF BROILER LITTER USED IN EXPERIMENT 1, LARGE SILO STUDY[a]

Item	Broiler litter
Dry matter, %	77.7
Composition of dry matter, %	
Crude protein	40.0
Ether extract	2.4
Crude fiber	19.2
Ash	13.8
NFE	24.7
Water-soluble carbohydrates	3.6
Total nitrogen	6.4
Composition of total nitrogen, %	
Protein nitrogen	43.0
Non-protein nitrogen	57.0
Uric acid nitrogen	34.6
Ammonia nitrogen	15.0

[a]Values represent an average of four samples of litter.

Table 13 contains the chemical composition of the initial mixtures and silages. As in the small silo study, initial mixture means and silage means represent an average of two and six replicates per moisture level, respectively. In the initial mixtures, dry matter was the only component that varied significantly ($P<.01$) between treatments. For the ensiled materials, dry matter remained significantly ($P<.01$) different between treatments. There was, however, an increase in dry matter of the 22% moisture silage by 2.2 percentage units over that of the corresponding initial mixture. Also, ether extract of the 40% silage was significantly ($P<.01$) higher than for the 22% silage. A similar relationship was observed in the initial mixtures, but differences were not significant.

The fermentation characteristics presented in table 14 indicate that the extent of fermentation in litter ensiled on a large scale was similar to litter fermented in small laboratory silos. Initial mixture pH values were 7.64 and 7.61 for the 22 and 40% treatments, respectively, as compared to similar values of 7.74 and 7.72 for comparable moisture levels in the small silo study. However, unlike the results presented in table 7, the pH of the 22% moisture litter increased rather than decreased as a result of ensiling. This could be attributed to the liberation of ammonia during ensiling. In the 40% moisture silage, pH was 5.72 following fermentation.

Initial mixtures of both moisture levels contained no detectable levels of lactic or acetic acids. Lactic acid production was quite low in the 22% moisture silage, and acetic acid production was nil. These negligible levels were significantly ($P<.01$) lower than lactic

TABLE 13. COMPOSITION OF INITIAL MIXTURES AND SILAGES, EXPERIMENT 1, LARGE SILO STUDY

Type of material	Estimated moisture	Dry matter	Composition of dry matter				
			Crude protein	Ether extract	Crude fiber	Ash	NFE
	%	%	%	%	%	%	%
Initial mixtures	22	77.9[a]	39.0	2.18	19.6	13.6	25.6
	40	60.2[b]	40.6	2.50	18.9	14.0	24.0
Silages	22	80.1[c]	39.2	2.09[c]	21.7	14.1	22.9
	40	60.4[d]	39.8	2.46[d]	20.6	14.4	22.7

[a,b]Means for initial mixtures having different superscripts are significantly ($P<.01$) different.

[c,d]Means for silages having different superscripts are significantly ($P<.01$) different.

TABLE 14. FERMENTATION CHARACTERISTICS OF INITIAL MIXTURES AND SILAGES, EXPERIMENT 1, LARGE SILO STUDY

Type of material	Estimated moisture	pH	Level, % of dry matter		
			Lactic acid	Acetic acid	Water-soluble carbohydrates
	%				
Initial mixtures	22	7.64	0	0	3.55
	40	7.61	0	0	3.72
Silages	22	8.18[a]	0.13[a]	0[a]	3.48[a]
	40	5.72[b]	2.83[b]	2.08[b]	2.95[b]

[a,b]Means for silages having different superscripts are significantly ($P<.01$) different.

and acetic levels of 2.83 and 2.08%, respectively, for the 40% moisture silage. Both of these values are somewhat lower than those observed for the 40% silages in the small silo study. The level of water-soluble carbohydrates was higher ($P<.01$) for the 22% silage than for the 40% silage.

In table 15 are shown the levels of nitrogen components of the initial mixtures and the silages. Total nitrogen and all nitrogen component levels failed to vary significantly between moisture levels in the initial mixtures, although uric acid nitrogen in the 40% moisture silage was considerably higher than in the other treatment. Ammonia nitrogen showed a similar trend. Even though an attempt was made to thoroughly mix the litter obtained from various areas of the broiler house before bagging for transport to Blacksburg, there exists the possibility that litter subjected to one treatment could differ substantially from that used for the other treatment with respect to chemical composition, particularly when a quantity of 3.3 metric tons is collected from one house.

In the silages, total, protein and non-protein nitrogen levels were quite similar between treatments. Also, silage total nitrogen levels were not appreciably different from those of the initial mixtures. However, silage protein nitrogen was substantially higher and, consequently, silage NPN was lower than corresponding values observed for initial mixtures. It can be speculated that protein nitrogen determined on the silages may have contained some non-protein nitrogen compounds that were collected along with the protein upon precipitation with tungstic acid. The possibility also exists that NPN of the

TABLE 15. NITROGEN COMPONENTS OF INITIAL MIXTURES AND SILAGES, EXPERIMENT 1, LARGE SILO STUDY

Type of material	Estimated moisture	Total nitrogen	Composition of total nitrogen			
			Protein nitrogen	Non-protein nitrogen	Uric acid nitrogen	Ammonia nitrogen
	%	% of DM	%	%	%	%
Initial mixtures	22	6.25	43.5	56.5	34.4	15.7
	40	6.50	42.8	57.2	37.8	20.2
Silages	22	6.27	48.9	51.1	32.4[a]	17.8
	40	6.36	48.6	51.4	38.4[b]	19.5

[a,b]Means for silages having different superscripts are significantly ($P<.01$) different.

initial mixtures contained some protein nitrogen. These differences in protein nitrogen and NPN between initial mixtures and silages do not readily lend themselves to an explanation on the basis that they may be an artifact of active fermentation, since the differences between the 22% treatment for initial and ensiled materials parallel those of the 40% treatment, and active fermentation did not occur in the litter ensiled at 22% moisture.

Uric acid nitrogen in the ensiled materials differed significantly ($P<.01$) between moisture levels. Possibly, this was the result of a shift in nitrogen from uric acid toward ammonia for the 22% silage (Schefferle, 1965) since uric acid nitrogen was lower and ammonia nitrogen was higher in the 22% moisture silage than in the 22% moisture initial mixture.

Bacteria counts of initial mixtures and silages are presented in table 16. Means shown in this table represent two replicates for each initial mixture moisture level and eight replicates for each silage moisture level. Compared to counts obtained for 20 and 40% moisture initial mixtures in the small silo study, total bacteria counts obtained for initial mixtures in this study were approximately 1.5 to 2.3 times higher. Coliform counts were almost 10 times higher. Tests performed on the initial mixtures for salmonella, shigella and proteus gave negative results for the existence of all three organisms. In the silages, total bacteria and coliform counts were reduced to 625 million and 24 organisms per gram of wet litter, respectively, for the material containing 22% moisture even though fermentation did not take place in this litter to any measureable extent.

