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Nutritive value of several silages produced from caged layer excreta and corn stover

Victor L. Fulgoni

To the Graduate Council:

I am submitting herewith a thesis written by Victor L. Fulgoni entitled "Nutritive value of several silages produced from caged layer excreta and corn stover." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

Karl M. Barth, Major Professor

We have read this thesis and recommend its acceptance:

J.B. McLaren, R.N. Heitman

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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We have read this thesis
and recommend its acceptance:

R. D. Hunter

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NUTRITIVE VALUE OF SEVERAL SILAGES PRODUCED FROM CAGED LAYER EXCRETA AND CORN STOVER

A Thesis

Presented for the

Master of Science

Degree

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Victor L. Fulgoni, III

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ABSTRACT

Two total-collection trials were conducted to determine the nutrient digestibility and nitrogen utilization of caged layer excreta-corn stover silages treated with or without silage additives. In trial 1, silages were produced from 18 or 30% excreta, 50% corn stover and various amounts of water to achieve a 50% moisture silage, and fed to 12 mature wether sheep.

The pH, after ensiling, was 4.6 for the 18% excreta silage and 5.0 for the 30% excreta silage. The 18% excreta and the 30% excreta silages contained: 48.8 and 45.8% dry matter; and on a dry matter basis, 10.5 and 14.0% crude protein; 1.30 and 1.69% ether extract; 29.2 and 28.5% crude fiber; 8.2 and 11.8% ash; 50.9 and 44.2% nitrogen-free extract; 46.2 and 46.4% acid-detergent fiber; and 4.57 and 7.18 mg/g uric acid, respectively. Dry matter intake of the 18% excreta silage was 1.17 kg/day and was similar to the 1.15 kg/day of the 30% excreta silage. Apparent digestion coefficients for the 18% and the 30% excreta silages were: dry matter, 46.4 and 47.1%; organic matter, 48.9 and 49.8%; crude protein, 59.4 and 65.2%; ether extract, 71.5 and 75.2%; crude fiber, 47.6 and 50.0%; nitrogen-free extract, 46.9 and 43.8%; and acid-detergent fiber, 35.0 and 36.5%, respectively. Total digestible nutrients were 46.1 for the 18% excreta silage and 45.5 for the 30% excreta silage. Dry matter, organic matter, crude fiber and acid-detergent fiber digestibilities were similar across treatment ($p>.05$). A significant increase in the digestibility of crude protein ($p<.01$) and ether extract ($p<.05$) was found for the 30% excreta silage while the 18% excreta silage supported higher ($p<.05$) nitrogen-free extract digestibility.

The nitrogen intake, nitrogen retention, true nitrogen digestibility, absorbed nitrogen retained, intake nitrogen retained, net protein utilization and net protein value of the 18% excreta silage were 19.7 g/day, 8.51 g/day, 85.09%, 50.42%, 9.77%, 36.06% and 4.51%, respectively, while for the 30% excreta silage they were 25.6 g/day, 1.94 g/day, 84.68%, 9.80%, -22.85%, 8.36% and 1.17%, respectively. The nitrogen intake was higher ($p<.01$) for the 30% excreta silage. All of the other nitrogen utilization parameters except true nitrogen digestibility were significantly higher ($p<.01$) for the 18% excreta silage. The true nitrogen digestibility was similar ($p>.05$) for both silages.

In trial 2, 16 wether sheep were used to determine the effect of silage additives on fermentation of excreta silage, nutrient digestibility and nitrogen utilization. The silage treatments were: no additives (control), Silabac (a bacterial additive), phosphoric acid (an acid additive) or the combination of Silabac and phosphoric acid. The level of excreta used in this trial was 22.5%; the corn stover was 50% of the ensiling material and again water was added to produce a 50% moisture silage.

The nutritional composition of the silages was quite variable. The dry matter of the silages treated with no additives (control), Silabac, phosphoric acid or the combination of the latter two was 58.4, 53.5, 55.2 and 61.6%, respectively; other nutrients, on a dry matter basis were: crude protein, 9.2, 8.6, 8.4 and 10.1%; ether extract, 1.22, 0.96, 0.85 and 1.20%; crude fiber, 27.9, 28.0, 30.4 and 28.2%; ash 12.5, 11.4, 9.4 and 15.2%; nitrogen-free extract, 49.1, 51.1, 51.0 and 44.8%; acid-deterent fiber, 42.5, 42.4, 45.0 and 40.9% and uric acid 5.98, 3.30, 3.63 and 9.38 mg/g, respectively.

