FERMENTATION CHARACTERISTICS AND NUTRITIONAL VALUE OF ENSILED DEEP PIT CAGED LAYER WASTE AND CORN FORAGE

by

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(ABSTRACT)

Deep-pit caged layer waste which had accumulated for about 2-yr was collected from beneath hens housed on wire mesh cages, was mixed with chopped corn forage and ensiled in 2 kg cardboard containers double lined with polyethylene bags and sealed to study fermentation characteristics and microbial analyses. Proportions of corn forage and caged layer waste, wet basis, were 100:0, 80:20, 70:30, 60:40, 50:50 and 40:60. Corn forage and caged layer waste in ratios of 100:0, 70:30, 60:40 and 50:50 mixtures, were ensiled in 210 liter metal drums doubled lined with polyethylene bags, to study fermentation characteristics, microbial analyses, chemical composition and to conduct a metabolism trial. For both types of silos the pH of the ensiled mixtures increased (P<.01) as level of waste increased. Lactic acid was higher (P<.01) for waste containing silages, compared to corn silage. Total coliforms, fecal coliforms, salmonella, shigella and proteus were decreased or eliminated by ensiling. Dry matter, crude protein, and ash increased (P<.01) with waste levels.

In a sheep metabolism trial, 30 wethers were fed diets consisting of the five silages in large silos, also, corn silage with sufficient soybean meal added to increase the crude protein content to that of 70:30 silage was used as a fifth diet.

Digestibility of dry matter and organic matter was higher ($P<.01$) for the corn silage diet, compared to the corn forage-waste silage diets, but the differences were small for organic matter. Within corn forage-waste silages a linear decrease ($P<.05$) was recorded in dry matter digestibility as caged layer waste increased. Apparent digestibility of dry matter, crude protein, organic matter, neutral detergent fiber (NDF), and acid detergent fiber (ADF) was higher ($P<.01$) for corn silage supplemented with soybean meal, compared with 70:30 corn forage-waste silage diet. Higher ($P<.01$) N utilization was obtained for sheep fed the corn silage diet, compared with those fed the waste treated silages. No difference ($P<.05$) in N retention was recorded when sheep were fed 70:30 corn forage-waste silage diet or corn silage supplemented with soybean meal.

DEDICATION

This thesis is dedicated in the memory of my Late Uncle, Shri. Annasaheb D. Magar.

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INTRODUCTION

With the advent of large scale intensive commercial caged layer operations, many such operations lack land area for efficient and economical disposal of caged layer waste. This has resulted in an excessive rate of caged layer waste application on crop land, which in return has caused a serious waste disposal problem.

Therefore, from the standpoint of cost and return, handling and disposing caged layer waste for crop production has been economically handicapped because of the availability, convenience and low cost of using inorganic fertilizers, limited land availability and increased public consciousness of enviornmental pollution. This has challenged scientists to find methods to recycle the waste nutrients most effectively where feasible. One alternative way of utilizing the nutrients in caged layer waste would be to feed the waste to ruminants. Caged layer waste would serve as source of crude protein, minerals, and energy.

Crude protein nitrogen is made up of true protein N and non-protein nitrogen (NPN). The NPN consists primarily of uric acid, NH_3, urea and creatinine. The NPN and fiber make caged layer waste a more valuable feedstuff for ruminants than non-ruminants, because of the unique ability of ruminants to utilize the NPN and fiber, due to the presence of ruminal microorganisms. Feeding of caged layer waste would reduce the waste disposal problem as well as serve as a method for recovering some of the potentially valuable nutrients contained in the waste, and would free concentrate grains for use for human consumption in developing countries.

Caged layer waste contains pathogenic organisms which can cause diseases such as botulism, abortion, cystitis and other diseases. However, adoption of appropriate processing methods will eliminate these pathogens. Drying of caged layer waste to remove excessive moisture and to destroy harmful pathogens is one of the methods to process caged layer waste to use as a feed ingredient. However, high fuel costs limit its use. A more economical and efficient method to process the caged layer waste for its use as a feed ingredient would be ensiling. Ensiling is an inexpensive processing method that can be used easily on a farm, provided anaerobic conditions are maintained. The method involves the making of a product that is acceptable to livestock.

Corn silage is a highly palatable feed and an excellent source of energy, however, it is deficient in protein and calcium. Caged layer waste is rich in these nutrients, therefore, ensiling the caged layer waste with corn forage would make a more balanced and desirable product. Also, the destruction of pathogenic organisms could be accomplished due to the heat and organic acids produced during ensiling.

Studies were performed to investigate the effect of ensiling varying mixtures of caged layer waste and corn forage on elimination of pathogens, fermentation characteristics, digestibility and nitrogen utilization when fed to sheep. The specific objectives were: 1) To study the fermentation characteristics of ensiled mixtures of different proportions of caged layer waste and corn forage; 2) To evaluate fermentation as a means of destroying pathogens present in ensiled mixtures of caged layer waste and corn forage; 3) To study nitrogen utilization and digestibility in sheep fed ensiled mixtures of caged layer waste and corn forage; 4) To study ruminal and blood parameters in sheep fed ensiled mixtures of caged layer waste and corn forage.

REVIEW OF LITERATURE

Depending upon the type of poultry enterprise, poultry wastes can be classified as 1) caged layer waste, sometimes designated as dried poultry waste 2) broiler litter and 3) turkey litter. Caged layer waste, a major waste product of layer operations, is composed of bird excreta, broken eggs, feathers and spilled feed collected beneath the birds housed in wire mesh cages. Litter refers to the waste product of broiler or turkey operations, and consists of excreta, spilled feed, feathers and bedding material, such as wood shavings, peanut hulls and saw dust.

Nutritive Value of Caged Layer Waste

Caged layer wastes vary in chemical composition and digestibility, depending upon the plane of nutrition of the hens, feed spillage into the wastes, loss of feathers, broken eggs, stage of lay, housing environment, length of time from excretion to collection and waste management system (White et al., 1944; Flegal et al., 1972; Forsht et al., 1974; Evans et al., 1978).

Crude Protein. Caged layer wastes are relatively high in crude protein content, averaging 28%, dry basis, (Liebholz, 1969; Bull and Reid, 1971). Amino acid N ranges from 37 to 45% of total N (Liebholz, 1969). Uric acid, NH_3 and urea amount to approximately 39%, 4% and 3.5% of the total N, respectively. Approximately 50 to 60% of total nitrogen is NPN (Evans et al., 1978). Uric acid is the main NPN component of caged layer waste (Morgan, 1970).

Blair (1972) reported that uric acid in caged layer wastes was of no value to non-ruminants. It has been shown that rumen microorganisms are capable of efficiently utilizing uric acid as a source of N to synthesize protein (Belasco, 1954; Jurtshak et al., 1958). Uric is more efficiently utilized than urea (Oltjen and Dinius, 1976) probably because it is less soluble in water (Muller, 1980) and that uric acid is broken down more slowly than urea, with a gradual release of soluble NPN and NH_3, which allows for efficient NPN utilization (Oltjen, 1968). Utilization of NPN was efficient following an adaptation period of 21 to 33 d (Oltjen, 1968).

In vitro studies by Koenig et al. (1978) showed the ability of ruminal microbes to adapt to and utilize uric acid. The ruminal microorganisms required a 2 to 3 d adaptation period before they were capable of utilizing uric-acid N found in poultry wastes. Adapted microbes were capable of degrading uric acid within 6 h of incubation period.

The utilization of urea by ruminants has been demonstrated by Virtanen (1966). Many ruminal microorganisms utilize NH_3 and some even prefer it to free amino acids (Bryant and Robinson 1962, 1963).

Minerals. Caged layer waste is high in ash content, mainly due to high calcium in layer diets. Thus, supplementation of waste-based diets with minerals is usually not required, since caged layer waste is rich in minerals, particularly Ca and P (Oliphant, 1974; Smith 1974; Clark and Dethrow, 1975). Calcium and P of caged layer waste have been reported to be 9 and 1.5% respectively (Brugman et al., 1964; Liebholz, 1969; Lowman and Knight, 1970; Bull and Reid, 1971). Average respective values of 8.8% Ca and 2.5% P, dry basis, have been reported by Bhattacharya and Taylor (1975). In ruminants the availability of Ca and P in dried caged layer waste when used as sole source of protein supplement in an adequate diet was found to be 92 and 72 %, respectively (Bull and Reid, 1971).

Energy. Caged layer waste may also serve as a good source of energy, depending upon the levels of structural carbohydrates and other indigestibles in the diets of laying hens (Smith et al., 1970). Pryor and Conner (1964) reported gross energy values averaging 3,850 kcal/kg for dried poultry waste of chickens fed different diets. Gross energy values of 3533 kcal/kg, dry basis, for layer waste have been reported by Polin et al. (1971). In sheep fed dehydrated layer waste a value of 2.22 mcal/kg metabolizable energy was reported (Parigi-Bini, 1969). Similarly, Brugman et al. (1964) reported a gross energy value of 3.6 kcal/g for layer house poultry litter, with an apparent energy digestibility of 59.2% by cattle and 60.3% by sheep (Lowman and Knight, 1970). Digestible energy values of 1911 kcal/kg in cattle and 1875 kcal/kg in sheep have been reported (Bhattacharya and Taylor, 1975). Tinnimit et al. (1972) found a TDN value of 52.3%, dry basis, for dehydrated poultry waste. This compares with the TDN value of 59.8%, dry basis, reported by Bhattacharya and Fontenot (1966) for broiler litter. Digestibility of energy of poultry waste fed as a sole diet was 60.3% (Lowman and Knight, 1970). Salo et al. (1975) reported a metabolizable energy value of 1.58 mcal/kg dry matter for layer waste, which is slightly lower than the value of 1.74 mcal/kg dry matter reported by Lowman and Knight (1970). Thus, with a TDN value of 58% (Bucholtz et al., 1971) of caged layer is equivalent in available energy to good quality hay. The energy value of caged layer waste is affected by ash content. The high ash content ranging from 17 to 34%, dry basis, may lower its energy value (Liebholz, 1969; Lowman and Knight, 1970; Bull and Reid, 1971; Bhattacharya and Taylor, 1975). Evans et al. (1978) reported that a 33% increase in ash content in caged layer waste resulted in a 14% decrease in gross energy.

Variation in Nutritional Value. The length of drying period, storage time and the time lapsed between excretion and collection of caged layer waste have been reported to have an effect on dry matter, ash and N content of layer excreta (Evans et al., 1978). Loss of moisture content during storage due to high temperatures in layer houses have been reported to be the main causes of increased dry matter content in layer wastes. An increase in ash and increased loss of N have been reported with longer drying and storage of layer wastes. Evans et al. (1978) studied the magnitude of variation imposed on layer excreta composition due to the diet, stage of production and method of manure management. Diets exerted a major influence on resultant fresh waste composition. Composting increased loss of organic matter, N and dry matter, and increased ash content. Stage of production did not appear to be a major factor contributing to the compositional changes in hen excreta. Energy content and fiber fractions of excreta decreased with composting. Uric acid N also decreased with composting. Heat drying of poultry wastes resulted in losses of N (Caswell et al., 1975; El-Sabban et al., 1970; Fontenot et al., 1971). Use of chemicals reduces loss of nutrients (Caswell et al., 1975) but overprotection with formaldehyde could render the N less available for ruminants (Seltzer et al., 1969).