TABLE 16. BACTERIA COUNTS OF INITIAL MIXTURES AND SILAGES, EXPERIMENT 1, LARGE SILO STUDY

Type of material	Estimated moisture	Total bacteria	Coliforms	Salmonella	Shigella	Proteus
	%	10^9 per gram	10^3 per gram			
Initial mixtures	22	3.68	1,109	-	-	-
	40	5.83	815	-	-	-
Silages	22	0.625[a]	0.024[c]	-	-	-
	40	0.039[b]	0[d]	-	-	-

[a,b]Means for silages having different superscripts are significantly ($P<.05$) different.

[c,d]Means for silages having different superscripts are significantly ($P<.01$) different.

These results are in agreement with reduced coliform counts in litter allowed to accumulate for greater than 1 year as reported by Halbrook et al. (1951). However, Lovett et al. (1971) found bacteria counts to be unchanged in litter stored in unprotected heaps for 1 to 34 months. Counts of 39 million total bacteria and 0 coliforms per gram of 40% moisture silage were similar to counts obtained for the same treatment in the small silo study.

In table 17 are shown the levels of arsenic and monensin sodium residues in the initial mixtures and silages. In all materials, arsenic levels were within the ranges of 0.2 to 76.3 ppm and 1.1 to 59.7 ppm reported for poultry litter by Messer et al. (1971) and Webb and Fontenot (1975) respectively. Arsenic levels differed considerably between moisture levels in both the initial mixtures and silages but were quite similar within a given moisture level when initial mixtures were compared to silages. Creger et al. (1973) also reported the presence of arsenic (as 3-nitro-4-hydroxyphenylarsonic acid) in litter following fermentation. Analysis for monensin sodium revealed no detectable levels of this drug in either the initial mixtures or the silages.

Nitrogen Utilization, Apparent Digestibility and Ruminal Fluid and Blood Parameters. No palatability problems were observed during the metabolism trial for the rations containing broiler litter as there were no feed refusals. Nitrogen utilization data are presented in table 18. Nitrogen intakes, expressed as grams per day, were 12.04, 12.20, 12.87 and 12.34 for the rations containing processed litter, 22% moisture litter silage, 40% moisture litter silage and soybean

TABLE 17. ARSENIC AND MONENSIN SODIUM RESIDUES IN INITIAL MIXTURES AND SILAGES, EXPERIMENT 1, LARGE SILO STUDY[a]

Type of material	Estimated moisture	Concentration, dry basis	
		Arsenic	Monensin sodium
	%	ppm	ppm
Initial mixtures	22	6.2	0
	40	4.7	0
Silages	22	6.2	0
	40	4.8	0

[a]Analysis performed on composited samples only.

TABLE 18. NITROGEN UTILIZATION AND APPARENT DIGESTIBILITY BY SHEEP, EXPERIMENT 1

Item	Nitrogen supplements			
	Processed litter	Litter silage, 22% moisture	Litter silage, 40% moisture	Soybean meal
Nitrogen utilization				
Nitrogen intake, g/day	12.04	12.20	12.87	12.34
Nitrogen excretion, g/day				
Fecal	4.40	4.47	4.47	4.55
Urinary	7.15[a]	6.23[a,b]	6.74[a,b]	5.79[b]
Total	11.55[a]	10.70[a,b]	11.21[a]	10.34[b]
Nitrogen retention				
Grams per day	0.49[a]	1.49[b]	1.66[b]	2.01[b]
Percent of intake	4.1[a]	12.2[b]	12.9[b]	16.3[b]
Percent of absorbed	6.5[a]	19.5[b]	19.9[b]	25.6[b]
Apparent digestibility, %				
Dry matter	74.3[c]	73.9[c]	74.3[c]	69.9[c]
Crude protein	63.5	63.3	65.3	63 2
Ether extract	68.6[c,d]	69.5[d]	71.4[d]	64.2[c]
Crude fiber	64.2[a]	64.0[a]	63.8[a]	54.8[b]
NFE	80.5	79.8	80.1	76.8

[a,b]Means having different superscripts are significantly (P<.01) different.

[c,d]Means having different superscripts are significantly (P<.05) different.

meal, respectively.

Fecal nitrogen excretion did not differ significantly among treatments. Urinary nitrogen excretion was significantly (P<.01) higher for the processed litter treatment than for the soybean meal treatment but did not differ significantly from values for the wethers fed the 22% and 40% moisture litter silages. Total nitrogen excretion for the lambs fed soybean meal was significantly (P<.01) lower than for lambs fed processed litter or 40% moisture litter silage.

Regardless of the manner in which expressed, nitrogen retention was significantly (P<.01) lower for the processed litter ration than for the other three rations. Retention for the wethers fed the litter silages was not significantly different from that of the wethers fed soybean meal as the source of supplemental nitrogen. Nitrogen retention values for the soybean meal treatment were quite similar to those reported by Harmon et al. (1974). However, the extremely low retention of nitrogen supplied by processed litter is not in agreement with the results obtained by Caswell et al. (1975) or Harmon et al. (1974) when they fed rations containing dry heat processed litter. It should be recognized, however, that the conditions of processing employed by these workers were not as severe as those used to process the litter fed in this study.

The apparent digestibility data are also presented in table 18. Treatment did not significantly affect the apparent digestibility of crude protein or NFE. The apparent digestibility coefficient for crude fiber in the ration containing soybean meal was significantly (P<.01) lower than values for the three litter rations. This may have

been the result of a proportionately higher level of ground corn cobs in that ration. It contained 43.2% cobs as compared to a range of 34.6 to 37.1% cobs in the three rations supplemented with litter. This depression in crude fiber digestibility appeared to have resulted in lower ($P<.05$) dry matter digestibility for the soybean meal supplemented diet than for the others. The apparent digestibility coefficients obtained for the four rations generally agree with the ranges established by Bhattacharya and Fontenot (1966), Caswell et al. (1975), and Harmon et al. (1974, 1975b) for conventional rations supplemented with litter or soybean meal.

In table 19 are shown the ruminal fluid pH and ammonia nitrogen and blood urea of the wethers fed the four rations. Ruminal fluid pH values for the four treatments were within 0.2 pH unit of each other and were not significantly different among rations. The ruminal fluid ammonia nitrogen values of 26.2 and 26.0 mg/100 ml for the sheep fed processed litter and 40% moisture litter silage rations, respectively, were higher ($P<.01$) than the value of 14.2 mg/100 ml for the soybean meal ration. Similarly, Harmon et al. (1974) reported ruminal fluid ammonia nitrogen levels to be elevated by the inclusion of litter in rations for lambs. This response may be due to the higher level of ammonia and other NPN in rations containing litter, as compared to those supplemented with soybean meal. Blood urea levels followed the same general trend as ruminal fluid ammonia nitrogen levels, were within the normal range and were not significantly different among treatments.

Ruminal fluid volatile fatty acid concentrations of the four groups of wethers fed the experimental rations are shown in table 20.