Dry matter intake was 1.22, 0.97, 0.98 and 1.14 kg/day for the silages containing no additives, Silabac, phosphoric acid and the combination of both additives, respectively. Apparent digestion coefficients for these silages were: dry matter, 36.9, 40.8, 39.6 and 42.2%; organic matter, 40.7, 42.8, 45.0 and 44.2%; crude protein, 47.5, 40.5,31.3 and 45.9%; ether extract, 66.0, 58.8, 66.0 and 75.6%; crude fiber, 39.5, 44.1, 47.6 and 43.4%; nitrogen-free extract, 41.8, 46.4, 45.4 and 43.5%; and acid-detergent fiber, 33.3, 31.1, 37.1 and 36.2%, respectively. Total digestible nutrients were 37.7, 40.8, 41.8 and 38.5% for these silages, respectively. Dry matter digestibility was higher ($p<.01$) for the additive treated silages than that of the control silage although the organic matter digestibility was similar for all silages. The crude protein digestibility was higher ($p<.05$) for the Silabac treated silage than that of the phosphoric acid silage. However, ether extract digestibility was higher ($p<.05$) for the phosphoric acid silage than that of the silage treated with Silabac. Silage made with the combination of additives had higher ($p<.01$) ether extract digestibility than the mean of Silabac and phosphoric acid silages. Crude fiber dibestibility was higher ($p<.05$) for all the treated silages while there were no differences among treated silages ($p<.10$). Conversely, phosphoric acid treated silages supported higher ($p<.05$) acid-detergent fiber digestibility than that of the Silabac treated silage but the control silage and the mean of the additive treated silages had similar acid-detergent fiber digestibility ($p<.10$). Total digestible nutrients were higher ($p<.05$) with the additive treated silages than the control silage. A higher TDN ($p<.05$) was obtained when the additives were used singly rather than in combination.

Nitrogen intakes were 17.7, 13.2, 13.0 and 18.4 g/day for the control, Silabac, phosphoric acid and Silabac plus phosphoric acid silages, respectively. The nitrogen retention, true nitrogen digestibility, absorbed nitrogen retained, net protein utilization and net protein value for these silages were -2.93, -4.09, -3.67 and -3.52 g/day; 76.2, 72.7, 64.3 and 72.7%; 35.4, 27.4, 36.0 and 29.7%; 27.9, 20.2, 23.3 and 21,5% and 2.57, 1.85, 1.95 and 2.18%, respectively. Nitrogen intake was higher ($p<.05$) for the control silage than for the mean of the additvie treated silages while the silage treated with the combination of additives had higher nitrogen intake than that of the silages treated with the individual additives. The only other difference in nitrogen utilization was that of a higher ($p<.10$) true nitrogen digestibility with the Silabac treated silage over that of the phosphoric acid treated silage.

In addition, the changes in ruminal pH, volatile fatty acid and protozoa concentration were monitored as sheep were adapting to caged layer excreta-corn stover silage. To study ruminal changes, three fistulated wethers were initially fed hay and then abruptly changed to excreta silage. Also, the ruminal changes, when hay was reintroduced and when silage was offered after the latter hay period, were observed.

Regression equations were formulated for each phase with day or day^2 as the independent variables and pH, volatile fatty acid and protozoa concentrations as the dependent variables. Predicted values were calculated from these equations for certain days of the study. These predicted values indicated that ruminal pH increased (6.38 to 6.74) when feeding excreta silage and promptly decreased when hay was refed (6.74 to 6.41). Total volatile fatty acid concentration decreased upon silage feeding (101.3 to 77.1 mM/l) and dramatically increased when hay was refed (77.1

to 120.6 mM/l). Molar percent acetate decreased (71.7 to 64.9%) upon silage feeding and increased slightly upon hay feeding (64.9 to 66.9%). Conversely, molar percent propionate increased (19.4 to 24.6%) during silage feeding but remained constant upon refeeding hay (21.0%). Molar percent butyrate increased while sheep were on the silage (6.3 to 7.0%) and increased further when hay was refed (7.0 to 8.5) and collectively the molar percent of other acids followed the same pattern as butyrate.

Predicted protozoa concentrations, total, Entodinia, Dasytricha and Isotricha decreased when silage was fed but increased rapidly upon reintroduction of hay: total, 13.19 to 6.86 to 20.12 X 10^4/ml; Entodinia, 11.10 to 6.86 to 18.24 X 10^4/ml; Dasytrich, .27 to -.01 to .23 X 10^4/ml; Isotricha, .13 to .03 to .20 X 10^4/ml. Conversely, Diplodinia initially increased when silage was fed and then decreased (.38 to .57 to .45 X 10^4/ml). However, this protozoa did increase upon refeeding hay (.45 to 1.46 X 10^4/ml).

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CHAPTER I

INTRODUCTION

In the past two decades, agriculture has become very intensified. The poultry industry is one of the more intensified segments of agriculture and, because of this, approximately 50 million tons of poultry manure are produced annually. This manure is easily obtainable, especially in laying houses where the hens are kept in raised cages and their excreta drop below into a collection area. Poultry manure contains considerable quantities of nitrogen and minerals, and for this reason, it has traditionally been used as fertilizer. However, heavy fertilization with manure can lead to run-off problems which could contaminate water ways and potentially risk human health.

Due to its nutritional composition, a logical use for poultry manure is as a feed for animals. The nitrogen in the manure is mainly non-protein nitrogen and is primarily uric acid therefore, feeding this material is primarily limited to ruminants. In the rumen, microorganisms utilize non-protein nitrogen and convert it to bacterial protein-nitrogen which can be used by the host animal. The advantage of recycling manure through feeding is that more food can be made available for human comsumption. Poultry manure, when fed, is mainly used to supply nitrogen and, therefore, replaces valuable protein supplements and still allows for an adequate supply of beef and dairy products. The preformed protein such saved will be available for feeding of non-ruminants or available for even higher priority use, such as for human comsumption.