Nitrogen Utiliztion by Ruminants. El-Sabban et al. (1970) fed autoclaved and cooked caged layer waste as N sources for sheep. The digestibility of crude protein was 74.3% for the control soybean meal diet. Diets containing autoclaved and cooked caged layer waste showed significantly lower crude protein digestibilities. However, N retention was higher in sheep fed waste diets, compared to those fed soybean meal diets. Dry matter digestibility did not differ among the control and waste diets.

Sheep were fed diets containing 11% crude protein with caged layer wastes as protein sources, at levels of 20.1% and 31.9% of the total diet, supplying 45 to 49% of total dietary protein, respectively. There was no major difference in apparent digestibility of dry matter, organic matter and N (Tinnimit et al., 1972).

Gihad (1976) conducted studies to evaluate the value of dried poultry waste and a urea-molasses mixture as a protein supplement for tropical hay. Protein supplements contributed 33.3% of the daily diets. Apparent digestibility of dry matter, crude protein and crude fiber were not significantly different. However, N retention, expressed as a percent of digested, was higher for sheep fed the urea-molasses mixture than for those fed the dehydrated poultry manure supplemented diet.

Smith and Calvert (1972) substituted poultry excreta for 0, 50 and 100% of the N provided by soybean meal in sheep diets. The study indicated no differences in digestibility of crude protein among treatments.

Tinnimit et al. (1972) reported apparent digestibility of N to be 58% when diets containing dried poultry waste were fed to sheep. Crude protein digestibilities of 73% and 77% have been reported for layer wastes by Bull and Reid (1971) and Lowman and Knight (1970), respectively. Brugman et al. (1964) reported digestion coefficients of 77.82% for crude protein when laying house litter was fed to Hereford bulls along with dried potato pulp. The apparent digestibility of N in dried poultry waste was 77.2% when fed to sheep (Lowman and Knight, 1970), which compares to the value of 73 to 83% reported by Bull and Reid (1971). Smith and Calvert (1976) fed sheep diets containing 19 and 38% dried broiler excreta. The N digestibility increased from 9.9 to 57.5%.

Koenig et al. (1978) reported that ruminal microorganisms are capable of utilizing uric acid N in waste as well as urea, after an adaptation period of 2 to 3 d. The uric acid degradation by the adapted microorganisms occurs within a 6 h incubation period, which compares to the incubation periods of 2 to 5 h or more for deamination of uric acid (Jurtshuk et al., 1958; Oltjen et al., 1968).

Filipot et al. (1975) reported a reduction in the apparent digestibility of N when the ensiled caged layer waste was treated with paraformaldehyde, compared to the waste treated with tannic acid. Treating waste by autoclaving, ethylene oxide, sulfuric acid or paraformaldehyde had no significant effect on N utilization in sheep fed broiler litter (Fontenot et al., 1971; Harmon et al., 1974; Caswell, 1975). Ayangbile (1987) reported apparent digestibility of crude protein in caged layer waste-wheat straw silages, treated with formaldehyde, dry molasses and no treatment to be 52.31%, 63.63% and 43.08%, respectively. Arvat et al. (1978) reported that sheep fed silages containing 22.7% caged layer waste did not show a significant difference in apparent digestibility of N, but had a lowered N retention, compared to the control diet.

Organic Matter Digestibility. Tinnimit et al. (1972) reported that increasing the level of dehydrated caged layer waste in diets of sheep from 20 to 80% resulted in reduction in organic matter digestibility from 76.5% to 67.5%. Dry matter digestibility also dropped from 73.5% to 57.9%. Comparing organic matter and dry matter digestibility of dried poultry waste and soybean meal with each supplying 49% of total dietary protein, there was no significant difference in digestibility. Sheep supplemented with dried poultry excreta tended to consume more feed and convert more digestible organic matter available for growth, as compared to sheep fed diets supplemented with alfalfa (Smith and Lindhal, 1977). However, differences were not significant. Goering and Smith (1977) reported a digestibility value of 65% for organic matter digestibility when sheep were fed dehydrated caged layer waste ensiled with corn forage. Lowman and Knight (1970) reported decreased dry matter and organic matter digestibilities when dried poultry waste replaced barley in the diet. A decrease in organic matter digestibility from 70.2% to 46.0% was reported as the level of caged layer waste-bagasse silage replaced the basal diet (Samuels, 1980). Apparent digestibility of organic matter was 33.56% for non-treated caged layer waste-wheat straw silages, compared to 38.9, 45.71 and 40.48% for formaldehyde, dry molasses and dry molasses+salt treatments, respectively (Ayangbile, 1987). Albert (1977) reported that when sheep were fed diets containing corn silage and 80:20 and 60:40 mixtures (corn silage caged layer waste, dry basis), the organic matter digestibilities were 71%, 69% and 60%, respectively.

Performance Studies in Non-Ruminants Fed Caged Layer Waste.

In chicks fed diets in which upto 20% poultry manure was substituted with proper adjustment in energy content of the diets, the growth of chicks was comparable to those fed a standard broiler diet (McNab et al., 1972). Increasing dried poultry waste from 5 to 20% in the diets of chicks, containing 2990 kcal/kg, progressively decreased body weights and feed efficiency (Biely et al., 1972; Lee and Yang., 1976). Similar responses were observed by Sheppard (1970) as the level of dried poultry waste was increased above 5% in the diets of broiler chicks, but supplementing the diets with a high-energy source restored the growth rate. Lee and Blair (1973) reported that 5% and 10% supplementation of dried poultry waste in the broiler starter and finisher diets did not affect growth rate.

The metabolizable energy value of dried poultry waste for feeding poultry is exceptionally low, compared to most of the traditional poultry diets (Polin et al., 1971; Nesheim, 1972). This dried poultry waste could be of value to growing pullets which need to have low levels of energy for desirable growth rate. The metabolizable energy value of caged layer waste is only 6% of that of corn fed to laying hens (Rinehart et al., 1973). Feed efficiency is inversely related to the amount of poultry waste in the diet of growing chicks (Flegal and Zindel, 1971). Feeding up to 38.2% dried poultry waste to broilers had no detectable effect on flavor of broilers (Cunningham and Lillich, 1975). Incorporation of dried caged layer manure into the diets of pigs at levels of 10, 20 and 30% resulted in a reduction in growth and feed efficiency (Perez-Aleman et al., 1971).

Performance Studies in Ruminants Fed Caged Layer Waste.

Oliphant (1974) reported no change in average daily gains in steers fed dehydrated caged layer waste as a N replacement for fish meal and soybean meal in a barley-based diet. Similar results were reported by Cooper et al. (1974) when steers were fed dried caged layer waste, urea or soybean meal as sources of supplemental protein.

Rate of gain, feed efficiency and carcass grades were not significantly different in steers fed supplemental N from soybean meal or dehydrated poultry waste (El-Sabban et al., 1970). No differences were detected in the taste of beef roasts from cattle fed autoclaved or dried caged layer waste, when compared to those fed soybean meal or urea as a protein supplement. Similarly, Cullison et al. (1976) reported that feeding dried hen manure to steers produced acceptable beef roasts, compared to the steers fed supplemental soybean meal protein diets. Similarly, diets supplemented with autoclaved poultry waste or soybean meal, when fed to steers, did not produce significant differences in carcass quality of steers (Rusnak et al., 1966).

Koenig et al. (1978) treated caged layer waste with 37% formaldehyde solution and used it in feeding to ewe lambs and steers at 0% and 10% levels. The feed/gain ratios were not different (P>.05) between the levels used. Weight gains were decreased (P<.05) for steers receiving poultry waste, due to decreased feed intake. Lamb weight gains were not significantly different (P>.05) between 0% and 10% waste levels.

Bucholtz et al. (1971) conducted feeding trials with steers to determine if dried poultry waste can replace a portion of protein supplements in ruminant diets. Steers were fed soybean meal, dried poultry waste and 1:1 dried poultry waste and soybean meal. The average daily gains were 1.52, 1.25 and 1.31 kg, respectively. The poor performance of steers fed dried poultry waste was due to ingredient-sorting by cattle.

Based on the summary of a number of performance studies in cattle fed diets containing dehydrated poultry excreta, Smith and Wheeler (1979) reported average daily gain of 1.07 vs 1.10 and feed to gain ratio of 7.24 vs 6.49, when cattle were fed control diets and diets supplemented with dehydrated poultry excreta, respectively. Milk yield was 18.42 vs 18.17 kg/day and milk fat was 3.73 vs 3.80 %, respectively . A summary of studies of sheep fed diets containing dried poultry excreta showed average daily gain to be 0.189 for control vs 0.171 kg in lambs fed dried poultry excreta supplemented diets.

Lambs fed corn silage supplemented with dried poultry excreta performed better than those on diets supplemented with soybean meal or urea (Goering and Smith, 1977). The lower feed-to-gain ratio for lambs consuming dried poultry waste supplemented diet suggests that this diet was used more efficiently by the lambs than the control diets.

Kali and Merrill (1975) reported that when dairy heifers were fed diets containing corn silage supplemented with 12% dried caged layer waste there was an increase of 20% in dry matter intakes and 50% in daily gains, when compared to a control diet of corn silage. Clark and Dethrow (1975) reported that steers gained significantly more on corn silage diets supplemented with dried poultry excreta than those fed corn silage diets supplemented with only soybean meal.

Oltjen and Dinius (1976) reported that steers fed 40% of the total dietary N from poultry waste gained weight more ($P<.05$) rapidly and efficiently than steers fed similar levels of N from urea or biuret.

Air dried poultry waste could serve as the only supplemental N source for dairy cows producing upto 28 kg of milk /d, with no effects on animal health, milk flavor or lactation persistency (Bull and Reid, 1971). Thomas et al. (1972) fed dairy cows dehydrated caged layer waste at a level of 23% of total dietary N and 11% of total dry matter intake. Milk production was higher for cows fed dried poultry than excreta those fed inadequate protein diets. Production of waste-fed cows was equal to cows fed a conventional protein supplemented diet. In another feeding trial Thomas et al. (1972) reported that inclusion of 25 or 50% dried poultry waste in sheep diets decreased weight gains, compared to sheep fed on a control diet.

"Urimix" a commercial product containing 90% dried poultry excreta, 5% animal fat and 5% molasses was fed to lactating cows at levels of 20% and 40%. Reduction in milk production occurred when diets containing 40% Urimix was fed (Kristensen et al. 1976).

In studies substituting dried poultry waste at 0, 50 and 100% of the total dietary N provided by soybean meal, it was found that the use of poultry waste resulted in slight decrease in daily gains (Smith and Calvert, 1972). Van Horn and Silva (1976) reported reduced milk production in dairy cows fed 20% and 30% of dried poultry excreta containing 60% ash.

Evans et al. (1978) reported daily gains of 16 and 11 kg in sheep fed caged layer waste treated with 2% molasses and 1% propionic acid, respectively. Supplementing corn silage with wet hen excreta resulted in similar weight gains, compared to cattle fed urea as a protein supplement, but lower weight gains, compared to diets supplemented with soybean meal (Smith et al., 1978).