TABLE 19. RUMINAL FLUID pH AND AMMONIA NITROGEN AND BLOOD UREA OF SHEEP, EXPERIMENT 1

Item	Nitrogen supplements			
	Processed litter	Litter silage, 22% moisture	Litter silage, 40% moisture	Soybean meal
Ruminal fluid				
pH	6.21	6.18	6.40	6.30
NH_3-N, mg/100 ml	26.2[a]	18.4[a,b]	26.0[a]	14.2[b]
Blood urea, mg/100 ml	19.5	16.3	19.3	16.1

[a,b]Means having different superscripts are significantly ($P<.01$) different.

TABLE 20. RUMINAL FLUID VOLATILE FATTY ACID CONCENTRATIONS OF SHEEP, EXPERIMENT 1

Item	Nitrogen supplements			
	Processed litter	Litter silage, 22% moisture	Litter silage, 40% moisture	Soybean meal
Volatile fatty acids, μ moles/ml				
Acetic	50.7	50.7	49.0	50.2
Propionic	19.4[a]	25.1[b]	18.9[a]	19.5[a]
Butyric	8.7	7.6	8.4	8.7
Valeric	1.0	1.0	0.9	1.1
Isobutyric	1.4	1.4	1.1	1.7
Isovaleric	2.1[a]	1.1[b]	1.6[a,b]	1.5[a,b]
Total	83.2	86.9	79.9	82.7
Volatile fatty acids, moles/100 moles				
Acetic	60.9	58.3	61.5	60.8
Propionic	23.3	28.9	23.6	23.5
Butyric	10.4	8.8	10.5	10.5
Valeric	1.2	1.3	1.1	1.4
Isobutyric	1.7	1.6	1.4	2.1
Isovaleric	2.6[a]	1.2[c]	2.0[a,b]	1.8[b.c]

[a,b,c]Means having different superscripts are significantly ($P<.05$) different.

When expressed as μ moles/ml, propionic was significantly ($P < .05$) higher for lambs fed the 22% moisture silage than for the other three groups. Isovaleric was significantly ($P < .05$) lower than for lambs fed processed litter. Expressed as moles/100 moles, isovaleric was significantly ($P < .05$) lower for the 22% moisture litter silage group than for the processed litter or 40% moisture litter silage group. Also, isovaleric in wethers fed the soybean meal ration was significantly ($P < .05$) lower than in wethers fed processed litter.

Palatability. In table 21 data on the daily dry matter intake by cattle fed rations containing ensiled litter are presented. Dry matter intakes by the four groups of cattle fed rations supplemented with processed litter, 22% moisture litter silage, 40% moisture litter silage or soybean meal were 5.10, 3.29, 3.60 and 7.89 kg/day, respectively. The values for the two groups fed ensiled litter were significantly ($P < .01$) lower than for cattle fed the conventional soybean meal supplemented ration. Since litter contributed 50% to total ration dry matter in the first three treatments, the value of 3.60 kg/day for the 40% moisture litter silage ration would indicate an approximate litter dry matter intake of 1.80 kg/day. This is much lower than the value of 3.46 kg reported by Creger *et al.* (1973) for heifers fed litter silage containing an average of 36.5% moisture. Perhaps in the present study, the feeding period was too short and the animals did not have time to adjust to the rations. In previous experiments (Fontenot *et al.*, 1971a), an adjustment was noted to cattle fed rations containing 25 or 50% processed broiler litter. The intake of 5.10 kg/day for the processed litter ration was not significantly

TABLE 21. DRY MATTER INTAKE BY CATTLE, EXPERIMENT 1

Item	Nitrogen supplements			
	Processed litter	Litter silage, 22% moisture	Litter silage, 40% moisture	Soybean meal
Kilograms per day	5.10[a,b]	3.29[a]	3.60[a]	7.89[b]
Grams per $W_{kg}^{0.75}$ per day	65.3[a,b]	41.2[a]	45.8[a]	97.5[b]

[a,b]Means having different superscripts are significantly ($P<.01$) different.

different from the other three treatments. Intakes, expressed as grams of dry matter per $W_{kg}^{0.75}$ per day, followed the same pattern as dry matter intake expressed as kilograms per day with respect to amounts and significant differences.

In table 22 are shown the eating patterns of cattle fed the four rations. During the first 6 hr. that the steers were confined to individual stalls daily, the number of minutes per hour spent eating the rations generally followed the same trend as the amount eaten presented in table 21. Furthermore, the difference between the first 3 hr. and the second 3 hr. in the stalls for a given ration were not markedly different. A number of significant differences were observed among treatment means for the first and second 3-hr. periods throughout the entire 15 days of feeding. These differences most frequently followed the same pattern as those observed for dry matter intake. The time spent eating during the last 10 hr. in the stalls was generally similar between treatments within a given 3-day period, and were similar between 3-day periods within a given treatment. No significant differences were observed among measurements for the last 10 hr.

Experiment 2--Ensiling Broiler Litter with High Moisture Corn Grain

Composition of Corn and Litter. The composition of the high moisture corn grain and broiler litter ensiled in this study is given in table 23. The corn was harvested at a moisture content of 26.3%. Water-soluble carbohydrates constituted 3.6% of the corn dry matter. This value is similar to the level of 4.7% determined by Danley and

TABLE 22. EATING PATTERNS OF CATTLE, EXPERIMENT 1

Days	Hours	Nitrogen supplements			
		Processed litter	Litter silage, 22% moisture	Litter silage, 40% moisture	Soybean meal
		min./hr.			
1 to 3	0 to 3[a]	9.3[d]	6.2[d]	6.1[d]	15.3[e]
	3 to 6[b]	9.1[d,e]	4.2[f]	7.2	12.9[e]
	6 to 16[c]	4.0	2.2	4.2	3.8
3 to 6	0 to 3	7.4[d]	4.9[d]	4.9[d]	16.8[e]
	3 to 6	10.4[d]	5.1[e]	6.1[d,e]	11.4[d]
	6 to 16	4.1	2.9	3.8	3.9
6 to 9	0 to 3	9.8[d,e]	5.4[d]	4.7[d]	16.1[e]
	3 to 6	12.4[d]	5.9[e]	8.1[e]	14.8[d]
	6 to 16	3.9	2.9	3.1	3.2
9 to 12	0 to 3	9.1[d]	6.6[d]	4.4[d]	17.5[e]
	3 to 6	9.8[d,e]	6.8[d]	6.9[d]	13.6[e]
	6 to 16	3.8	3.7	3.7	3.9
12 to 15	0 to 3	9.3[d,e]	8.5[d,e]	5.0[d]	16.4[e]
	3 to 6	10.1[d,e]	7.1[d]	6.3[d]	14.7[e]
	6 to 16	4.2	3.5	4.1	3.9

[a]3:00 pm to 6:00 pm

[b]6:00 pm to 9:00 pm

[c]9:00 pm to 7:00 am

[d,e,f]Means within the same row having different superscripts are significantly ($P < .01$) different.