Other byproducts of agriculture are crop residues such as corn stover, wheat straw, oat straw, cotton gin trash, etc. It has been estimated that over 1,430,000 tons of corn stover alone are available in Tennessee and 953,000 mature brood cows could be maintained through the winter on this crop residue even though corn stover is a low quality forage. One possible way to feed this residue is to allow the cows access to the corn field after grain harvesting. However, this necessitates the fields to be fenced and thus increases material and labor costs. Alternative methods are to harvest the stover in bales or ensile it as stalklage. Researchers have successfully added non-protein nitrogen compounds to corn stover at ensiling to increase the nitrogen content of the stalklage. Therefore, it is feasible that corn stover can be ensiled with poultry manure to increase the nutritional value of the stalklage. Fresh manure can contain some harmful bacteria which could be introduced to animals upon feeding. Fortunately, proper ensiling has been found to be an adequate processing method to reduce the number of pathogens present in the manure.

The objectives of this study were to determine the nutrient digestibility and nitrogen metabolism of several caged layer excreta-corn stover silages fed to mature wether sheep. These silages varied in levels of excreta and in presence or absence of fermentation aids. In addition, the changes in pH, volatile fatty acid concentration and protozoa numbers in the rumen of fistulated sheep were observed during ration changes from long hay to caged layer excreta-corn stover silage and vice versa.

CHAPTER II

REVIEW OF LITERATURE

Caged Layer Excreta vs. Broiler Litter

Fontenot and Webb (1974) have stated that there are two main types of poultry manure: caged layer excreta and broiler litter. Broiler litter is from broilers and is a combination of fecal and urinary excretions and a base of absorbent material called bedding. The function of the bedding is to remove the moisture present in the excreta. The bedding material may be straw, sawdust, wood shavings, dried sugar cane, peanut hulls, etc. The bedding material used and the ratio of excreta to bedding greatly affects the nutritional value of the broiler litter. Conversely, caged layer excreta is usually free of any absorbent material because it is allowed to collect below their cages and thus the birds do not have any contact with their excreta.

The individual composition of broiler litter (BL) and caged layer excreta (CLE) is variable but there are some distinct differences between these two manures. Some of the major differences were reported in a review of animal waste feeding by Bhattacharya and Taylor (1975). Crude protein of the dried CLE (28%) was slightly lower than that of dried BL (31%). Parker et al. (1959) reported that upon drying, CLE and BL loses 17 and 11.6% of its original nitrogen, respectively. After correcting for these drying losses there is only one percentage unit difference (34.7 vs. 33.7%) in the crude protein content of the fresh manures, with BL being higher.

The composition of the nitrogenous compounds is different between these two manures. The true protein content is higher in BL (16.7 vs. 11.3%) (Bhattacharya and Taylor, 1975). Blair (1974) reported that the true protein was composed of undigested feed protein, endogenous fecal and urinary compounds, internal secretions, spilled feed, and probably products of bacterial fermentation in both the lower gut of the bird and in the accumulated manure in the poultry house. The higher true protein content of the BL may be due to increased spilled feed or the true protein present in the bedding material.

The amino acid pattern and concentration of the two manures are similar except for three amino acids. Cysteine is higher (1.17 vs. .09%) and glutamate (1.66 vs. 2.19%) and glycine (.88 vs. 2.14%) are lower in CLE (Flegal and Zindel, 1970; Bhattacharya and Fontenot, 1966).

The digestible energy (DE) and total digestible nutrients (TDN) of BL are higher than those of CLE when fed to sheep. The DE and TDN of BL are 2440 kcal/kg and 72.5%, respectively, while CLE contained 1911 kcal/kg DE and 52.3%. The lower DE and TDN of CLE are probably due to a combination of factors. The most important factor is the higher ash content of CLE (28%) as compared to BL (15%). The ash contains no energy and therefore acts as a diluting agent. However the ash in CLE contains considerably more essential minerals especially calcium and phosphorus (350% more calcium and 150% more phosphorus). Another factor that leads to higher DE and TDN in BL is that is contains slightly more ether extract (3.3 vs. 2.0%) then CLE (Bhattacharya and Taylor, 1975).

Problems With Feeding Fresh Excreta

One of the major problems associated with feeding fresh caged layer excreta to animals is the possible introduction of pathogenic organisms

directly to animals and indirectly to humans. Bhattacharya and Taylor (1975), in their review of animal waste feeding, separated possible pathogens into those concerning human health and those affecting animal health.

Viral and bacterial pathogens and their resultant diseases can adversely affect human health. The viral pathogens are New Castle's (conjunctivitis) and Chlamydia (pneumonia). Bacterial pathogens are Erysipelothrix rhusiopathia (erysipelas), Listeria monocytogenes (listeriosis), Mycobacterium avium (tuberculosis and tuberculin sensitivity), Candida albicans (vaginitis, oral lesions and bronchopulmonary infection), Aspergillus fumigatus (rhinitis, asthma and pulmonary disorders), Clostridia botulinum (food poisoning) and Salmonella spp. (enteritis).

The pathogenic organisms present in CLE and affecting animals, by species, are Salmonella pullorum (cattle and swine), Erysipelothrix rhusiopathia (swine and sheep), Listeria monocytogenes (poultry, cattle and sheep), Mycobacterium avium (monkeys and swine). This wide assortment of pathogens are not present in all CLE.

Other health problems can arise due to possible presence of coccidiostats, arsenicals, mycotoxcins, heavy metals, hormones, sulfa drugs, chlorinated hydrocarbons and carbamates. Some of these substances are added to the feed of the broilers and are excreted in the feces. Fortunately many of these contaminants are not fed to caged layers and thus are not present in their excreta (Taylor et al., 1974). The egg industry, in many cases, starts one-day old chicks out on wire and these birds remain off the floor and away from pathogens in their

excreta for their productive lives. Rearing birds in raised cages reduces the need for prophylactic medication to prevent disease and therefore, antibiotics or other medications are given only for therapeutic reasons (Hamblin, 1980).