Incorporation of poultry waste in ruminant diets has produced daily gains of at least 90 to 92% of that produced by using soybean meal, when waste is used as a protein source (Smith et al., 1972). There was a trend for decreased daily gains as the levels of waste was increased (Cullison et al., 1976). This reduction can be attributed to the low energy value in the waste-containing diets rather than a direct effect of waste (Thomas et al., 1972).

Ensiled Caged Layer Waste.

The Ensiling Process. Ensiling involves achieving a stable, low pH in the ensiled mass, and production of a sufficient concentration of lactic acid and other organic acids, as a result of the presence of microorganisms within the ensiled mass. The process inhibits other forms of microbial activities, and thus preserves the ensiled or fermented material until the silages are opened (Barnett, 1954).

The ensiling process depends primarily upon the following three interrelated factors: 1) the composition of the material placed in the silo, 2) degree to which anaerobic conditions are maintained in the silos and 3) the bacterial population in the ensiled material (Heath et al., 1985).

During the ensiling process there is production of heat due to the continued plant respiration and activities of aerobic bacteria until all of the entrapped oxygen is utilized. Once the anaerobic condition is established, the anaerobic bacteria utilize the soluble carbohydrates to produce organic acids, mainly lactic and acetic acids. These acids, in turn, lower the pH of the material and stop further action of bacteria (Barnett et al., 1954). There is a minimal loss of readily-fermentable carbohydrates, once anaerobic conditions are established and pH of the silages is 4.5 or less (McDonald, 1982).

The ensiling process involves preserving the forage material with a minimal loss of nutrients and limited break down of proteins. This can be accomplished essentially through establishing rapid anaerobic conditions in the silos, by using finely chopped material and thorough packing of the silage material in the silos (McCullough, 1984). Sterling and Whittenburg (1963) reported a dramatic increase in the number of lactic acid producing bacteria once proper ensiling conditions are established.

The ensiling process prevents the loss of crude protein and converts part of the NPN into true protein (Muller, 1980), and increases the solubility of N, resulting in a greater N utilization by ruminants (Goering and Waldo, 1974).

Silage making is a low-cost process with a potential of reducing or eliminating harmful microorganisms (McCaskey and Anthony, 1975). The ensiling process takes approximately 18 to 21 d (Muller, 1980; Barnett, 1954) to complete. If proper pH is not reached within a specific period, butyric acid producing bacteria dominate and an increase in pH is observed (McDonald, 1981). This type of fermentation, generally denoted as clostridial type of fermentation, produces a foul smelling, slimy, unpalatable silage. The clostridial fermentation attacks the protein and amino acids and convert them to VFA, NH_3 and amines. This results in N loss and reduced acceptability of the product by the animals (McDonald et al., 1973).

The ensiling process has advantages of masking odors or other factors that could reduce intake, and preserves and controls or completely eliminates harmful pathogens (McCaskey and Anthony, 1975; Harmon et al., 1975).

Ensiled Caged Layer Waste Studies. Albert (1977) ensiled 3-yr-old caged layer waste with corn forage at 20 and 40%, of the total dry matter. The final pH of the ensiled mixtures decreased, compared to the initial mixtures. However, final pH increased with the increased levels of waste. Total bacteria were reduced and coliform and proteus organisms were eliminated. Lactic acid levels were higher for silages containing waste.

Digestibilities of dry matter and organic matter by the lambs decreased, compared to the soybean meal supplemented diets. Crude protein digestibility increased with increasing levels of waste, however, fiber digestibility decreased.

Samuels (1980) ensiled 24-h-old caged layer waste with ground sugarcane bagasse at levels of 40%, 50%, 60% and 70%. The pH of the ensiled mixtures increased as the levels of waste increased. Lactic acid levels were highest for 40% and 50% waste levels. Total coliforms, fecal coliforms and proteus organisms were decreased or eliminated by ensiling. Dry matter and crude protein digestibilities were highest for the 40% waste diet, and lowest for the bagasse diet. Nitrogen retention in sheep fed ensiled waste-bagasse diets was similar to that in sheep fed the basal diet.

Kali and Merril (1975) ensiled chopped whole plant corn with 5, 10 or 15% dried caged layer waste. The pH values for the respective silage mixtures were 4, 4.1 and 4.3. The waste-containing silages were readily consumed by dairy heifers with dry matter intakes 10 to 15% higher than that of corn silage.

Saylor and Long (1974) ensiled caged layer waste (28% dry matter) and ground orchard grass hay (91.5% dry matter) for 60 d in proportions of 100:0, 90:10, 80:20, 70:30 and 60:40, dry basis, with and without 5% ground shelled corn. Silage quality was poor in 100% and 90% waste mixtures. Mixtures containing 80%, 70% and 60% caged layer waste had pH values of 7.1, 6.8 and 5.2, lactic acid levels of .1, .7 and 15.6 mg/g, VFA values of 55.7, 39.5 and 23.5 mg/g and crude protein levels of 13.3, 17.7 and 20%, respectively. Differences were significant among treatments. Added ground corn did not have any effect on ensiling. In earlier studies, Saylor and Long (1972) ensiled corn field residue and caged layer waste or cattle manure in a 40:60 ratio. In vitro digestibilities of organic matter and crude protein were highest for treatments containing caged layer waste.

Goering and Smith (1977) ensiled whole plant corn forage for 90 d with urea, soybean meal, dried poultry excreta or liquid cow manure. Lactic acid, expressed as percent of dry matter, was 4.5, 4.1, 5.9 and 7.6 and pH values were 3.9, 3.9, 4.2 and 3.8, respectively. Sheep fed silages containing dried poultry excreta had significantly higher N retention and weight gains.

Shanon et al. (1978) ensiled fresh caged layer waste with chopped corn plant at 27% level, wet basis. Average pH was 5.25. Average daily gain was .73 kg, which compared to the values of steers fed a control diet.

Arvat et al. (1978) ensiled caged layer waste with ground corn, ground hay, salt and water. Average daily gains were lower for waste silages compared to the control. Apparent digestibility of N was not different from the control, however, dry matter digestibility was lower for waste silages.

Yokoyama and Nummy (1976) ensiled whole corn plant material alone or with cattle, swine and poultry wastes at levels of 53, 23 and 16%, respectively, according to N content. The pH values were 3.9, 4.2, 3.9

and 4.0 and lactic acid, expressed as percent of dry matter, was 5.09, 5.61, 8.29 and 8.88, respectively.

Caged layer waste accumulated for 3 d was treated with 1% propionic acid and 2% molasses and fed to sheep (Evans et al., 1978). During this time sheep had access to corn silage. Intake of wastes was increased by the addition of propionic acid and molasses, but propionic acid had a more positive effect.

Filipot et al. (1975) ensiled caged layer waste treated with 3% tannic acid (w/w) or 2% paraformaldehyde with chopped alfalfa hay. When such diets were fed to sheep the paraformaldehyde-treated waste silages resulted in decreased apparent digestibilities of dry matter, N and energy, compared to those with tannic acid treated silages. Lactic acid production was decreased for waste silages treated with paraformaldehyde. The pH was higher for silages containing wastes, compared to soybean meal silages. Propionic and butyric acid were higher in caged layer waste silages. Acetic acid production was similar among all silages.

Health Aspects of Feeding Animal Wastes

Pathogenic Organisms. Brock (1974) reported a concern of feeding wastes containing the enteric bacteria. These bacteria include Escherichia coli, Shigella spp, Salmonella spp, Proteus spp and Arizona spp.

Salmonella spp are found mainly in poultry wastes. In a survey by Kraft et al. (1969) with feces collected from 32 caged layer houses, approximately 10% of the feces samples showed a positive test for

Salmonella. The densities of the organism ranged from 10,000/g in fresh waste samples to .8 to 148/g in older samples. Proteus and E. coli were detected in fresh caged layer waste samples. Salmonella was not detected in the excreta (Zindel, 1970). In another study by Pelczar and Reid (1972) coliforms were not detected in 60% of the samples analyzed.

Ensiling mixtures of 30% caged layer waste, 20% broiler litter and 50% ground corn decreased the pH to 4.8. No Salmonella or Proteus organisms were found in the ensiled mixtures (Vezey and Dobbins, 1975).

Fresh caged layer waste treated with 1.5% sodium bisulfite, 1% formaldehyde or 10% molasses showed no counts of total and fecal coliforms (Ayangbile, 1987). Untreated waste silages showed insignificant counts of total coliforms.

Drying caged layer waste at 93 to 760 C to produce dried poultry waste eliminated the problem of harmful pathogens in caged layer waste (Forsht et al., 1974). Lee (1974) reported decreased numbers of organisms in dried cage layer waste with no detection of Salmonella. Total elimination of Arizona spp, S. pullorium, S. typhimurium and E. coli was observed when caged layer waste was heated at 68 C (Messer et al., 1971). Analysis for Salmonella and Proteus organisms was done on dried caged layer waste samples collected from different parts of the United States (Chang et al., 1974). The tests for the pathogens were reported to be negative. Although the pathogens in caged layer waste are effectively reduced or eliminated by drying them in commercial dryers, cost is high (Blair, 1975). Also, drying has been shown to reduce the N content in caged layer waste. Yushok and Bear (1943) reported a loss of 17.6% of N present in poultry manure, when the waste was dried at 105 C. Manoukas et al. (1964) found N and gross energy losses ranging from 7.1 to 15.2% and 1.2 to 20.2%, respectively, when poultry excreta was dried at 65 C for 24 h. Higher drying temperatures and longer drying periods increased the losses of N from broiler excreta (Kubena et al., 1973). Also, drying reduces the availability of phosphorus for intestinal absorption (Tagari et al., 1981).

Samuels (1980) reported a marked reduction or complete elimination of total coliforms, fecal coliforms and proteus organisms when caged layer waste was ensiled with sugarcane bagasse at different levels of waste. Total bacteria were reduced and coliform and proteus organisms were completely eliminated when caged layer waste was ensiled with corn forage at different levels of waste (Albert, 1977). Similar results were reported by Ayangbile (1987) with ensiled mixtures of fresh caged layer waste and wheat straw.

The minimum pH required for the growth of Salmonella was 4.4 for a lactic acid-adjusted culture media (Chung and Goepfert, 1970). The higher levels of waste ensiled in the mixture were beneficial since acid development was considerably greater and coliforms were eliminated in these mixtures in less than 10 d. (Knight et al., 1977).

Thus, a more economical method to process caged layer waste for its use as a feed ingredient would be to ensile it with other high energy feedstuffs. Production of heat, lactic acid and lowered pH during ensiling reduce or eliminate the pathogens in the waste. At the same time palatability and availability of the ensiled mass is improved.

Mineral Residues. Copper values of 150 ppm (Long et al., 1969; Hodgetts, 1971), 28 to 109 ppm (Blair, 1974), 94 ppm (Calvert and Smith, 1976) and 51.1 ppm (Bruhn et al., 1977) were reported for caged layer wastes. Sheep fed 0, 25, 50% dehydrated poultry waste containing 30, 24, 35 ppm Cu, respectively, did not show significant changes in liver Cu (Thomas et al., 1972). Feeding dehydrated poultry waste that contained 94 ppm of Cu to cattle increased levels of Cu in the liver, however blood, muscle and kidney Cu levels remained unchanged (Smith and Calvert, 1976).