TABLE 23. COMPOSITION OF HIGH MOISTURE CORN GRAIN AND BROILER LITTER USED IN EXPERIMENT 2[a]

Item	High moisture corn grain	Broiler litter
Dry matter, %	73.7	81.3
Composition of dry matter, %		
Crude protein	9.5	37.3
Ether extract	2.9	2.8
Crude fiber	4.7	19.3
Ash	1.3	13.3
NFE	81.6	27.3
Water-soluble carbohydrates	3.6	2.6
Total nitrogen	1.5	6.0
Composition of total nitrogen, %		
Protein nitrogen	93.5	44.0
Non-protein nitrogen	6.5	56.0
Uric acid nitrogen	0	34.0
Ammonia nitrogen	1.0	14.1

[a]Values represent an average of eight samples of corn grain and two samples of litter.

Vetter (1974a) for corn harvested at 22% moisture. Analysis of the corn grain for nitrogen components indicated that a relatively small portion of the total nitrogen was in the form of non-protein nitrogen. Ammonia nitrogen amounted to only 1.0% of the total nitrogen.

With respect to dry matter, ether extract, NFE and water-soluble carbohydrate levels, the litter used in this study was more similar to litter used in the small silo litter fermentation study than that used in the large silo litter silage study. All other chemical components were quite similar to those of litter described in table 12.

Fermentation and Associated Effects. Silo temperature data are presented in tabular form in appendix table 39. As reported for the two litter silage studies previously discussed, daily silo temperature data collected in this study generally reflected daily ambient temperature. In the present study, daily silo temperatures could not be recorded during the same 35-day period described in the large silo litter fermentation study due to malfunctional instrumentation.

Upon opening the silos, considerable surface mold was observed on both the corn and the corn-litter mixture. Heavy damage by rats to the polyethylene bags sealed around each ensiled mass was probably responsible for the extent to which molding occurred. Beyond the surface layer of mold, the corn possessed a sweet aroma typical of fermented grain. The fermented corn-litter mixture had a less pleasing aroma than the corn but smelled definitely better than initial samples of the same grain-waste mixture.

The compositions of the initial and fermented corn and corn-litter mixture are shown in table 24. The means for the initial materials

TABLE 24. COMPOSITION OF INITIAL AND FERMENTED MATERIALS, EXPERIMENT 2

Type of material	Dry matter	Composition of dry matter				
		Crude protein	Ether extract	Crude fiber	Ash	NFE
	%	%	%	%	%	%
Initial						
Corn	73.7[a]	9.4[a]	2.66	4.88[a]	1.28[a]	81.8[a]
Corn-litter mixture	76.6[b]	19.5[b]	2.69	9.58[b]	5.60[b]	62.6[b]
Fermented						
Corn	74.3[c]	9.4[c]	2.67	4.89[c]	1.27[c]	81.8[c]
Corn-litter mixture	79.0[d]	20.1[d]	2.61	9.01[d]	5.71[d]	62.6[d]

[a,b]Means for initial materials having different superscripts are significantly ($P<.01$) different.

[c,d]Means for fermented materials having different superscripts are significantly ($P<.01$) different.

represent an average of six observations for corn and two observations for the corn-litter mixture. Means for the fermented products in tables 24, 25 and 26 represent an average of six replications for each of the two types of ensiled feeds. All means for initial materials, except those for ether extract, were significantly ($P<.01$) different between the corn and the corn-litter mixture. Significance was also observed for the fermented materials. Proximate constituents were essentially unchanged as a result of fermentation. The addition of litter to corn grain elevated the crude protein content to approximately 20%. The crude fiber level of this mixture was only 9.01%.

Fermentation characteristics of both the initial and fermented materials are presented in table 25. As a result of fermentation, pH dropped approximately 1.7 units (from 6.23 to 4.67) for the fermented corn as compared to only 0.7 units (from 7.50 to 6.77) for the corn-litter mixture. The high ammonia level of the corn-litter mixture probably prevented the pH of this material from being depressed more than it was during fermentation. This appears to be a particularly reasonable explanation since lactic acid levels in the fermented materials were identical and acetic acid levels were quite similar. Also, there was considerable difference in pH of the initial materials. Acetic acid was present in the corn-litter mixture at a level of 0.19% prior to fermentation. Acetic production in this material was quite low, since it was elevated only to a level of 0.25% after ensiling. Water-soluble carbohydrate levels of the initial materials were not significantly different. This constituent was lowered from 3.38% initially to 2.95% after ensiling in the corn-litter mixture, making the final

TABLE 25. FERMENTATION CHARACTERISTICS OF INITIAL AND FERMENTED MATERIALS, EXPERIMENT 2

Type of material	pH	Level, % of dry matter		
		Lactic acid	Acetic acid	Water-soluble carbohydrates
Initial				
Corn	6.23[a]	0	0[a]	3.56
Corn-litter mixture	7.50[b]	0	0.19[b]	3.38
Fermented				
Corn	4.67[c]	0.49	0.23	2.54[e]
Corn-litter mixture	6.77[d]	0.49	0.25	2.95[f]

[a,b]Means for initial materials having different superscripts are significantly (P<.01) different.
[c,d]Means for fermented materials having different superscripts are significantly (P<.01) different.
[e,f]Means for fermented materials having different superscripts are significantly (P<.05) different.

level significantly ($P < .05$) higher than that of 2.54% for the corn ensiled alone. Similar pH values, relative increases in lactic acid and acetic acids and proportionate decreases in water-soluble carbohydrate content of fermented high moisture corn has been reported by McLaren and Matushima (1968), Prigge et al. (1974) and Danley and Vetter (1974a).

In table 26 are shown the nitrogen components of the initial and fermented products. Both initially and following fermentation, all nitrogen components differed significantly ($P < .01$) between the corn and the corn-litter mixture. Total nitrogen of the two feeds was not changed by ensiling. Of particular importance is the fact that both materials showed a substantial decrease in protein nitrogen as a result of fermentation. Accompanying this response was a substantial increase in ammonia nitrogen in both cases. In the corn-litter mixture, hydrolysis of uric acid also apparently made a significant contribution to ammonia nitrogen. Danley and Vetter (1974b) also showed a substantial elevation of ammonia nitrogen in fermented corn grain containing 22% moisture.

The results of total bacteria and coliform counts and the qualitative tests for salmonella, shigella and proteus performed on the initial and fermented materials are shown in table 27. Means presented in this table are representative of six and two replicates, respectively, for the initial corn and the initial corn-litter mixture. Means for fermented materials represent eight replicates of each of the two feeds. Initially, total bacteria and coliform counts were quite high for the two materials, and the corn-litter mixture gave a positive test for proteus. No reasonable explanation exists for the fact that the coliform count of the initial corn-litter mixture was less than half of the

TABLE 26. NITROGEN COMPONENTS OF INITIAL AND FERMENTED MATERIALS, EXPERIMENT 2

Type of material	Total nitrogen	Composition of total nitrogen			
		Protein nitrogen	Non-protein nitrogen	Uric acid nitrogen	Ammonia nitrogen
	% of DM	%	%	%	%
Initial					
Corn	1.51[a]	93.2[a]	6.8[a]	0[a]	1.0[a]
Corn-litter mixture	3.12[b]	75.4[b]	24.6[b]	18.6[b]	10.6[b]
Fermented					
Corn	1.50[c]	83.3[c]	16.7[c]	0[c]	3.2[c]
Corn-litter mixture	3.22[d]	67.1[d]	32.9[d]	13.0[d]	13.2[d]

[a,b]Means for initial materials having different superscripts are significantly ($P<.01$) different.