Ways To Alleviate Problems

Since the egg industry does not feed many of the above mentioned substances, the major health problem with CLE is that of pathogens. These pathogens may be reduced in number or eliminated completely by various processing methods. The major methods include heat treatment, acid treatment, aerobic composting and anaerobic composting (ensiling).

Heat treatment. Heat is used in a variety of methods to decrease pathogens. The excreta may be dried or steamed. Many researchers have successfully fed dried or dehydrated poultry waste. The pathogens present in the excreta were essentially eliminated as evidenced by no adverse effects on animal health (Thomas et al., 1971; Tinnimit et al., 1972; Lowman and Knight, 1970; Gihad, 1976; Leibholz, 1969; Blair, 1974; Georing and Smith, 1977; Smith et al., 1976; Cullision et al., 1976; Oltjen and Dinius, 1976).

Long et al. (1969) used steam under either atmospheric pressure or 30 lb pressure with the resultant product called cooked poultry waste (CPW) and hydrolyzed poultry waste (HPW), respectively. On a dry matter basis, the HPW contained more crude protein and ether extract than CPW. However, CPW contained more crude fiber, ash and nitrogen-free extract. El-Sabban et al. (1970) compared CPW, HPW (called autoclaved poultry waste in their study) and dried poultry waste (DPW). The DPW was dried

for one minute in a constant flow forced-air-commercial dryer at a starting temperature of 450°C and an ending temperature of 150°C. The chemical composition of CPW and HPW were similar but crude protein and ether extract were lower and ash higher in DPW. In the above studies, the processed excreta contained few pathogens since the animals remained in good health.

The advantages of using heat treatment are its effectiveness in destroying pathogens and the ease of handling the product. The major disadvantage is cost which varies with the cost of fuel and the amount of moisture in the excreta. Blair (1975), using a 1975 price for oil ($.50/gallon), reported a drying cost of $9.50/ton of 40% moisture excreta while one ton of 80% moisture excreta cost $61.50 to dry. At today's oil prices these costs are at least double.

Another disadvantage is the loss of energy and nitrogen content upon drying. Shannon and Brown (1969) reported that nitrogen and energy losses upon drying were dependent on the drying temperature. With drying temperatures of 60°C and 120°C the nitrogen losses were 4.6 and 10.6%, respectively. The energy losses were 2.8 and 5.5% for the lower and higher temperatures, respectively. When excreta were freeze-dried, 4.8% of the nitrogen and 1.3% of the energy was lost. Parker et al., (1959) stated a loss of 17% of the original nitrogen upon drying at 78°C for 10 hours. Overall, these losses were variable and seem to be related to the age and moisture content of the excreta. It has been reported that non-protein nitrogen compounds, such as uric acid, present in high-moisture excreta are spontaneously converted to ammonia. The ammonia can escape from the excreta and the nitrogen content is decreased even before drying (El-Sabban et al., 1970).

Acid treatment. Bacterial growth has been substantially decreased in high moisture corn when treated with organic acids (Bothast et al., 1975). The success with moist grains has led to the treatment of caged layer excreta with acids to destroy pathogens. Acid treatment has successfully destroyed pathogens present in CLE since animals fed the treated excreta remained healthy (Evans et al., 1978b; Smith et al., 1979). Evans et al. (1978b), varying the dry matter of the excreta (50, 70 and 80%) and the propionic acid level (1.0, 1.5, 2.0% w/w, wet basis), reported that nitrogen was preserved for up to 90 days with 1.0% propionic acid. None of the propionic acid levels were able to preserve nitrogen past 60 days in the low DM excreta. This lack of preservation may be a function of NPN conversion to ammonia which subsequentially volatized and was lost, Smith et al., (1979) used an 80% propionic acid-20% acetic acid mixture supplied at .5% (w/w) to the fresh excreta as a processing method. Salmonella typhinarium were isolated from untreated excreta but none were found in the treated excreta or the excreta diets.

Composting

This processing method reduces the number of pathogenic organisms and improves storage ability while preventing putrifcation (Syrett, 1977). Composting can be conducted aerobically or anaerobically (ensiling).

Aerobic composting. Stambough and White (1975) preferred aerobic composting of CLE because of (1) low odor release, (2) neglible leaching of soluble substrates into the ground water supplies, (3) minimal

run-off into waterways, (4) elimination of bacteria and parasite eggs and (5) available storage capacity. Aerobic composting produces temperatures within the mass of 50 to 75°C which aids in the evaporation of water and the elimination of bacteria and parasite eggs. Berkowitz et al. (1974) and Alexander et al. (1968) reported that Salmonella, a common pathogen in CLE, was inhibited in composting manure. Since a proper carbon-nitrogen ration is necessary for the maintenance of aerobic composting, straw, corn stover or other low nitrogen residues may need to be added.

The primary problem associated with aerobic composting of CLE is the cost of equipment to keep the compost pile aerobic. Some type of tiller or mixer is necessary. Another disadvantage of aerobic composting of CLE is that organic matter and nitrogen are lost (Evans et al., 1978a).