Lactating cows were fed diets containing dehydrated poultry waste with 13 to 15.9 ppm Cu, dry basis (Calvert and King, 1977). The milk Cu levels were .61 and .71 ug/g, dry basis, respectively. Bruhn et al. (1977) reported no significant differences in Cu content of milk when cows fed diets supplemented with 9.9% dried poultry waste with 51.1 ppm Cu over a 4 wk period were compared to the milk of cows fed a control diet. They reported that the Cd in dried poultry waste was 1.3 ppm in waste, which was higher than the control diet. The levels of Cd found in the raw milk of both dried poultry waste and control diet fed cows averaged 6.24 and 3.71 ug/g respectively. These differences however, were not significant.

Arsenic, Cu and Se are used as feed additives in the diets of poultry, while Cd, Pb and Hg are not added to the diets but occur naturally in the feeds (Fontenot et al., 1979).

Calvert and Smith (1976) reported no significant differences in Cd or Pb content of steer diets containing 12.1% dried poultry waste. The level of Cd in the kidneys of steers, dry basis, averaged 5 ppm for controls and 1.7 ppm for dried poultry waste-fed steers. Vijchulata et al.

(1980) reported an increase in liver Cu from 55 to 490 mg/kg in steers fed diets containing upto 25% caged layer waste.

Fontenot et al. (1971) suggested Cu content of waste fed to sheep should be controlled, as sheep are highly sensitive to Cu in their diets. Suttle and Price (1976) reported that 15 mg/kg dry matter of Cu in diets of sheep may cause problems in sheep. Arsanilic acid and 3-nitro-4-hydroxyphenylarsonic acid are compounds added to laying hen diets (Calvert, 1973). El-Sabban (1969) and Brugman et al. (1964) reported the presence of arsenic and arsanilic acid in laying house litter at concentrations of 29 ppm and 48 ppm, respectively. Steers fed diets containing dried poultry waste had liver arsenic levels of .38 ppm, compared to .28 ppm in livers of animals fed a control diet (El-Sabban, 1970). Calvert (1970) reported that in sheep fed diets containing arsenical compounds a withdrawl period of 6 d was sufficient to decrease the arsenic levels substantially. In another study lactating cows were fed dried poultry waste containing 18 ppm As or As from arsanilic acid by a capsule over 5 d. In cows fed arsanilic acid there was an increase in milk and blood As concentrations, compared to cows fed dried poultry waste.

<u>Pesticide Contamination.</u> El-Sabban et al. (1970) and Fontenot et al. (1971) reported that pesticide residue levels in the fat of cattle and sheep fed poultry wastes did not exceed that found in control animals. Maximum acceptable levels of chlorinated hydrocarbons was reported to be around 10 ppb (McConnell et al., 1975)

Low residues levels of rabon, an oral pesticide used to control parasites and fly larvae in poultry wastes, were detected in hen manure (Wasti et al., 1970). However, rabon has not been found to be of any potential danger to cattle (Ivey et al., 1968). Miller and Gordon (1973) reported no health or reproductive problems and no accumulation of rabon in the milk when dairy cows were fed 252 ppm rabon.

Smith et al. (1976) reported illegal levels of polychlorinated biphenyls (PCB) in the milk of cows fed 32% dried poultry waste in their diets for 50 d. The excreta was from hens fed 20 ppm PCB. This level was above the level recommended by FDA. A PCB level of .4 ppm or less in dried poultry waste has been reported to result in no serious PCB residues in milk fat.

El-Sabban et al. (1970) reported no differences in the levels of hydrocarbon residues in the back fat of steers fed diets containing processed caged layer waste or a control ration containing soybean meal or urea.

The use of chlorinated hydrocarbons in agriculture has been reduced considerably, which should diminish the incidence of the pesticides in animal products (Bhattacharya and Taylor, 1975).

Regulatory Aspects of Feeding Caged Layer Waste. In 1967, the Food and Drug Administration (FDA) passed a regulation stating that it would not sanction the use of poultry wastes as animal feed due to the presence of drug residues or their metabolic derivatives and potentially hazardous microorganisms (Kirk, 1967; Taylor et al., 1974). In 1980 the FDA delegated the responsibilities of regulating the use of animal wastes as feedstuff to the indivisual states (FDA, 1980). After consideration of number of state regulations and regulatory options the Animal Waste Task Force developed a Model Regulation, which emphasizes testing, labeling and registration requirements for processed animal waste products as animal feed ingredients (AAFCO, 1984).

EXPERIMENTAL PROCEDURE

Ensiling Caged Layer Waste with Corn Forage

The same caged layer waste and corn forage were used to make small and large silos. The caged layer waste used for this study was deep-pit caged layer waste collected from a commercial layer house[1]. The waste had accumulated for approximately 2 yr on a concrete floor beneath hens housed in wire mesh cages. The hens were receiving a 16% crude protein diet.

The waste was collected directly under the cages with a front-end loader, placed in 210 liter metal drums, single lined with polyethylene bags and transported to Blacksburg, VA. The drums were kept uncovered while being transported and until processing the following day. The collected waste was powdery, and contained some feathers and live insects.

The caged layer waste from all drums was mixed in a horizontal mixer. The mixture was then placed on a polyethylene sheet on the ground. As the waste was emptied from the mixer several samples were taken at regular intervals. Later, the samples were composited and subsampled to represent the intial caged layer waste samples.

The corn forage used in this study, was harvested in late fall. The chopped corn forage was mixed to obtain a homogenous mixture, after which the forage was placed on a polyethylene sheet and sampled as described

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[1] Glennwood Farms INC., Jetersville, VA.

for the caged layer waste. The samples were composited and subsampled to represent the intial corn forage samples.

Small Silo Study. A small silo study was conducted to evaluate fermentation characteristics and microbial parameters in corn forage ensiled alone and with caged layer waste. Corn forage was ensiled alone or with caged layer waste in ratios of 100:0, 80:20, 70:30, 60:40, 50:50 and 40:60, wet basis, respectively. Approximately 16 kg of each mixture were prepared, by separately weighing amounts of each component for the respective mixtures. The mixtures were prepared by adding known amounts of each component into a horizontal mixer and mixing for 10 min. As corn forage and caged layer waste for each mixture were weighed, samples of each component were taken for chemical analysis. There were six silos per treatment, thus giving a total of 36 small silos. Each small silo had approximately a total capacity of 2 kg.

After thorough mixing each mixture was sampled aseptically for microbial and chemical analysis. The sampling for each treatment mixture was done in the beginning, midpoint and towards completion of filling the small silos. Samples for microbial study were taken in previously sterilized .5 liter mason jars. All microbial studies were done on the samples within a period of 24 h. Samples for chemical analysis were taken at the same time as microbial samples except for the fact that the size of sample for chemical analysis was larger. All samples for chemical analysis were frozen for later analysis.

Small silos were prepared by firmly packing the respective treatment mixtures into 2 kg capacity cardboard containers, double lined with polyethylene bags. Packing was done by hand to ensure maximum exclusion of air. After packing, each bag was individually sealed. The silos were weighed and taken to the metabolism barn where they were kept at room temperature until time of opening.

The small silos were opened after an average fermentation period of 120 d. Two silos from each treatment were opened and analyzed for microbial parameters. All microbial studies were done on the same day the silos were opened. As the small silos were opened observations were made on appearance and odor of the silages. The top 4 to 5 cm material from each opened silo were discarded because of mold growth. Samples for microbial and fermentation characteristics were taken immediately from different locations of the silos. Samples for microbial analysis were taken aseptically with sterilized gloves in .5 liter sterile mason jars. Samples for chemical analysis were taken in the same way in double lined polyethylene bags, and frozen for later analysis.

Large Silo Study. Large silos were filled with corn forage alone or mixed with caged layer waste to study fermentation parameters and to conduct a metabolism trial. Chopped corn forage was ensiled alone or with caged layer waste in ratios of 100:0, 70:30, 60:40 and 50:50, wet basis, respectively. For each mixture the appropriate amount of corn forage was weighed into a horizontal mixer. For the corn forage-waste mixtures appropriate amounts of waste were weighed into the mixer and the mixture was mixed for 10 min. As the corn forage and waste were put into the mixer, samples were taken. Two samples each of corn forage and caged layer waste were taken from each of the respective loads as they were put into the mixer. These samples of corn forage and caged layer waste were composited and subsampled, resulting in two subsamples for each of the respective mixtures. After thorough mixing, the mixtures were emptied into 210 liter metal drums double lined with polyethylene bags (.08 mm). As the mixtures were put into each of the drums, handful samples were taken at intervals. Two such samples were taken for each drum, and frozen for later chemical analysis as the drums were packed by trampling. Each bag was tied separately after expelling the air.

Samples for microbial study were taken aseptically in previously sterilized .5 liter mason jars. All microbial studies were done within 24 h.

The large silos were opened after an average fermentation period of 160 d. One drum from each treatment was opened on the day the metabolism trial began. This ensured the least exposure of the silage material to aerobic conditions. Upon opening the large silos, observations were made on appearance and odor of the silages. From each of the large silos opened the top 5 cm material were discarded because of mold growth. Samples for microbial analysis and chemical analysis were taken immediately from different locations of the silos as described for small silos. Respective large silos were selected randomly and opened as the silage material for that particular treatment was needed during the metabolism trial. All microbial analyses were done on the same day they were opened.

Microbial and Chemical Determinations

Total coliforms and fecal coliforms were determined quantitatively (Millipore Corporation, 1973), using the Quebec colony counter. Also, a qualitative test was conducted on the samples to detect the presence of Salmonella, Shigella and Proteus (Lewis, 1964).

Kjeldahl nitrogen was determied on initial waste, initial corn forage mixes, initial mixtures and silages of both the small and large silos (A.O.A.C., 1980). Water extracts were prepared for both small and large silos by blending 25 g of sample material with 225 ml of distilled and sterilized water in .5 liter mason jars in a Waring blender at full speed for 1 min. The homogenate was filtered through four layers of previously sterilized cheese cloth. The filtrate was collected in sterilized beakers and used for determining pH (electrometrically), lactic acid (Barker and Summerson, 1941, as modified by Pennington and Sutherland, 1956), water-soluble carbohydrates (Dubois et al., 1956 as adapted to corn plants by Johnson et al., 1966) and microbial counts. Care was taken to maintain aseptic conditions without any contamination from previous samples.

Dry matter determination on samples of small and large silos was done by drying duplicate 200 g samples in a forced draft air oven at 60 C until a constant weight was reached. Following equilibration with atmospheric air, the duplicate dried samples were weighed, composited and ground in a Wiley mill with a 1 mm. screen. The ground material of large silos was then subjected to analyses of acid detergent fiber (ADF) (Goering and Van Soest, 1970), neutral detergent fiber (NDF) (Van Soest and Wine, 1967), lignin and cellulose (Van Soest and Wine,1968).

Hemicellulose was determined by difference between ADF and NDF. Ash was determined by A.O.A.C. (1980).

Metabolism Trial

Thirty crossbred (1/2 Dorsett x 1/4 Finn x 1/4 Rambouillett) wethers with an average weight of 37 kg were used to study the effects of feeding different ensiled mixtures of corn forage and caged layer waste on ration digestibility, N utilization and blood and ruminal parameters. Animals were blocked according to weight, and were randomly allotted within blocks to the following diets: (1) 100% corn silage (negative control) (2) ensiled mixture of 70% corn forage and 30% caged layer waste (wet basis) (3) ensiled mixture of 60% corn forage and 40% caged layer waste (wet basis) (4) ensiled mixture of 50% corn forage and 50% caged layer waste (wet basis) (5) corn silage with sufficient soybean meal added to increase the crude protein content to that of the 70:30 silage. Silages used for feeding the animals were from the large silo study.