[c,d]Means for fermented materials having different superscripts are significantly ($P<.01$) different.

TABLE 27. BACTERIA COUNTS OF INITIAL AND FERMENTED MATERIALS, EXPERIMENT 2

Type of material	Total bacteria	Coliforms	Salmonella	Shigella	Proteus
	10^9 per gram	10^3 per gram			
Initial					
Corn	0.807	695	-	-	-
Corn-litter mixture	1.470	290	-	-	+
Fermented					
Corn	0.030[a]	0.199	-	-	-
Corn-litter mixture	0.117[b]	0.149	-	-	+

[a,b]Means for fermented materials having different superscripts are significantly ($P<.05$) different.

coliform count for the initial corn when corn supplied approximately 67% of the corn-litter mixture. According to Kroulik et al. (1955) the coliforms in the ground corn grain were probably of the Aerobacter genus.

Following fermentation, the total bacteria counts were 3.7 and 8.5% of the initial counts for the corn and the corn-litter mixture, respectively. Though greatly reduced to counts of 199 and 149 per gram for the corn and the corn-litter mixture, respectively, coliforms were still present after ensiling. Proteus had also survived. These results do not agree with those of Harmon et al. (1975a) who found total bacteria counts and coliform counts to be less than 100,000 and 0 per gram, respectively, for fermented corn forage-litter mixtures.

In table 28 are shown the levels of arsenic and a number of medicinal drugs in the initial and fermented corn-litter mixture. The arsenic assay was performed only on composited samples since analysis of these samples indicated that fermentation had noeffect on the level of arsenic. Analysis for amprolium was performed first on composited samples. Results of these tests indicated that amprolium may be slightly reduced through fermentation. However, upon analysis of the two initial samples and the six fermented samples of the corn-litter mixture, mean values of 18.9 and 17.7 ppm, respectively, were obtained. The difference was not significant. No detectable levels of ethopabate or monensin sodium were found in the initial or fermented samples. Creger et al.

TABLE 28. ARSENIC AND MEDICINAL DRUG RESIDUES IN INITIAL AND FERMENTED CORN-LITTER MIXTURES, EXPERIMENT 2[a]

Item	Initial	Fermented
Arsenic,[b] ppm	1.4	1.8
Amprolium,[c] ppm	18.9	17.7
Ethopabate,[b] ppm	0	0
Monensin sodium,[b] ppm	0	0
Sulfaquinoxaline,[c] ppm	71.3[d]	43.6[e]
Zinc bacitracin,[b] units/g	0.095	0

[a]Values expressed on dry basis.
[b]Analysis performed on composited samples only.
[c]Analysis performed on individual samples following examination of data from composited samples.
[d,e]Means having different superscripts are significantly ($P<.01$) different.

(1973) reported no detectable levels of amprolium or ethopabate in fermented broiler litter. Sulfaquinoxaline was significantly ($P<.01$) reduced from 71.3 ppm initially to 43.6 ppm after fermentation. As in the small silo litter fermentation study, the complexity of the assay for zinc bacitracin prohibited analysis of individual samples. Bacitracin was present in the initial corn-litter mixture at a level of 0.095 units per gram. The antibiotic was not detected in the fermented material.

Nitrogen Utilization, Apparent Digestibility and Ruminal Fluid and Blood Parameters. Five of the six wethers fed the ration designated as "ensiled corn," which was not supplemented with protein, had feed refusals during the preliminary period of the metabolism trial. Four of this group continued to refuse part of their feed allowance through the collection period, with one animal periodically refusing only a small portion of his allowance. The other three wethers refused substantial portions of their allowances. The poor consumption of this ration was probably due to the low protein content. No palatability problems were encountered with the other three rations.

Nitrogen utilization data are presented in table 29. Nitrogen intakes were similar for the three supplemented rations at 10.22, 10.35 and 10.97 g per day for the ensiled corn-litter, ensiled corn and processed litter and ensiled corn and soybean meal rations, respectively. For the unsupplemented ration, daily nitrogen intake was 5.63 g. Throughout the remainder of this discussion concerning the metabolism trial, this ration will periodically be referred to as the low protein

TABLE 29, NITROGEN UTILIZATION AND APPARENT DIGESTIBILITY BY SHEEP, EXPERIMENT 2

Item	Ration designation			
	Ensiled corn	Ensiled corn-litter	Ensiled corn + proc. litter	Ensiled corn + soybean meal
Nitrogen utilization				
Nitrogen intake, g/day	5.63	10.22	10.35	10.97
Nitrogen excretion, g/day				
Fecal	3.53[a]	4.02[b]	4.26[b]	3.60[a]
Urinary	2.47[a]	5.01[b]	5.44[b]	5.10[b]
Total	6.00[a]	9.03[b,c]	9.70[b]	8.70[c]
Nitrogen retention				
Grams per day	-0.37[a]	1.19[b]	0.65[b]	2.28[c]
Percent of intake	-6.9[a]	11.7[b]	6.6[b]	20.7[c]
Percent of absorbed	-19.4[a]	19.3[b,c]	11.1[b]	30.8[c]
Apparent digestibility, %				
Dry matter	53.6[a]	68.7[b]	65.8[b]	68.8[b]
Crude protein	37.2[a]	60.7[b]	58.9[b]	67.2[c]
Ether extract	76.6[a]	62.2[b]	63.5[b,c]	69.3[c]
Crude fiber	30.3[a]	67.9[b]	65.4[b]	62.8[b]
NFE	64.5[a]	73.2[b]	68.9[a,b]	72.9[b]

[a,b,c]Means having different superscripts are significantly ($P<.01$) different.

ration. Nitrogen retention was significantly (P<.01) lower for the unsupplemented ration than it was for the rations containing litter or soybean meal. Nitrogen intake by wethers on this treatment was inadequate to maintain positive nitrogen balance.

Retention expressed in grams per day or as a percent of intake was significantly (P<.01) higher for the ration supplemented with soybean meal than for either of the rations containing litter. This was due primarily to lower (P<.01) fecal nitrogen excretion by sheep fed the soybean meal supplemented ration. Expressed as a percent of absorbed, nitrogen retention for the ration containing the ensiled corn-litter mixture was not significantly different from the soy supplemented diet. The trend toward lower nitrogen retention for animals fed processed litter than for those fed ensiled corn-litter tends to agree with the results obtained for processed litter in the metabolism trial described for Experiment 1. In the present study, however, nitrogen retention for the ration supplemented with processed litter was not significantly different from that of the ration containing ensiled litter. Although retention was lower for the litter-fed than the soy-fed sheep, it is clear that the litter nitrogen was utilized quite efficiently, if the results are compared to those for the sheep fed the low protein ration.