Anaerobic composting (ensiling). Ensiling is actually anaerobic composting. Again, as in aerobic composting, a proper carbon-nitrogen ratio is necessary (Syrett, 1977). This can be achieved with the addition of low nitrogen crop residues or even corn green chop to the CLE. During the ensiling process, the sugars present are fermentated by bacteria to lactic and acetic acids. As the acid content increases, the pH decreases and most pathogenic bacteria are eliminated. Eventually, the acid concentration and the pH stabilize. Under these conditions even the lactic acid producing bacteria might be eliminated. The finished silage is then essentially free of bacteria (McCullough, 1978). McCaskey and Anthony (1975) reported that to destroy Salmonella, a major pathogen in CLE, a pH of less then 5.0 must be achieved. These

researchers also reported that acetic acid was more inhibitory than lactic acid at pH of 4.0 and 5.0. Vezey and Dobbins (1975) reported that the lowest pH obtained with CLE silage was 4.6 while Saylor and Long (1974) reported that their lowest pH was 5.2.

Successful fermentation of excreta-containing products is dependent on the moisture content of the ensiling material. Pathogens may survive without proper fermentation and acid production. Caswell et al. (1977) reported limited fermentative activity in silages with moisture contents of 20% and below. Conversely, putrifaction occurred in CLE-grass hay silages containing more than 65.7% moisture (Saylor and Long, 1974). Therefore, it seems that the proper moisture level is between 35 and 60% (Cross, personal communication).

As the silo is being filled, some oxygen becomes trapped in the packed material. This oxygen must be depleted before ensiling can commence. While the oxygen is present, some water-soluble carbohydrates are oxidized aerobically, releasing substantial quantities of heat. This heat causes the condensation of the hemi-cellulose fraction of the ensiling material with the nitrogen fraction. This reaction is called Maillard reaction and is characterized by a caramelized odor and a brown color of the silage. The Maillard reaction decreases the availability of crude protein and, therfore, decreases crude protein digestibility of the silage. This is one possible disadvantage of this processing method although the Maillard reaction can be minimized by proper ensiling techniques.

Caged Layer Excreta Feeding

The nitrogen excretion product of avian species is mainly uric acid. However, considerable amounts of true protein are present in the excreta.

Leibholz (1969) reported that CLE contains 41% free amino acids while Blair (1975) stated that 33% of the excreta nitrogen is true protein. Uric acid values of CLE, as a percent of the nitrogen, reported are 38.7% (Leibholz, 1969), 39 to 50% (Oltjen and Dinius, 1976), to as much as 62.3 to 64.8% (Smith et al., 1978). The variable uric acid content is related to the length of time excreta accumulated below the cages (Evans et al., 1978a). It has been reported that the non-protein compound uric acid is superior to urea and biuret when fed as a nitrogen source to cattle. The probable reason for this is the slow release of ammonia in the rumen from uric acid (Oltjen et al., 1968).

The feeding of caged layer excreta is usually limited to ruminants because micro-organisms in the rumen are capable of utilizing non-protein nitrogen as a nitrogen source to form high biological-value bacterial protein. This protein is then utilized by the host animal. Sheep and beef cattle have been fed CLE, processed in different ways, by various workers.

Sheep. Gihad (1976) fed low quality hay supplemented with 300 g/day dried caged layer excreta (22% crude protein). The dry matter (DM) intake and the apparent crude protein digestibility were 839 g/day and 66.9% respectively, for 55 kg sheep.

In that study, dried CLE was comparable to soybean meal (SBM) as a protein supplement based on feed intake and rate of gain. El-Sabban et al. (1970) reported that feeding 28% hydrolyzed CLE (48% CP) as a protein supplement in a semi-purified ration decreased the crude protein digestibility as compared to 26% SBM and 25% cooked CLE (48% CP) supplements ($p<.05$). Dry matter intake by lambs was similar in all protein-supplemented rations

and was approximately 550 g/day. Dried CLE has also been found to be comparable to meat meal as a protein supplement for sheep based on rate of gain (Leibholz, 1969).

Beef cattle. Smith et al. (1978) fed unprocessed CLE, SBM or urea as a supplement to a corn silage ration. The DM intakes of all the supplemented rations, approximately 4.0 kg/day, were similar when fed to 90 kg bull calves. Dry matter intakes of a ground-shelled corn ration supplemented with 4.8% SBM, 4.9% hydrolyzed CLE (35% CP) or 4.9% dried CLE (25% CP) were found to be similar when fed to steers averaging 301 kg (El-Sabban et al., 1970). In a later study, Smith et al. (1979) reported increased DM intake of a corn silage ration when 22% wet, acid-treated CLE (32% CP on DM basis) was supplemented as a nitrogen source as compared to 3.5% SBM or 0.6% urea supplements.

Researchers have found that CLE in various forms used as a nitrogen supplement, supports similar gains and feed efficiencies as SBM (Smith et al., 1978; El-Sabban et al., 1970). Carcass characteristics and meat acceptibility were not affected by adding CLE to the diet (Smith et al., 1978; Smith et al., 1979; El-Sabban et al., 1970).

Corn Stover Feeding

Johnson et al. (1966) reported that 40 to 50% of the corn dry matter is left in the field after grain harvesting. This byproduct is a low quality roughage due to its high cellulose and hemi-cellulose content and its extensive lignification of the cell walls. Chemical treatment with NaOH has been used with some success in increasing fiber digestibility by delignifing the cell walls (Klopfenstein et al., 1972; Berger et al., 1979).