Prior to the beginning of the trial all animals were treated for internal parasites with Ivermectin[2] and with 500,000 I.U. of vitamin A and 75,000 I.U. of vitamin D, injected intramuscularly trial. Sheep were placed in false bottom metabolism stalls similar to those described by Briggs and Gallup (1949) which allowed for separate collection of feces and urine. All animals were fed 700 g of dry matter of the respective

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[2] MSDAGVET, Div. of Merck & Co., Rahway, NJ.

diets daily. The diets were fed twice daily, one half at 0700 h and the second half at 1900 h.

Transition to the experimental diets from a diet consisting of 61.4% mixed grass hay, 28.8% corn, 9.6% soybean meal, dry basis, was done by substituting the experimental diets at a rate of 10% per feeding. If the sheep failed to consume a particular diet at a feeding time that same percentage of basal and experimental diet was fed until most of it was consumed.

The metabolism trial consisted of a 5-d adaptation period to the metabolism stalls, 7-d transition period to experimental diets, 10-d preliminary period during which 100% of the experimental diets were fed, and 10-d collection period. Water was available to the animals throughout the feeding trial except during the two 2-h feedings.

Samples of feeds were obtained at each feeding 2 d prior to the beginning until 2 d prior to the end of the collection period. Samples of feed were obtained as they were weighed, placed in double lined polyethylene bags and frozen for later chemical analysis. At the end of the trial the feed samples were thawed, composited and subsampled for proximate analysis. Similarly, feed refusals for each feeding period were collected separately, by animals, in double lined polyethylene bags and frozen for later chemical analysis. At the end of the metabolism trial refusals were thawed, composited for each animal, weighed and subsampled for proximate analysis. As each silo was opened samples were taken for microbial and chemical analysis. Microbial analysis was done on the same day the samples were taken. Samples for chemical analysis were labeled and frozen for later analysis.

Feces were collected once daily, and dried in a forced-draft oven at a maximum temperature of 60 C for a minimum of 24 h. The feces were composited in metal cans double lined with plastic bags and loose fitting lid to equilibrate with atmospheric moisture. At the end of the collection period the total fecal collection was weighed, mixed and subsampled and ground in a Wiley mill through a 1 mm screen. Urine was collected in 4 liter polyethylene containers containing 15 ml of 1:1 (w/w) solution of concentrated H_2SO_4 and water plus approximately 500 ml water. Total urine was collected once daily and diluted to a constant weight (5000 g) with water and a 2% sample by volume was taken and placed in tightly capped bottles, and was refrigerated. At the end of the collection period the urine samples were further subsampled and refrigerated until analyzed.

On the last day of the collection period ruminal fluid samples were taken 2-h post feeding, using a stomach tube, with a metal strainer on the end. The samples were strained through four layers of cheese cloth and used for determination of pH (electrometrically), VFA (Erwin et al. 1961) and NH_3N (Beecher and Whitten 1970). Blood samples were taken 6-h post feeding by puncturing the jugular vein, and analyzed for urea N (Coulombe and Favreau 1963).

Samples of diets, refusals and feces were analysed for dry matter, crude protein, NDF, ADF, lignin, cellulose, hemicellulose and ash as described above. Urine was analyzed for nitrogen (AOAC, 1980).

Statistical Analyses

The data was treated by analysis of variance by the general linear model procedure of SAS (1982).

In the small and large silo studies the following contrasts were made: corn silage vs corn forage-waste silages; differences within corn forage-waste silages were tested by orthogonal polynomials for linear, quadratic, cubic and quartic trends (small silos), and linear, quadratic and cubic trends for large silos.

In the metabolism trial, the contrasts were: Corn silage vs corn forage-waste silages; within waste treated silage diets the differences over waste levels were tested by orthogonal polynomials for linear and quadratic trends; 70:30 corn forage-waste silage vs corn silage supplemented with soybean meal.

RESULTS AND DISCUSSION

Composition of Deep Pit Caged Layer Waste

Dry matter content of the waste samples averaged 69.2% (table 1). The crude protein content of the 2-yr-old deep pit caged layer waste averaged 25.6%, dry basis, lower than the value of 27.81% reported by Liebholz (1969), 36.87% reported by Bull and Reid (1971) or 28.7% reported by Samuels (1987) for fresh wastes. However, the crude protein content was higher than the value reported by Albert (1977) for 3-yr-old caged layer waste (22.58%, dry basis) samples. These differences could be due to the time lapse between time of excretion and collection, which could have allowed gradual break down of uric acid N to soluble forms, resulting in N losses.

Ash content of the waste averaged 39.46%, dry basis, which is higher than ash values reported by Ayangbile (1987), Bull and Reid (1971) and Liebholz (1969) in fresh wastes but lower than the ash values reported by Albert (1977). White et al. (1944) observed an increase in the ash content of wastes, from 20.41% to 35.85%, dry basis, after 10 wk. They attributed this increase in the ash content to the decomposition of organic matter in caged layer waste samples. Evans et al. (1978) reported an increase in ash content with storage of layer wastes. Composting increased ($P<.05$) ash content of excreta samples. This could explain the high ash content in the waste used in the present study.

The low value of 2.9%, dry basis, for the water-soluble carbohydrates could be the result of the fact that the feed mixture had already undergone monogastric digestion and probably some microbial degradation occurred in the waste while it was collecting in the layer house. The value for water-soluble carbohydrates is slightly higher than 1.31%, dry basis, reported by Albert (1977). Samuels (1980) reported 3.5% water-soluble carbohydrates, dry basis, in fresh layer waste.

Neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, lignin and hemicellulose values were 31.3%, 16.7%, 11.5%, 3.3% and 14.5%, dry basis respectively, compared to 34.8% NDF, 10.8% ADF, 9.2% cellulose, 1.8% lignin and 24% hemicellulose, dry basis, reported by Samuels (1980) in fresh caged layer waste.

Composition of Chopped Corn Forage

Dry matter of the samples of chopped corn forage used in both small and large silos averaged 32.6%, and crude protein content, dry basis, was 8.4% (table 1). Water-soluble carbohydrates, on dry basis, was 8.2%. The relatively low value of water-soluble carbohydrates in the corn forage could be attributed to various factors such as time and stage of maturity it was harvested. Johnson et al. (1966) reported that the soluble carbohydrate content decreased considerably from 29%, in August to 9.2 %, dry basis, in October as the stage of growth advanced from early milk to glaze stage. However in the present study sufficient carbohydrates were present in the corn forage for ensiling to take place.

Neutral detergent fiber, ADF, cellulose, hemicellulose, lignin and ash values compared closely to the values reported by NRC (1985).

TABLE 1. COMPOSITION OF CORN FORAGE AND CAGED LAYER WASTE USED IN SMALL AND LARGE SILO STUDIES

Item	Caged layer waste	Corn forage
Dry matter, %	69.2	32.6
Proximate components, %[a]		
Crude protein	25.6	8.4
Ash	39.6	3.3
Cell wall fractions, %[a]		
Neutral detergent fiber	31.3	51.6
Acid detergent fiber	16.7	26.2
Cellulose	11.5	22.1
Hemicellulose	14.5	25.4
Lignin	3.3	3.4
Water soluble carbohydrates, %[a]	2.9	8.2

[a] Dry basis.

Small Silo Study

Composition and Fermentation Characteristics of Mixtures. The values for the initial small silo mixtures represent an average of two replicates per treatment (table 2). With increasing levels of waste the dry matter, crude protein and ash increased, and water-soluble carbohydrates decreased. Dry matter, crude protein and ash were lower ($P<.01$) for corn silage, compared to corn forage-waste silages (table 3). The pH of the corn silage was 3.9, lower ($P<.01$) than for the ensiled corn forage-waste mixtures. Lactic acid was lower and water-soluble carbohydrates were higher ($P<.01$) for the corn silage. Within the corn forage-waste silages dry matter, crude protein and ash increased linearly ($P<.01$) with level of waste. The pH increased linearly ($P<.01$) and lactic acid decreased as level of waste increased, up to the 50% level then increased (quadratic effect, $P<.01$). Residual water-soluble carbohydrates showed a linear increase ($P<.01$).

Microbial Counts of Initial and Ensiled Mixtures. Microbial counts were lowest for the corn forage mixtures compared to the waste containing mixtures (table 4). All waste containing mixtures tested positive for Salmonella, Shigella and Proteus. As the waste levels were increased, total and fecal coliforms increased.

Microbial counts were reduced considerably after ensiling, in all waste silages (table 5). None of the organisms were detected in corn silage. Qualitative tests on waste containing silages tested negative for Salmonella, Shigella and Proteus for the 20, 30 and 40% waste levels,

TABLE 2. COMPOSITION OF CORN FORAGE AND CAGED LAYER WASTE MIXTURES, SMALL SILO STUDY[a]

	Corn forage : caged layer waste[b]					
Item	100:0	80:20	70:30	60:40	50:50	40:60
Dry matter, %	32.7	39.6	43.6	46.5	49.5	54.8
Crude protein, %[c]	8.6	15.1	17.1	18.9	20.0	21.4
Ash, %[c]	3.2	16.1	22.1	24.8	30.0	33.0
WSC, %[c,d]	8.4	7.1	6.7	6.4	6.3	6.0

[a] Two samples/treatment.
[b] Proportions on wet basis.
[c] Dry basis.
[d] Water soluble carbohydrates.

TABLE 3. COMPOSITION AND FERMENTATION CHARACTERISTICS OF ENSILED CORN FORAGE AND CAGED LAYER WASTE MIXTURES, SMALL SILO STUDY[a]

Item	Corn forage : caged layer waste[b]						
	100:0	80:20	70:30	60:40	50:50	40:60	SE[c]
Dry matter, %[e,g,h]	30.9	38.9	42.7	46.4	49.1	54.4	.31
Crude protein, %[d,e,g]	9.5	15.3	17.3	19.1	21.0	22.0	.31
Ash, %[d,e,g,j]	3.7	17.7	23.9	26.4	31.8	35.6	.40
pH[e,g]	3.9	5.2	5.5	5.7	5.9	6.4	.07
Lactic acid, %[d,e,g,h,i]	3.9	12.6	9.9	6.3	5.3	6.9	.31
WSC, %[d,e,f,g]	3.8	1.5	1.7	1.7	2.1	2.5	.15

[a] Six samples/treatment.
[b] Proportions on wet basis.
[c] Standard error of means.
[d] Dry basis.
[e] Corn silage vs waste treated silages differ (P<.01).
[f] Water soluble carbohydrates.
[g] Within waste treated silages linear effect signifant (P<.01).
[h] Within waste treated silages quadratic effect signifant (P<.01).
[i] Within waste treated silages cubic effect signifant (P<.01).
[j] Within waste treated silages quartic effect signifant (P<.01).