The apparent digestibility of the experimental rations is also presented in table 29. Coefficients were usually significantly (P<.01) lower for the low protein than for the supplemented rations. An exception to this was ether extract. Apparent digestibility of crude protein was lower (P<.01) for both litter-containing rations than for

the soybean meal supplemented ration. Digestion coefficients for dry matter, crude fiber and NFE were not significantly different among the litter and soybean meal supplemented treatments.

In table 30 are shown the ruminal fluid pH and ammonia nitrogen and blood urea data from the metabolism trial. Ruminal fluid pH was not significantly affected by treatment but tended to be higher for the lambs fed the rations containing litter. An explanation for this may be the higher ruminal fluid ammonia nitrogen levels. The value of 24.3 mg/100 ml for the ensiled corn and processed litter treatment was significantly ($P<.01$) higher than for the ensiled corn and soybean meal ration and low protein ration. Values for sheep fed the two litter-containing rations were not significantly different. Blood urea levels followed the same general trend as the ruminal fluid ammonia nitrogen levels. For the low protein diet, blood urea was approximately one-fourth to one-third of the levels for the supplemented treatments ($P<.01$). The low ruminal fluid ammonia nitrogen and blood urea levels observed for the ensiled corn diet were simply reflections of the very small amount of dietary nitrogen that entered the rumen in this group of wethers and the low conversion of corn protein to ammonia by rumen bacteria.

In table 31 are shown the concentrations of ruminal fluid volatile fatty acids in sheep fed the four experimental diets. Expressed as μ moles per milliliter, acetic was significantly (P .01) lower for lambs fed the low protein diet than for those fed the ration supplemented with processed litter. Propionic was significantly ($P<.05$) lower for animals fed the low protein ration than for those fed the rations supplemented

TABLE 30. RUMINAL FLUID pH AND AMMONIA NITROGEN AND BLOOD UREA OF SHEEP, EXPERIMENT 2

Item	Ration designation			
	Ensiled corn	Ensiled corn-litter	Ensiled corn + proc. litter	Ensiled corn + soybean meal
Ruminal fluid				
pH	6.48	6.67	6.61	6.51
NH_3-N, mg/100 ml	5.3[a]	20.3[b,c]	24.3[b]	14.1[c]
Blood urea, mg/100 ml	5.9[a]	21.0[b]	22.0[b]	18.0[b]

[a,b,c]Means having different superscripts are significantly ($P<.01$) different.

TABLE 31. RUMINAL FLUID VOLATILE FATTY ACID CONCENTRATIONS OF SHEEP, EXPERIMENT 2

Item	Ration designation			
	Ensiled corn	Ensiled corn-litter	Ensiled corn + proc. litter	Ensiled corn + soybean meal
Volatile fatty acids, μ moles/ml				
Acetic	31.7[a]	37.6[a,b]	44.0[b]	40.8[a,b]
Propionic	12.6[c]	13.7[c,d]	16.0[d,e]	16.9[e]
Butyric	5.2	5.1	5.1	7.1
Valeric	1.1	0.4	0.8	0.7
Isobutyric	1.5	1.5	1.8	1.5
Isovaleric	0.7[a]	1.1[a,b]	1.3[b]	1.1[a,b]
Total	52.8[a]	59.2[a,b]	68.9[b]	68.0[b]
Volatile fatty acids, moles/100 moles				
Acetic	59.7	63.5	63.8	59.9
Propionic	24.0	23.2	23.3	25.0
Butyric	9.6	8.6	7.2	10.5
Valeric	2.2	0.6	1.1	1.0
Isobutyric	3.0	2.4	2.7	2.1
Isovaleric	1.5	1.8	1.9	1.7

[a,b]Means having different superscripts are significantly ($P<.01$) different.

[c,d,e]Means having different superscripts are significantly ($P<.05$) different.

with processed litter or soybean meal. Isovaleric followed the same pattern as acetic. The low levels of acetic and propionic for the low protein ration probably resulted from impaired ruminal fermentation due to an inadequate level of nitrogen for the rumen microbes. Depressed isovaleric production in animals fed the ensiled corn ration may have been due to abnormally low levels of leucine entering the rumen or released by the rumen microbes. Total VFA levels were also significantly ($P<.01$) lower for this treatment than for the treatments in which processed litter or soybean meal supplied additional nitrogen. None of the VFA's were significantly affected by treatment when expressed as moles/100 moles. Values for each VFA tended to be quite similar among treatments, indicating that normal proportions of the various volatile fatty acids were not disrupted by feeding the low protein ration. Generally, VFA patterns for the lambs fed processed or ensiled litter were similar to that of the animals fed soybean meal.

Palatability. In table 32 are presented the dry matter intake data of the steers. Dry matter intakes were 5.94, 7.32, 7.20 and 7.04 kg per day for the ensiled corn, ensiled corn-litter, ensiled corn and processed litter and ensiled corn and soybean meal rations, respectively. All three supplemented rations were consumed in significantly ($P<.01$) greater amounts than the unsupplemented ration. As with the refusal problems encountered with the ensiled corn ration in the metabolism trial, depressed intake of the ensiled corn diet in the palatability trials was probably the result of the low protein level of this ration. The values for the rations containing litter were not significantly different from the conventional soybean meal supplemented

TABLE 32. DRY MATTER INTAKE BY CATTLE, EXPERIMENT 2

Item	Ration designation			
	Ensiled corn	Ensiled corn-litter	Ensiled corn + proc. litter	Ensiled corn + soybean meal
Kilograms per day	5.94[a]	7.32[b]	7.20[b]	7.04[b]
Grams per $W_{kg}^{0.75}$ per day	95.4[a]	115.0[b]	115.0[b]	107.9[a,b]

[a,b]Means having different superscripts are significantly ($P<.01$) different.

ration. There was, in fact, a trend for consumption to be slightly greater for the rations containing litter than for the ration containing soybean meal.

Expressed in grams per unit of metabolic size ($W_{kg}^{0.75}$) per day, intakes were 95.4, 115.0, 115.0 and 107.9 for the ensiled corn, ensiled corn-litter, ensiled corn and processed litter and ensiled corn and soybean meal rations, respectively. Intakes for the rations containing litter were identical and were not significantly different from the conventional soybean meal supplemented ration. However, there was a trend toward greater intake for cattle fed the diets supplemented with litter. Dry matter intake of the low protein ration (ensiled corn) was significantly ($P<.01$) lower than that of either litter containing ration but was not significantly different from the ration containing soybean meal.

The eating patterns of the cattle are presented in table 33. Generally, the time spent eating was not markedly different among rations. Unlike the eating pattern data from Experiment 1, the amount of each ration consumed in the present experiment was not always reflected in the time spent eating. Evidence of this is the fact that during the first 3 hr. of confinement for four of the five 3-day periods, the time spent eating the low protein (ensiled corn) ration was greater than that spent eating the ensiled corn-litter or the ensiled corn and soybean meal diets.