Berger et al. (1979) studied ensiling as a means of increasing nutrient availability of corn stover. Stalklage (ensiled corn stover) harvested at two different dates, was ensiled at 60% moisture with or without NaOH addition. Since the stalklage was low in nitrogen, the rations were supplemented with brewers grain and urea or with brewers grain, blood meal, meat meal and urea. Early harvested stover, after ensiling supported higher gains (.63 vs. .42 kg/day) and better efficiencies (14.8 vs. 10.8 feed, kg/gain, kg). Stalklage treated with NaOH gave variable results. However, Klopfenstein et al. (1972) reported that NaOH-treated 50% moisture stalklage, supplemented with SBM, had higher in vitro dry matter digestibility, and increased organic matter and cell wall constituents digestibility than untreated, SBM supplemented stalklage when fed to lambs.

Holloway et al. (1977) ensiled corn stover at 52% moisture. Mature wether sheep, when fed this stalklage, had lower DM digestibility (35.9 vs. 48.9%) and acid-detergent fiber digestibility (37.1 vs. 46.0%) than when the seep were fed dry corn stover. However, crude protein digestibilities of these rations were similar. Also, beef cows consumed more dry corn stover DM than stalklage DM (10.7 vs. 5.3 kg/cow/day) although cows on either ration lost similar amounts of weight (59.1 kg).

Colenbrander et al. (1971a and 1971b) added inexpensive NPN sources to the corn stover before ensiling instead of feeding expensive concentrates as a nitrogen supplement after ensiling. These NPN sources were either urea (0, .25, .50 and .75% w/w) or ammonium pyrophosphate (0, .29, .58 and .87% w/w). The DM of the resultant silages was similar but crude protein increased linearly with increasing increments of urea or ammonium pyrophosphate addition. In an animal feeding study, these researchers

reported that corn stalklage containing ammonium pyrophosphate increased gain and feed efficiency while urea-containing stalklage supported similar performance as the untreated stalklage (.42 vs. .27 and .24 kg/day; 12.3 vs. 19.3 and 18.2 feed DM, kg/gain, kg). The better performance was attributed to the increased phosphorus supplied by the ammonium pyrophosphate.

Caged Layer Excreta-Residue Silages

Limited work has been reported on the utilization of these two agricultural byproducts, although Claybough (1975) stated the ensiling corn stover and CLE "is the most economical, logical and practical technique" to utilize these two materials. Barth and Mohammed (1980) fed both wheat straw or corn stover CLE silages to adult wethers. The DM intake of these rations were 860 and 930 gm/day, respectively. The digestibility of DM, organic matter (OM), crude protein (CP), ether extract (EE), crude fiber (CF), N-free extract (NFE) and acid-detergent fiber (ADF) was 50.2, 55.8, 80.3, 46.9, 56.1, 32.9 and 50.0% for the wheat straw-excreta silage and 50.4, 54.4, 89.7, 11.3, 56.9, 35.0 and 49.2% for the corn stover-excreta silage, respectively. Total digestible nutrients were 47.2% for the wheat straw-excreta silage and 45.8% for the corn stover-excreta silages.

When the energy of the ration was increased by feeding oats, OM, EE and NFE digestibility increased ($p<.05$) while CF and ADF digestibility decreased ($p<.05$). Adding oats to the diet also somewhat increased total digestible nutrients ($p<.05$). Saylor and Long (1974) reported *in vitro* organic matter digestibility of 55.5 and 59.4% for grass hay ensiled with 70 or 60% fresh caged layer excreta, respectively.

Nitrogen retention was more positive for corn stover-excreta silage (2.8 gm/day) then wheat straw-excreta silage (0.7 gm/day) (Barth and Mohammed, 1980). True nitrogen digestibility, absorbed nitrogen retained, net protein utilization and net protein value were 92.4, 26.6, 24.6 and 5.5% for the wheat straw excreta silage, respectively and 92.4, 30.8, 28.4 and 7.0% for the corn stover-excreta silage. The addition of oats did not affect nitrogen metabolism.

Factors Affecting Ruminal Protozoa

Ruminal protozoa are classified as either holotrichs or oligotrichs. The holotrichs consist mainly of Isotricha and Dasytricha species. Isotricha spp. ferment soluble sugars and small granular starch to acetate, butyrate and lactate with hydrogen and carbon dioxide released as byproducts. Conversely, Dasytricha spp. utilize only soluble sugars to produce the same endproducts as the Isotricha spp. but methane may be an additional byproduct (Hungate, 1966; Church, 1976).

Oligotrichs, consisting of mainly Entodinia, Epidinia and Diplodinia, utilize only granular starch but the fermentation products are similar to those of the holotrichs (Hungate, 1966; Church, 1976).

Warner (1961) stated that many factors influence numbers and proportions of rumen micro-organisms, including protozoa. He found that animals fed the same ration can have very different protozoa populations. It was also stated that after an animal has been severely underfed or starved for 4 days the rumen may become devoid of some species of protozoa. Following refeeding the remaining protozoa increase in number to the point that the total microbial protoplasm returns to the pre-underfeeding levels. But this researcher was quick to point out that

the qualitative nature of the ration is more important then the quantitative aspect, which suggests that protozoa numbers may indicate the nutritional value of the ration.