TABLE 4. MICROBIAL COUNTS OF INITIAL MIXTURES OF CORN FORAGE AND CAGED LAYER WASTE MIXTURES, SMALL SILO STUDY[a]

Item	Corn forage : caged layer waste[b]					
	100:0	80:20	70:30	60:40	50:50	40:60
Total coliforms (10^3)[c]	.003	.918	4.924	11.04	13.12	14.43
Fecal coliforms (10^3)[c]	.001	.665	.787	.93	1.05	1.18
Salmonella[d]	-	+	+	+	+	+
Shigella[d]	-	+	+	+	+	+
Proteus[d]	-	+	+	+	+	+

[a] Two samples/treatment.
[b] Proportions on wet basis.
[c] Counts/gram of material.
[d] Qualitative study; (+) indicates presence, (-) indicates absence, of the respective microorganisms.

TABLE 5. MICROBIAL COUNTS IN ENSILED MIXTURES OF CORN FORAGE AND CAGED LAYER WASTE, SMALL SILO STUDY[a]

Item	Corn forage : caged layer waste[b]					
	100:0	80:20	70:30	60:40	50:50	40:60
Total coliforms (10^2)[c]	.00	1.63	2.84	3.95	4.51	5.58
Fecal coliforms (10^2)[c]	.00	.00	.01	.41	1.01	2.23
Salmonella[d]	-	-	-	-	+	+
Shigella[d]	-	-	-	-	+	+
Proteus[d]	-	-	-	-	+	+

[a] Six samples/treatment.

[b] Proportions on wet basis.

[c] Counts/gram of material.

[d] Qualitative study; (+) indicates presence, (-) indicates absence, of the respective microorganisms.

wet basis. Silages containing 50% and 60% waste, wet basis, tested positive for these organisms.

Large Silo Study

Fermentation Characteristics. Initial values for pH, lactic acid and water-soluble carbohydrates (WSC) for corn forage mixtures were averaging 6.5, .5, 8.2 and values for corn forage-waste mixtures ranged from 6.9 to 7.0, .01 to .02, 6.3 to 6.5, respectively, (table 6). Lactic acid in the initial corn forage-waste mixtures seemed to decrease with decreased levels of corn forage, probably a reflection of a high level in corn forage.

Corn silage had a pH value of 3.9 which indicates good ensiling (McDonald, 1981). Water-soluble carbohydrates were lower than 7.22%, dry basis, reported by Peterson et al. (1925). Barnett (1954) reported that a low level of lactic acid production in ensiled mass is an indication of poor ensiling. Langston et al., (1958) reported that lactic levels should be within a range of 3.03 to 13.16%, dry basis, respectively for a good quality silage. The pH was lower and lactic acid and WSC of post ensiled silages were higher (P<.01) for corn silage, compared to the corn forage-waste silages. Saylor and Long (1974) reported high lactic acid when caged layer waste was ensiled with orchard grass hay in 70:30 mixture. Within corn forage-waste silages, pH increased (P<.01) linearly with waste level. Lactic acid decreased up to the 60% waste level, then leveled off (quadratic effect, P<.01). Residual WSC increased linearly (P<.01) with addition of waste. An increase in lactic acid with a drop

TABLE 6. FERMENTATION CHARACTERISTICS OF CORN FORAGE AND CAGED LAYER WASTE MIXTURES, PRE[a] AND POST[b] ENSILING, LARGE SILO STUDY

Item	Corn forage : caged layer waste[c]				
	100:0	70:30	60:40	50:50	SE[d]
pH					
Pre-ensiled	6.5	6.9	7.0	7.0	
Post-ensiled[e,f,g]	3.9	5.5	5.6	6.2	.02
Lactic acid, %[h]					
Pre-ensiled	.5	.0	.0	.0	
Post-ensiled[e,f,g]	3.8	9.0	4.8	4.8	.16
Water soluble carbohydrates, %[h]					
Pre-ensiled	8.2	6.5	6.4	6.3	
Post-ensiled[e,f,g]	5.0	1.8	1.9	2.8	.11

[a] Two samples/treatment.

[b] Four samples/treatment.

[c] Proportions on wet basis.

[d] Standard error of means.

[e] Corn silage vs waste treated silages differ ($P<.01$).

[f] Linear effect of waste treatment significant ($P<.01$).

[g] Quadratic effect of waste treatment significant ($P<.01$).

[h] Dry basis.

in WSC was noticed in all silages regardless of waste treatment. Similar trends of decreased WSC and increased lactic acid have been reported by Harmon et al. (1975a) for corn forage-broiler litter, Goering and Smith (1977) for corn forage-caged layer waste, Berger (1978) for orchard grass-swine waste, Samuels (1980) for sugarcane bagasse-caged layer waste and Albert (1977) for corn forage-caged layer waste. Goering and Smith (1977) reported that high concentrations of lactic acid are produced due to higher buffering capacity due to the ash content in the waste containing silages. This high buffering capacity could result in a prolonged fermentation and a concomitant build up in lactic acid as a requirement to decrease pH. Barnett (1954) reported that adequate levels of soluble carbohydrates should be present to lower the pH of ensiled materials. Woolford (1972) reported a level of 6% or higher, dry basis is desirable for good fermentation. The presence of 6.4 and 6.3%, dry basis, WSC in 60:40 and 50:50 mixtures, wet basis, of corn forage and caged layer waste, could be a reason of lowered levels of lactic acid produced in these silages. Since the 50:50 mixture contained lowest levels of WSC and highest levels of ash, the WSC may have been depleted before the lactic acid level reached its peak. Therefore there was a cessation of the fermentation process. Samuels (1980) reported similar results. Peterson et al. (1925) reported that of the total acids produced from corn forage during ensiling, only 9.8% was lactic acid.

Volatile Fatty Acids. The total VFA concentration was highest for the waste silages, compared to corn silage (table 7). Acetic acid was the major fatty acid produced for all silages, with traces of propionic

TABLE 7. EFFECT OF ENSILING DIFFERENT PROPORTIONS OF CORN FORAGE AND CAGED LAYER WASTE UPON VOLATILE FATTY ACID CONCENTRATION LARGE SILO STUDY[a]

Item	Corn forage : caged layer waste[b]				SE[c]
	100:0	70:30	60:40	50:50	
	%[d]				
Total[e,f,g]	1.3	4.5	5.3	3.2	.07
Acetic acid[e,f,g]	1.0	4.3	5.1	3.1	.05
Propionic	.2	.2	.1	.1	.02
Isobutyric	.1	.1	.1	.0	.02
Butyric	.0	.0	.0	.0	.00
Isovaleric	.0	.0	.0	.0	.00
Valeric	.0	.0	.0	.0	.00

[a] Four samples/treatment.
[b] Proportions on wet basis.
[c] Standard error of means.
[d] Dry basis.
[e] Corn silage vs waste treated silages differ ($P<.01$).
[f] Within waste treated silages linear effect significant ($P<.01$).
[g] Within waste treated silages quadratic effect significant ($P<.01$).

and isobutyric acids. Similar results have been reported by Goering and Smith (1977) when corn forage was ensiled with dried poultry excreta. In the present study acetic acid was lowest (P<.01) for the corn silage. With increasing levels of the waste the total VFA and acetic acid increased, but dropped with the treatment containing 50% waste. A quadratic effect (P<.01) within waste treated silages was noticed for acetic acid production and total VFA.

Microbial Counts. The microbial population, especially total and fecal coliforms, for the initial corn forage-waste mixtures was higher than for the corn forage mixture (table 8). Within the corn forage-waste mixtures total coliforms and fecal coliforms increased as the waste level increased. This indicated that the caged layer waste contained those organisms. All the corn forage-waste initial mixtures gave a positive test for Salmonella, Shigella and Proteus. Corn forage mixtures gave very low counts for the total and fecal coliforms, and tested negative for Salmonella, Shigella and Proteus. Following ensiling, all silages showed either a marked reduction or complete elimination of the organisms. Silages containing 30% and 40% waste, wet basis, tested negative for the qualitative tests for Salmonella, Shigella and Proteus. However, the silages containing 50% waste tested positive for these organisms. In the 50% waste silages the Salmonella, Shigella and Proteus organisms probably thrived because pH in these silages was higher (6.2) compared to 5.5 and 5.6 for 30% and 40% waste treated silages, respectively. Reduction or complete elimination of the total and fecal organisms have been reported

TABLE 8. MICROBIAL COUNTS OF PRE[a] AND POST[b] ENSILED MIXTURES, LARGE SILO STUDY

	Corn forage : caged layer waste[c]			
Item	100:0	70:30	60:40	50:50
Pre-ensiled				
Total coliforms (10^3)[d]	.003	1.137	14.86	18.58
Fecal coliforms (10^3)[d]	.001	.842	.91	1.26
Salmonellae[e]	-	+	+	+
Shigellae[e]	-	+	+	+
Proteuse[e]	-	+	+	+
Post-ensiled				
Total coliforms (10^2)[d]	.00	2.08	2.89	3.47
Fecal coliforms (10^2)[d]	.00	.00	.35	.46
Salmonellae[e]	-	-	-	+
Shigellae[e]	-	-	-	+
Proteuse[e]	-	-	-	+

[a] Two samples/treatment.

[b] Four samples/treatment.

[c] Proportions on wet basis.

[d] Counts/gram of material.

[e] Qualitative study; (+) indicates presence, (-) indicates absence, of the respective microorganisms.

by Albert (1977) and Samuels (1980) with cage layer waste ensiled with corn forage and sugarcane baggasse, respectively.

Proximate and Cell Wall Composition of Initial Mixtures and Silages. Initial corn forage mixtures had lowest dry matter content, initial and final mixtures, respectively (table 9). There was an increase (P<.05) in the dry matter content of inital and final silage waste mixtures with increasing levels of waste, due to the higher dry matter content in the waste. The slight decrease in the dry matter content of each of silages (table 10), compared to the initial mixtures could be attributed to the respiration of plant cells and the action of microbes in the ensiled mass (Peterson et al., 1925).

The increase (P<.05) in the crude protein levels with level of waste was also due to the higher crude protein content in the waste. Since corn silage is low in crude protein and feeding of it often requires supplementation with a protein source, the significant increase in crude protein with each level of waste addition could provide considerable savings in feed costs and alleviate protein supplementation in high silage feeding operations.

The increase (P<.01) in the ash content with level of waste reflected higher levels of ash in waste than corn forage. Silages seemed to have a higher percentage of ash compared to initial mixtures, which could have resulted from the decomposition of organic matter. Similar results have been reported Samuels (1980). The increased ash content with respect to each level of waste addition might also be expected to supply essential minerals, especially Ca and P. Values of 9% Ca and 1.5% P have

TABLE 9. COMPOSITION OF INITIAL MIXTURES OF CORN FORAGE AND CAGED LAYER WASTE, LARGE SILO STUDY[a]

Item	Corn forage : caged layer waste[b]				
	100:0	70:30	60:40	50:50	SE[c]
Dry matter, %[d, e]	32.6	43.2	46.7	51.7	.01
Proximate components, %[f]					
Crude protein[d, e]	8.5	16.4	17.9	19.7	.21
Ash[d, e]	3.3	25.2	27.9	30.6	.15
Cell wall components, %[f]					
NDF[d, g]	51.2	39.0	35.4	37.5	.84
ADF[d, h]	26.2	21.5	19.9	19.1	.34
Cellulose[d, e]	22.4	17.6	16.2	14.8	.30
Hemicellulose[d]	25.0	17.5	15.5	18.4	.46
Lignin	3.2	3.3	3.2	3.4	.12

[a] Two samples/treatment.
[b] Proportions on wet basis.
[c] Standard error of means.
[d] Corn forage vs waste treated mixtures differ ($P < .01$).
[e] Linear effect of waste treatment significant ($P < .01$).
[f] Dry basis.
[g] Neutral detergent fiber.
[h] Acid detergent fiber.