Results of these studies indicate that litter can be successfully ensiled if the moisture content is elevated or if mixed with high moisture corn grain. Utilization of the litter biologically processed

TABLE 33. EATING PATTERNS OF CATTLE, EXPERIMENT 2

Days	Hours	Ration designation			
		Ensiled corn	Ensiled corn-litter	Ensiled corn + proc. litter	Ensiled corn + soybean meal
		min./hr.			
1 to 3	0 to 3[a]	14.0	16.3	15.8	14.8
	3 to 6[b]	10.9	11.6	12.9	10.4
	6 to 16[c]	4.8	5.4	6.3	5.6
3 to 6	0 to 3	15.9	15.4	13.3	15.2
	3 to 6	9.7	11.3	11.9	10.3
	6 to 16	4.3	5.9	5.4	5.7
6 to 9	0 to 3	17.5	16.8	18.6	16.7
	3 to 6	12.1	12.5	11.9	11.1
	6 to 16	4.9[d]	6.4[e]	5.7[d,e]	6.0[e]
9 to 12	0 to 3	18.6	17.1	20.3	18.4
	3 to 6	10.4	11.3	10.0	10.9
	6 to 16	4.3	6.4	6.1	5.5
1w to 15	0 to 3	17.4	13.8	19.0	14.0
	3 to 6	10.0	12.6	9.9	11.5
	6 to 16	4.9[d]	6.7[e]	5.6[d,e]	5.3[d]

[a]3:00 pm to 6:00 pm

[b]6:00 pm to 9:00 pm

[c]9:00 pm to 7:00 am

[d,e]Means within the same row having different superscripts are significantly ($P < .05$) different.

under either system of fermentation appears to be satisfactory. Intake by cattle of the ration containing broiler litter fermented after elevation of the moisture content was less satisfactory, indicating a need for further research to elucidate the cause of this response. Possibly, allowing the cattle a longer period of time to adjust to the litter-containing rations may alleviate this depression of intake. Litter fermented with high moisture corn grain appears to be a reasonable approach to utilization of the waste as well as a feasible system of fattening cattle, since this material was readily accepted when offered to beef steers. Additional research is needed to evaluate the utilization and palatability of mixtures containing a greater proportion of litter. This would mean that a greater quantity of the waste would be disposed of, and the cost of feeding the mixture would be lowered. Also, fermented mixtures should be fed experimentally in long term trials in which performance is measured.

SUMMARY

The feasibility of ensiling broiler litter alone, with added water or with high moisture corn grain was evaluated. Wood shaving based broiler litter was ensiled in small laboratory silos (about 4 liters) at moisture levels of 15.6 (no water added), 20, 30, 40, and 50%. Maximum fermentation was approached at 40% moisture as measured by silage pH and levels of lactic and acetic acids and water-soluble carbohydrates. Coliform bacteria were eliminated by ensiling at 20 to 50% moisture.

In a subsequent study, litter was ground and 545 kg were ensiled alone (22% moisture) or with added water to elevate the moisture to 40%. Active fermentation occurred, and coliforms were eliminated in the silage containing 40% moisture. Twenty-four wethers and 12 steers were used in a metabolism study and a palatability study, respectively. Four rations were supplemented with: 1) dry heat processed litter (260 C at a depth of 1.3 cm for 30 min.); 2) 22% moisture litter silage; 3) 40% moisture litter silage; or 4) soybean meal. Supplements supplied 50% of the dietary nitrogen in the metabolism trial. Nitrogen retention was lower ($P<.01$) for the ration supplemented with processed litter than for the other rations. Apparent digestibility was not significantly different among the three rations supplemented with litter, but digestion coefficients for dry matter and crude fiber were lower ($P<.05$) for the ration supplemented with soybean meal.

Litter supplied 50% of the total ration dry matter in the palatability study. Dry matter intakes by cattle were similar for the two rations containing litter silage and were significantly ($P<.01$) lower than for cattle fed the conventional soybean meal supplemented ration.

In another study, ground high moisture (26%) corn grain was ensiled alone or with ground litter in a 2 to 1 ratio in approximate 1 metric ton masses. The extent of fermentation in the corn-litter mixture was less than in corn ensiled alone. Twenty-four wethers were used in a metabolism trial and 12 steers were individually fed in two 15-day palatability trials. The four rations tested in both studies contained: 1) ensiled corn; 2) ensiled corn-litter mixture; 3) ensiled corn and dry heat processed litter (260 C at a depth of 1.3 cm for 30 min.); or 4) ensiled corn and soybean meal.

Nitrogen intake was similar for the three supplemented rations (2, 3, 4) fed in the metabolism study. Nitrogen retention was significantly ($P<.01$) higher for the soybean meal than for the litter-containing rations. This can be attributed mainly to lower fecal nitrogen excretion. Coefficients of apparent digestibility were usually significantly lower for the unsupplemented than for the supplemented rations. Apparent digestibility of crude protein was lower ($P<.01$) for both litter-containing rations than for the soybean meal supplemented ration. Digestion coefficients for dry matter, crude fiber and NFE were not significantly different among rations 2, 3, and 4. Dry matter intakes tended to be higher for cattle fed litter than for those fed the soybean meal supplemented ration. Intake was lowest ($P<.01$) for the unsupplemented ration.

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APPENDIX

TABLE 34. EXAMPLE OF ANALYSIS OF VARIANCE, EXPERIMENT 1, SMALL SILO STUDY (ACETIC ACID IN SILAGES, PERCENT OF DRY MATTER)

Source	Degrees of freedom	Sum of squares	Mean squares	F
Total	29	46.34		
Replicate	5	0.96	0.19	1.90
Treatment	4	43.45	10.86	108.63**
Error	20	1.93	0.10	

**(P<.01).

TABLE 35. EXAMPLE OF ANALYSIS OF VARIANCE, EXPERIMENT 1, PALATABILITY TRIALS (DRY MATTER INTAKE, KILOGRAMS PER DAY)

Source	Degrees of freedom	Sum of squares	Mean squares	F
Total	23	126.80		
Trial	1	0.89	0.89	0.31
Block	2	1.97	0.99	0.34
Treatment	3	79.62	26.56	9.25**
Trial X treatment	3	4.13	1.38	0.48
Error	14	40.19	2.87	

**(P<.01).

TABLE 36. EXAMPLE OF ANALYSIS OF VARIANCE, EXPERIMENT 2, METABOLISM TRIAL (NITROGEN RETENTION, GRAMS PER DAY)

Source	Degrees of freedom	Sum of squares	Mean squares	F
Total	23	26.27		
Block	5	1.26	0.25	1.25
Treatment	3	21.98	7.33	36.65**
Error	15	3.03	0.20	

**(P<.01).

TABLE 37. TEMPERATURE CHANGES OF ENSILED BROILER LITTER, EXPERIMENT 1, SMALL SILO STUDY

Days after ensiling	Ambient	Estimated moisture, %[a]				
		15.6	20.0	30.0	40.0	50.0
	Temperature, C					
0	25.0	24.9	25.0	20.3	21.8	21.6
7	23.0	24.0	23.7	21.2	24.3	24.9
14	24.7	25.2	24.6	22.6	24.8	25.5
21	27.0	26.8	26.2	23.8	26,1	27.3
28	23.9	25.2	24.2	21.1	24.5	25.8
35	23.8	25.6	24.1	21.2	24.7	25.9
42	26.3	27.7	26.6	24.0	26.6	27.6

[a]Values represent an average of two silos per moisture level.