The protozoa population in the rumen is sensitive to the pH in the rumen. Purser and Moir (1959) reported that if the pH drops below 6.0, as seen in concentrate feeding, inhibition of cellular division occurs and protozoa numbers decrease. Christiansen et al. (1964) found that, as the particle size of the ration was changed from a coarsely ground ration to a finely ground ration protozoa numbers decreased from 8.5 X 10^4 to 4.1 X 10^4 protozoa/ml. When animals were changed from a full-feed regime to two thirds of that regime, protozoa numbers increased from 0 to 15.2 X 10^4 protozoa/ml. The previous results may be due to the resultant changes in the rate of passage of the digesta.

Lyle (1979) reported that as animals were changed from an all-forage diet to a forage ration supplemented with grain, total protozoa initially increased from 1.7 X 10^5 to 7.24 X 10^5/ml. As expected, the major increase in total protozoa was primarily due to increased Entodinia since the dietary starch content increased. When the ration consisted of only grain, the starch content in the diet increased even more and the ruminal pH dropped to such levels (pH 5.93) as not to support protozoa survival and defaunation occurred. This again emphasizes the fact that protozoa are sensitive to the composition of the ration entering the rumen.

Factors Affecting Ruminal pH

The pH of the rumen can vary with location within the rumen, with the diet, with time after feeding and with CO_2 levels of the rumen fluid

(Church, 1976). It was also reported that the pH of the rumen is relatively high when the animal was fed low quality roughage and relatively low when the animal was fed silage.

Briggs et al. (1957) reported an inverse relationship between volatile fatty acid concentration and pH. Lactic acid concentration in the rumen was also inversely related to pH. Other factors that can affect pH have been reported (1) ash content (Cason et al., 1954), (2) level of ammonia nitrogen in the rumen (Clark and Weiss, 1952) and (3) physical characteristics of the feed (Bailey, 1961). Oltjen and Dinius (1976) reported that after a 4 day adaptation period, ruminal pH of steers fed a timothy hay-cracked corn ration was similar when supplemented with either urea, biuret or dried CLE. However, after 28 days of adaptation, biuret promoted the highest ruminal pH ($p<.10$).

Factors Affecting Volatile Fatty Acid Concentration in the Rumen

The volatile fatty acids (VFA) found in the rumen are formate, acetate, isobutyrate, propionate, isovalerate, valerate and traces of carproate and caprylate (Church, 1976). Usually only the major acids, acetate, propionate and butyrate, are reported while the other acids are combined and called the higher acids (these acids have a higher number of carbon atoms). The concentration of these acids in the rumen depend on (1) the rate of acid production, (2) the rate of acid absorption, (3) the rate of passage of rumen contents, (4) saliva and water dilution, (5) acid utilization by rumen microbes and (6) conversion of acids to other rumen metabolites and the actual interconversion of the acids (Wheaton et al., 1970).

Oltjen and Dinius (1976) reported that total VFA (mM/l) in the rumen fluid was similar for steers fed a timothy hay-cracked corn ration supplemented with either uric acid, biuret or dried CLE. However, butyrate and valerate concentration was higher and acetate concentration was lower in the rumen of steers fed the dried CLE ($p<.05$).

Silage Additives

Bolsen (1978) describes silage additives as products that (a) supply lactic acid producing organisms, (b) supply nutrients required by lactic acid producing micro-organisms and (c) supply enzymes and/or micro-organisms that increase the availibility of carbohydrates and other nutrients needed by lactic acid producing bacteria. One could add to this list a substance that promotes the proper environmental conditions for the optimal growth of lactic acid producing micro-organisms. Such substances are inorganic acids which would selectively promote the acidophillic lactic acid producing micro-organisms.

Lactobacillus additives. Bolsen (1978) summarized 10 experiments in which lactobacillus organisms were added to the ensiling mixture. An average of the results showed that dry matter recovery was improved 5.4% over the control silage. When animals were fed the silage, daily gain was improved 9.2% and feed efficiency increased 7.2% above that of the control silages. LaBarbera et al. (1980) reported decreased dry matter and crude protein recovery from alfalfa silage treated with .05% (w/w) Silabac, the manufacturer's recommended level. However, when the Silabac was added at .25% (w/w), dry matter and crude protein recoveries were greater than in the untreated alfalfa silage. Silabac was found to promote better aerobic stability, after ensiling, than the control

silage (Bolsen et al., 1980a and 1980b). This may indicate that Silabac treated silages are preserved better than untreated silages. It was also reported that silages treated with Silabac had a slower initial temperature rise than the control silage (15 days vs. 9 days, respectively). The post ensiling temperatures were also lower for the Silabac treated silages. This would indicate that this additive might conserve protein and energy in the ensiling material by decreasing the severity of the Maillard reaction.

Phosphoric acid additive. Wilson and Webb (1937) preferred adding phosphoric acid to silages because it "produces preservative conditions for the fodder, increases the quantity of phosphorus available to the animal and results in a higher phosphatitic fertilizer." Phosphoric acid was added at various levels to mixed grass and ensiled (Pagé and Maynard, 1940). They reported that phosphoric acid addition decreased the amount of proteolysis during ensiling and that phosphoric acid would be safer to use as a silage additive than the acid mixture of A. I. Virtanen which involves adding a corrosive mixture of hydrochloric and sulfuric acids. The latter mixture of acids actually stabilized the fodder while the former allows bacteria to ferment the carbohydrates present in a weakly acidified environment.