TABLE 10. COMPOSITION OF ENSILED MIXTURES OF CORN FORAGE AND CAGED LAYER WASTE, LARGE SILO STUDY[a]

Item	Corn forage : caged layer waste[b]				
	100:0	70:30	60:40	50:50	SE[c]
Dry matter, %[d,e,f]	32.1	42.1	46.0	51.6	.03
Proximate components, %[g]					
Crude protein[d,e]	9.4	17.1	18.5	19.7	.14
Ash[d,e,f]	3.6	25.7	27.8	31.5	.12
Cell wall components, %[g]					
NDF[d,e,f,h]	46.8	35.2	35.1	31.2	.43
ADF[d,e,f,i]	25.6	21.1	21.8	19.2	.33
Cellulose[d,e,f]	20.7	16.4	16.5	14.4	.21
Hemicellulose[d,e]	21.2	14.1	13.3	12.0	.25
Lignin	3.2	3.2	3.3	3.3	.22

[a] Four samples/treatment.
[b] Proportions on wet basis.
[c] Standard error of means.
[d] Corn silage vs waste treated silages differ (P<.01).
[e] Linear effect of waste treatment significant (P<.01).
[f] Quadratic effect of waste treatment significant (P<.01).
[g] Dry basis.
[h] Neutral detergent fiber.
[i] Acid detergent fiber.

been reported for caged layer waste by Brugman et al. (1964), Lowman and Knight (1970) and Bull and Reid (1971). Availability of Ca and P in poultry wastes were found to be 95% and 75%, respectively when poultry wastes were used as a sole source of proteins in ruminant diets (Bull and Reid, 1971).

Percentages of NDF, ADF, cellulose and hemicellulose decreased with increasing levels of waste in the mixtures. Lignin showed no marked changes with waste treatment. Similar results have been shown by Albert (1977) in ensiled corn forage and caged layer waste mixtures.

Chemical Composition of Diets

Dry matter, crude protein and ash were lower ($P<.01$), and NDF, ADF, cellulose and hemicellulose were higher ($P<.01$) for corn silage diet, compared to corn forage-waste silage diets (table 11). Within waste silages dry matter, crude protein and ash increased linearly; and NDF, ADF, cellulose and hemicellulose decreased linearly ($P<.01$) with level of waste. Dry matter and ash were higher, and NDF, cellulose and hemicellulose were lower ($P<.01$) for the 70:30 corn forage-caged layer waste diet, compared to corn silage supplemented with soybean meal. The crude protein content of 70:30 corn forage-caged layer waste diet was similar to that of the corn silage supplemented with soybean meal.

Apparent Digestibility

Sheep fed corn forage-waste silage containing 50% waste had highest refusals (179 g/d, dry basis) followed by silages containing 40 and 30%

TABLE 11. COMPOSITON OF ENSILED CORN FORAGE AND CORN FORAGE-CAGED LAYER WASTE MIXTURES FED TO SHEEP

Item	DIETS				
	Corn forage : Caged layer waste[a]				Corn silage + SBM[b]
	100:0	70:30	60:40	50:50	
Dry matter, %[c]	32.1	42.1	46.0	51.6	39.3
Proximate components, %[d]					
Crude protein[c]	9.3	17.1	18.5	19.8	17.6
Ash[c]	5.4	27.2	30.3	34.8	7.3
Cell wall components, %[d]					
NDF[c,e]	44.0	32.6	30.9	28.3	36.7
ADF[c,f]	24.5	20.5	18.8	17.7	20.7
Cellulose[c]	19.5	15.3	14.3	12.9	16.3
Hemicellulose[c]	19.5	12.1	12.1	10.6	15.9
Lignin	3.7	3.6	3.7	3.3	3.3

[a] Proportions on wet basis.

[b] Soybean meal.

[c] Corn silage vs waste treated silages differ ($P<.01$).

[d] Dry basis.

[e] Neutral detergent fiber.

[f] Acid detergent fiber.

waste levels (131 and 45 g/d, dry basis, respectively). When comparing the corn silage diet to the silage diets containing waste, digestibility of dry matter and organic matter were higher (P<.01) for the unsupplemented corn silage diet (table 12). The differences in digestibilities of organic matter were small, however. Apparent digestibility of crude protein was increased (P<.01) when corn forage was ensiled with waste, compared to ensiled corn forage alone. Filipot et al (1975) reported significant decrease in crude protein digestibilities when fresh caged layer waste was incorporated at level of 64%, wet basis, in sheep diets. The results of crude protein digestibilities agree with those reported by Lowman and Knight (1970), who reported increase in crude protein digestibility when dried poultry waste was added to corn forage. Similar results have been reported by Harmon et al. (1975b) when broiler litter was added to corn forage. Holter and Reid (1959) showed apparent digestibility increased exponentially as concentration of crude protein in forages increases. The apparent digestibility of cellulose and hemicellulose was higher (P<.01) for waste silages than corn silage fed alone. Digestibility of ADF and NDF also tended to be higher. The digestibilities of fiber fraction may have increased because the protein enriched feeds promote the microbial break down of fiber (Forbes and Garrigus, 1943).

Dry matter digestibility decreased linearly with waste level in corn forage-waste silages (P<.05). The difference was large when the waste level increased above 40%. Bull and Reid (1971) reported decreased dry matter digestibilities when air dried caged layer waste was added to the

TABLE 12. APPARENT DIGESTIBILITY OF ENSILED CORN FORAGE AND CORN CAGED LAYER WASTE MIXTURES FED TO SHEEP

	DIETS					
Item	Corn forage : Caged layer waste[a]				Corn silage + SBM[b]	SE[c]
	100:0	70:30	60:40	50:50		
	%					
Dry matter[d, e, i]	62.5	52.0	50.2	45.5	71.7	1.3
Crude protein[d, i]	53.7	62.8	64.8	62.2	78.4	1.2
Organic matter[d, i]	66.0	63.9	63.5	60.7	75.3	2.4
NDF[g]	55.6	57.2	63.8	58.6	65.0	2.7
ADF[h, i]	54.5	55.0	59.4	56.9	64.4	2.8
Cellulose[d]	58.1	68.4	70.0	67.5	69.0	2.0
Hemicellulose[d, f, i]	56.4	66.5	70.7	61.6	65.8	1.9
Lignin[i]	34.1	33.3	35.7	28.8	52.8	2.8

[a] Proportions on wet basis.

[b] Soybean meal.

[c] Standard error of means.

[d] Corn silage vs waste treated silages differ ($P<.01$).

[e] Linear effect of waste treated silages signifant ($P<.05$).

[f] Quadratic effect of waste treated silages signifant ($P<.05$).

[g] Neutral detergent fiber.

[h] Acid detergent fiber.

[i] 30% waste treated silage vs SBM supplemented corn silage differ ($P<.01$).

diets of dairy cows. Lowman and Knight (1970) reported a depression in dry matter and organic matter digestibilities when dried poultry waste replaced barley in the diet. In the present study hemicellulose digestibility showed a quadratic effect ($P<.05$), increasing when waste level increased from 30 to 40%, then decreasing for the 50% level.

Apparent digestibilities of dry matter, crude protein, organic matter lignin ($P<.01$) and ADF ($P<.05$) were higher for the soybean meal supplemented diet than the 70:30 silage.

Nitrogen Utilization

Nitrogen intake expressed as g/d, was lowest ($P<.01$), for the corn silage diet alone (table 13). The N intake for corn silage supplemented with soybean meal was not significantly different from the 70:30 silage diet. Within corn forage-waste silages highest N intake was for 70:30 silage diet, because of larger refusals by sheep fed the other two corn forage-waste silage diets.

Fecal, urinary and total N excretion was lower ($P<.01$) for the corn silage diet, compared to the waste diets. Within wasted treated silages fecal, urinary and total N excretion were similar ($P>.01$). Lambs fed 70:30 silage diets had higher fecal N excretion and lower urinary and total N excretion compared to the corn silage supplemented with soybean meals.

Nitrogen absorption was lower ($P<.01$) for the sheep fed the corn silage diet, compared those fed waste silages. Within corn forage-waste silages N absorption was not different. Lambs fed corn silage supplemented

TABLE 13. NITROGEN UTILIZATION BY SHEEP FED ENSILED CORN FORAGE AND CORN FORAGE-CAGED LAYER WASTE MIXTURES

	DIETS					
	Corn forage : Caged layer waste[a]				Corn silage +	
Item	100:0	70:30	60:40	50:50	SBM[b]	SE[c]
N intake[d], g/d	10.4	17.8	16.4	15.7	19.7	.99
N excretion[d,e], g/d						
Fecal	4.8	6.6	5.8	5.9	4.3	.40
Urinary	3.8	11.1	11.2	11.8	14.4	.57
Total	8.6	17.7	16.9	17.6	18.6	
N absorption[d,e], g/d	5.6	11.1	10.6	9.8	15.4	.67
N retention[d,f]						
Grams per day	1.8	.1	-.6	-1.9	1.1	.55
Percent of intake	17.2	.2	-3.7	-13.7	5.3	3.74
Percent of absorbed	31.9	.3	-5.7	-23.0	6.8	6.24

[a] Proportions on wet basis.

[b] Soybean meal.

[c] Standard error of means.

[d] Corn silage vs waste treated silages differ (P<.01).

[e] 30% waste treated silage vs SBM supplemented corn silage differ (P<.01).

[f] Linear effect of waste treated silages significant (P<.05).

with soybean meal had higher N absorption than those fed the 70:30 silage diet (P<.01).

Nitrogen retention expressed as g/d was higher (P<.05) for lambs fed the corn silage diet, compared to those fed the corn forage-waste silage (P<.01). Although N retention appeared to be low for 70:30 silage diet it was not significantly different from the soybean meal supplemented corn silage. Koenig and Boling (1980) used 9 yr old ewes, averaging 61.2 kg. In trial 1, ewes were fed 9.63% crude protein diet and in trial 2 ewes were fed 19.9% crude protein diet. Both diets were isocaloric (approximately 88% TDN). Nitrogen retention was similar for sheep fed low- and high-protein diets irrespective of the level of dietary protein. However, higher level of dietary crude protein resulted in high fecal and urinary N. The studies indicated that the low level of crude protein was sufficient to meet the needs of the animals. In sheep (31 kg) fed 12 and 21 g/d N the fecal and urinary N were 6.1 and 1.8, 5.3 and 6.2, respectively, (Bunting et al., 1987). Nitrogen retention expressed as percent of absorbed was 69% and 61% (differences not significant) for sheep fed the low and high protein diets, respectively. Evans and Boling (1978a) reported increased amino acid catabolism in older animals, perhaps due to a higher energy and lower amino acid requirement relative to young ewes. Thus, in the present study it appears that N intake of 10.4 g/d in the corn silage diet was sufficient for the 2-yr-old sheep. The high level of N intake for sheep fed corn forage-waste silages was above their requirements.