TABLE 38. TEMPERATURE CHANGES OF ENSILED BROILER LITTER, EXPERIMENT 1, LARGE SILO STUDY

Days after ensiling[a]	Ambient	Estimated moisture, %[b] 22.3	40.0
	----------	temperature, C	----------
0	14.0	14.3	14.1
10	3.7	9.7	15.5
16	1.7	10.7	6.3
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--	---	---	---
--	---	---	---
52	9.9	11.5	10.8
60	15.1	12.9	12.0
70	5.9	9.9	10.0
80	7.2	8.4	9.8
90	13.7	6.1	7.2
100	6.0	15.3	15.5
110	5.1	11.7	13.2
120	9.7	11.7	13.3
130	9.5	13.8	13.8
140	19.2	16.0	15.4
150	28.2	22.5	19.3
160	24.8	23.2	18.7
170	17.0	27.2	24.6
180	20.7	28.1	28.3
190	31.0	29.1	28.3
200	29.0	30.2	29.5
210	20.5	29.9	28.5

[a]Temperatures not recorded for 35-day period extending from day 17 through day 51.

[b]Values represent an average of two silos per moisture level through day 150. Values for days 160 through 210 represent one silo per moisture level.

TABLE 39. TEMPERATURE CHANGES OF ENSILED CORN AND CORN-LITTER MIXTURE, EXPERIMENT 2

Days after ensiling[a]	Ambient	Corn[b]	Corn-litter mixture[b]
	temperature, C		
0	22.0	25.0	26.4
10	9.0	20.4	20.8
20	15.2	14.5	14.5
30	14.5	10.7	10.9
40	12.3	12.9	14.9
50	0.5	13.2	16.1
58	1.7	12.0	15.2
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--	---	---	---
--	---	---	---
94	9.9	23.7	28.0
100	18.2	25.1	28.9
110	1.8	26.9	34.8
120	0.2	28.3	33.8
130	0	29.5	39.9
140	22.8	30.9	36.6

[a]Temperatures not recorded for 35-day period extending from day 59 through day 93.

[b]Values for the corn and the corn-litter mixture represent an average of six and two silos, respectively, through day 58. Values for days 94 through 140 represent an average of three silos for corn and one silo for the corn-litter mixture.

VITA

Larry Forrest Caswell, son of Mr. and Mrs. Forrest W. Caswell, was born on February 29, 1948, in East St. Louis, Illinois. He attended Caseyville Elementary School and Waterloo Elementary School and graduated from Waterloo High School, Waterloo, Illinois in June, 1966. He received a Bachelor of Science degree in Agriculture from Southern Illinois University, Carbondale, Illinois, in June, 1970. He entered Virginia Polytechnic Institute and State University in September, 1970, and received the Master of Science degree in Animal Science (Animal Nutrition) from that institution in June, 1973.

He was married to the former Sharon Rea Hern of Valmeyer, Illinois, June 13, 1970. He has one son, Timothy Clay, born November 16, 1971, and one daughter, Stacey Nicole, born April 9, 1974.

He is a member of the American Society of Animal Science and the fraternity of Alpha Zeta.

Larry Forrest Caswell

Larry Forrest Caswell

FERMENTATION, UTILIZATION AND PALATABILITY OF BROILER LITTER ENSILED AT DIFFERENT MOISTURE LEVELS AND WITH HIGH MOISTURE CORN GRAIN

by

Larry Forrest Caswell

(ABSTRACT)

The feasibility of ensiling broiler litter alone, with added water or with high moisture corn grain was evaluated. Wood shaving based broiler litter was ensiled in small laboratory silos (about 4 liters) at moisture levels of 15.6 (no water added), 20, 30, 40 and 50%. Maximum fermentation was approached at 40% moisture as measured by silage pH and levels of lactic and acetic acids and water-soluble carbohydrates. Coliform bacteria were eliminated by ensiling at 20 to 50% moisture.

In a subsequent study, litter was ground and 545 kg were ensiled alone (22% moisture) or with added water to elevate the moisture to 40%. Active fermentation occurred, and coliforms were eliminated in the silage containing 40% moisture. Twenty-four wethers and 12 steers were used in a metabolism study and a palatability study, respectively. Four rations were supplemented with: (1) dry heat processed litter [260 C at a depth of 1.3 cm for 30 min.]; (2) 22% moisture litter silage; (3) 40% moisture litter silage; or (4) soybean meal. Supplements supplied 50% of the dietary nitrogen in the metabolism trial.

Nitrogen retention was lower ($P<.01$) for the ration supplemented with processed litter than for the other rations. Apparent digestibility was not significantly different among the three rations supplemented with litter, but digestion coefficients for dry matter and crude fiber were lower ($P<.05$) for the ration supplemented with soybean meal.

Litter supplied 50% of the total ration dry matter in the palatability study. Dry matter intakes by cattle were similar for the two rations containing litter silage and were significantly ($P<.01$) lower than for cattle fed the conventional soybean meal supplemented ration.

In another study, ground high moisture (26%) corn grain was ensiled alone or with ground litter in a 2 to 1 ratio in approximate 1 metric ton masses. The extent of fermentation in the corn-litter mixture was less than in corn ensiled alone. Twenty-four wethers were used in a metabolism trial and 12 steers were individually fed in two 15-day palatability trials. The four rations tested in both studies contained: (1) ensiled corn; (2) ensiled corn-litter mixture; (3) ensiled corn and dry heat processed litter [260 C at a depth of 1.3 cm for 30 min.]; or (4) ensiled corn and soybean meal.

Nitrogen intake was similar for the three supplemented rations (2, 3, 4) fed in the metabolism study. Nitrogen retention was lowest ($P<.01$) for the unsupplemented ration (1). Retention was significantly higher ($P<.01$) for the soybean meal than for the litter-containing rations. This can be attributed mainly to lower fecal nitrogen excretion. Coefficients of apparent digestibility were usually significantly lower for the unsupplemented than for the supplemented rations. Apparent digestibility of crude protein was lower ($P<.01$) for both litter-

containing rations than for the soybean meal supplemented ration. Digestion coefficients for dry matter, crude fiber, and NFE were not significantly different among rations 2, 3 and 4. Dry matter intakes tended to be higher for cattle fed litter than for those fed the soybean meal supplemented ration. Intake was lowest ($P<.01$) for the unsupplemented ration.