Ruminal Fluid pH, Ammonia Nitrogen and Blood Urea Nitrogen

The ruminal fluid pH was lower for sheep fed corn silage alone, compared to the waste treated silage diets ($P<.01$) (table 14). There were no significant differences within corn forage-waste silages, however, values tended to increase with increasing waste levels. Higher pH values were recorded for sheep fed the 70:30 corn forage-waste silage diet ($P<.01$) than sheep fed corn silage supplemented with soybean meal.

Ruminal NH_3 was lower ($P<.05$) in corn silage fed sheep, compared to those fed the corn forage-waste silages ($P<.01$). A tendency for increased ruminal NH_3 was recorded as the levels of waste in silages increased. Similar results have been reported by Samuels (1980), Albert (1977) and Harmon et al. (1974) in diets containing poultry wastes. This high level of NH_3 in the waste silage diets could be due to the high NH_3 levels and NPN sources in the waste. Higher rumen ammonia was detected for the corn silage supplemented with soybean meal, compared to the 70:30 corn forage-waste silage diet ($P<.01$).

Blood urea nitrogen (BUN) was higher for the the sheep fed corn forage-waste silages, compared to sheep fed the corn silage diet ($P<.01$). An increase in BUN was observed, as waste levels increased. The lower BUN level for sheep fed the corn silage diet could be due the lower N intake by the animals. Preston et al. (1965) reported a high degree of correlation between N intake and BUN. A linear increase in the BUN was observed as the levels of waste in the diets increased ($P<.01$).

Ruminal Volatile Fatty Acids

TABLE 14. RUMINAL FLUID pH, AMMONIA NITROGEN AND BLOOD UREA NITROGEN IN SHEEP FED ENSILED CORN FORAGE AND CORN FORAGE-CAGED LAYER WASTE MIXTURES

	DIETS					
	Corn forage : caged layer waste[a]				Corn silage	
Item	100:0	70:30	60:40	50:50	+ SBM[b]	SE[c]
Ruminal pH[d,e]	6.5	7.4	7.2	7.5	6.7	.13
Ruminal NH_3-N[d,e], mg/dl	9.1	23.6	25.9	28.9	39.0	4.00
Blood urea[d,f], mg/dl	4.3	16.8	21.4	23.9	16.3	1.29

[a] Proportions on wet basis.
[b] Soybean meal.
[c] Standard error of means.
[d] Corn silage vs waste treated silages differ ($P<.01$).
[e] 30% waste treated silage vs SBM supplemented corn silage differ ($P<.01$).
[f] Linear effect of waste treated silages significant ($P<.01$)

Total VFA concentration was not significantly different among all the diets (table 15). Acetic acid tended to be higher for lambs fed waste diets, compared to those fed only corn silage. Butyric acid levels were highest for corn silage compared to the corn forage-waste silages (P<.01). Propionic, isobutyric, butyric, isovaleric and valeric concentrations were lower (P<.01), for animals fed 70:30 waste treated silages, than those fed corn silage supplemented with soybean meal. High concentrations of acetic and propionic acid seemed to occur for waste fed silages.

Conclusion

The results of this study indicate the feasibility of ensiling caged layer waste with corn forage. Ensiling caged layer waste with corn forage resulted in increase in levels of lactic acid, compared to corn forage ensiled alone, probably because of the buffering action of nitrogen and ash in the waste. The pH was reduced markedly, which resulted in a complete elimination or reduction of total and fecal coliforms. Ensiling caged layer waste with corn forage at 50 and 60% levels, wet basis, tested positive for Salmonella, Shigella and Proteus, which suggests not using such high levels of waste to avoid any animal health problems. In sheep fed diets containing corn silage, corn forage-waste silages and corn silage supplemented with soybean meal, digestibility of dry matter, crude protein, organic matter, ADF and lignin were highest for the corn silage supplemented with soybean meal diet. Nitrogen retention was highest for sheep fed corn silage alone. Animals fed isonitrogenously with diets

TABLE 15. RUMINAL VOLATILE FATTY ACIDS IN SHEEP FED ENSILED CORN FORAGE AND CORN FORAGE-CAGED LAYER WASTE MIXTURES

	DIETS					
Item	Corn forage : caged layer waste[a]				Corn silage + SBM[b]	SE[c]
	100:0	70:30	60:40	50:50		
Total, μ mole/ml	58.8	63.1	65.9	54.3	61.8	7.2
Moles /100 moles						
Acetic acid	61.7	64.5	68.2	67.6	57.1	4.9
Propionic[d]	21.3	24.4	20.7	21.6	22.8	1.7
Isobutyric[d]	.7	.7	.8	.8	1.4	.05
Butyric[d, e]	13.9	8.4	8.4	7.8	14.8	.66
Isovaleric[d]	1.0	.9	1.1	1.2	2.2	.07
Valeric[d]	1.3	1.0	.9	1.0	1.8	.08

[a] Proportions on wet basis.
[b] Soybean meal.
[c] Standard error of means.
[d] 30% waste treated silage vs SBM supplemented corn silage differ ($P<.01$).
[e] Corn silage vs waste treated silages differ ($P<.01$).

containing caged layer waste gave a similar N retention response as those fed the diet supplemented with a conventional protein source.

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APPENDIX

APPENDIX TABLE 1. EXAMPLE OF ANALYSIS OF VARIANCE, CORN FORAGE-CAGED LAYER WASTE SILAGES, SMALL SILO STUDY. WATER SOLUBLE CARBOHYDRATES.

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                              Corn silage vs corn forage-waste silages

SOURCE               DF     SUM OF SQUARES      MEAN SQUARE     F VALUE      PR > F     R-SQUARE       C.V.
MODEL                 5        18.62008429       3.72401686       34.70      0.0001     0.856807    15.1876
ERROR                29         3.11187000       0.10730586                 ROOT MSE                SC MEAN
CORRECTED TOTAL      34        21.73195429                                0.32757573           2.15685714

SOURCE               DF          TYPE I SS    F VALUE    PR > F      DF       TYPE III SS    F VALUE    PR > F
TRTNO                 5        18.62008429      34.70    0.0001       5       18.62008429      34.70    0.0001

CONTRAST         a   DF                 SS    F VALUE    PR > F
1 VS 2 3 4 5 6        1        14.91733762     139.02    0.0001

                                          Waste levels

SOURCE               DF     SUM OF SQUARES      MEAN SQUARE     F VALUE      PR > F     R-SQUARE       C.V.
MODEL                 4         3.70274667       0.92568667       17.54      0.0001     0.737262    12.1536
ERROR                25         1.31955000       0.05278200                 ROOT MSE                SC MEAN
CORRECTED TOTAL      29         5.02229667                                0.22974334           1.89033333

SOURCE               DF          TYPE I SS    F VALUE    PR > F      DF       TYPE III SS    F VALUE    PR > F
TRTNO                 4         3.70274667      17.54    0.0001       4        3.70274667      17.54    0.0001

CONTRAST             DF                 SS    F VALUE    PR > F
LINEAR                1         3.45120167      65.39    0.0001
QUADRATIC             1         0.17100119       3.24    0.0840
CUBIC                 1         0.03360667       0.64    0.4324
QUARTIC               1         0.04693714       0.89    0.3547
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a 1. Corn silage.
2 3 4 5 6. Waste treated silages.

APPENDIX TABLE 2. EXAMPLE OF ANALYSIS OF VARIANCE, CORN FORAGE-CAGED LAYER WASTE SILAGES, LARGE SILO STUDY. CRUDE PROTEIN.

Corn silage vs corn forage-waste silages.

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SOURCE                 DF      SUM OF SQUARES      MEAN SQUARE      F VALUE      PR > F      R-SQUARE        C.V.
MODEL                   3        340.15991111     113.38663704      1244.25      0.0001      0.996263      1.9574
ERROR                  14          1.27580000       0.09112857                  ROOT MSE                   CP MEAN
CORRECTED TOTAL        17        341.43571111                                 0.30187509              15.42222222

SOURCE                 DF         TYPE I SS    F VALUE    PR > F       DF        TYPE III SS    F VALUE    PR > F
TRTNO                   3      340.15991111    1244.25    0.0001        3       340.15991111    1244.25    0.0001

CONTRAST               DF                SS    F VALUE    PR > F
1 VS 2 3 4 a            1      326.40444444    3581.80    0.0001
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Waste levels

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SOURCE                 DF      SUM OF SQUARES      MEAN SQUARE      F VALUE      PR > F      R-SQUARE        C.V.
MODEL                   2         13.75546667       6.87773333        52.70      0.0001      0.921327      1.9598
ERROR                   9          1.17460000       0.13051111                  ROOT MSE                   CP MEAN
CORRECTED TOTAL        11         14.93006667                                 0.36126322              18.43333333

SOURCE                 DF         TYPE I SS    F VALUE    PR > F       DF        TYPE III SS    F VALUE    PR > F
TRTNO                   2       13.75546667      52.70    0.0001        2        13.75546667      52.70    0.0001

CONTRAST               DF                SS    F VALUE    PR > F
LINEAR                  1       13.72880000     105.19    0.0001
QUADRATIC               1        0.02666667       0.20    0.6619
```

---

a 1. Corn silage.
2 3 4. Waste treated silages.

APPENDIX TABLE 3. EXAMPLE OF ANALYSIS OF VARIANCE, CORN FORAGE-CAGED LAYER WASTE SILAGES, SHEEP METABOLISM TRIAL. DRY MATTER DIGESTIBILITY.

Corn silage vs corn forage-waste silages

```
SOURCE                  DF     SUM OF SQUARES        MEAN SQUARE     F VALUE        PR > F        R-SQUARE            C.V.

MODEL                    9      2767.14230338       307.46025593       29.44        0.0001        0.929819          5.7317

ERROR                   20       208.85942381        10.44297119                      ROOT MSE                     DMDIG MEAN

CORRECTED TOTAL         29      2976.00172719                                   3.23155863                     56.38060294


SOURCE                  DF        TYPE III SS    F VALUE    PR > F

TRTNO                    4      2688.47512851      64.36    0.0001
BLOCKNO                  5        78.66717487       1.51    0.2323


CONTRAST a              DF                 SS    F VALUE    PR > F

1 VS 2 3 4               1       797.89820492      76.41    0.0001
2 VS 5                   1      1168.71753124     111.91    0.0001
```

Waste levels

```
SOURCE                  DF     SUM OF SQUARES        MEAN SQUARE     F VALUE        PR > F        R-SQUARE            C.V.

MODEL                    3       154.08946391        51.36315464        3.74        0.0366        0.444727          7.5311

ERROR                   14       192.39162259        13.74225876                      ROOT MSE                     DMDIG MEAN

CORRECTED TOTAL         17       346.48108651                                   3.70705527                     49.22299244


SOURCE                  DF        TYPE III SS    F VALUE    PR > F

TRTNO                    2       131.54154908       4.79    0.0261
BLOCKNO                  1        22.54791484       1.64    0.2210


CONTRAST                DF                 SS    F VALUE    PR > F

LINEAR                   1       123.48155459       8.99    0.0096
QUADRATIC                1         8.05999449       0.59    0.4565
```

---

a 1. Corn silage.
2 3 4. Waste treated silages.
5. Corn silage supplemented with soybean meal.