Unfortunately, unless the phosphoric acid treated silages are supplemented with limestone, sodium bicarbonate or legume hay the acid-base balance of the animal can be disrupted as evidenced by acid urine and increased urinary ammonia levels (Lepard et al., 1940; King, 1943). Sodium bicarbonate was found to be better in neutralizing the effects of the phosphoric acid treated silage than limestone ($CaCO_3$) or legume

hay. Caged layer excreta contains considerable amounts of calcium in the form of calcium carbonate (Bhattacharya and Taylor, 1975; Evans et al., 1978a). This calcium is similar to that in limestone and should, therefore, neutralize some of the acid-base imbalance of the animal.

CHAPTER III

EXPERIMENTAL PROCEDURE

Two trials were conducted to determine nutrient digestibility and nitrogen utilization of caged layer excreta-corn stover silages by mature wether sheep. Trial 1, conducted in 1978, consisted of two dietary treatments. One of these rations was approximately at the maintenance level of crude protein while the other ration was above maintenance. Because nutrient requirements for adult wether sheep are not listed in N.R.C. (1975), they were estimated from those of non-gestating, non-lactating ewes. Trial 2 was conducted in 1979 and consisted of four dietary treatments which were designed to determine the effect of two silage additives, singly or in combination, on the nutritional value of caged layer excreta-corn stover silage. The four experimental treatments were: (1) untreated control silage; (2) Silabac[1]-treated silage; (3) phosphoric acid treated silage; and (4) a combination of treatments 2 and 3. In addition, a rumen parameter study was conducted concurrently with trial 1, utilizing three rumen fistulated wether sheep to determine the effect of caged layer excreta-corn stover silage on ruminal pH, volatile fatty acids and protozoa.

Digestion and Nitrogen Metabolism Studies

Ration constituents. In trial 1, the corn stover was obtained from plots where the corn grain had been hand harvested. The stover used in trial 2 was from a corn field in which the grain had been harvested mechanically. In both trials, individual stalks were cut by hand and then collectively ground through a hammermill to an average length of 1 cm.

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[1]Pioneer Hi-Bred International, Inc., Des Moines, Iowa.

collectively ground through a hammerhill to an average length of 1 cm. Since ensiling was not practical at the time of collection, the corn stover was dried in a forced air oven at 65° C for about 1 week to prevent mold spoilage. After drying, the stover was stored until ensiling.

Excreta, for both trials, were collected from caged laying hens fed a conventional type corn-soybean meal-alfalfa meal diet. This diet contained 16.6% crude protein, 2.9 Mcal/kg metabolizable energy, 3.2% calcium, 0.62% total phosphorus and 0.41% available phosphorus. The excreta used in trial 1 had accumulated below the cages for only a few days while, in trial 2, they had accrued for almost 6 months.

Preparation of the rations. The silages were calculated to contain approximately 50% moisture because successful fermentations have been reported in the moisture range of 30 to 60 percent. In trial 1, to obtain the two previously-mentioned levels of crude protein and about 50% moisture, different proportions of excreta, corn stover and water were used. In the maintenance ration, 18% wet excreta, 50% corn stover and 32% water by weight were combined while the above-maintenance ration contained 30% wet excreta, 50% corn stover and 20% water. In trial 2, 22% excreta, 50% corn stover, 28% water and the respective silage additives were used in the ensiling mixture. Silabac (a live bacterial additive) was supplemented at the manufacturer's suggested rate of .05%, ortho-phosphoric acid (reagent grade, an inorganic acid additive) was added at 0.4% (w/w) and in treatment 4, both additives were used, each at the above-mentioned rate.

The preparation of the ensiling mixture was similar for both trials. The fresh excreta were premixed with a small quantitiy of corn stover in

a Hobart mixer to prevent clumping. This premix was then placed in a horizontal Marion mixer and the remaining portion of corn stover was gradually added along with the appopriate quantities of water and, in trial 2, silage additives. After thorough mixing the material was packed, by hand, into 55 gallon steel drums lined with two layers of plastic bags. The bags were individually sealed with the exclusion of air above the ensiling mass. The drums were then placed in a storage room (temperature 20-25°C) and remained there during the ensiling period of six weeks.

Description of sheep. In trial 1, twelve mature grade Hampshire wether sheep were used. These sheep averaged 86.9 kg and ranged in age from 2 to 8 years. Sixteen grade Hampshire wethers were used in trial 2 and they averaged 75.3 kg and were between 3 years and 6 years of age.

General procedures. In trial 1, the wethers were paired as closely as possible to age and weight and six each were assigned to one of the silage treatment groups. While in trial 2, only weight was considered when allotting four wethers each to a silage treatment. The sheep were placed in metabolism crates (Briggs and Gallup, 1955) and maximum silage intakes were determined during a 10-day preliminary period. The animals were fed one-half their daily ration at 8 am and 4 pm. Water was offered for a one-half hour peroid prior to each feeding and a trace mineralized salt block was offered free choice. The preliminary period was followed by a 7-day collection period during which feed, refusal, feces and urine samples were collected. Feed and refusal samples were composited daily. Daily fecal outputs were measured and a 10% aliquot was composited daily for each sheep. Mold growth was inhibited by the addition of a few thymol crystals daily.

In trial 1, the daily urine excretions were diluted to a constant 2 liter volume and then a 10% aliquot was taken to be added to each composite sample while in trial 2, an undiluted 10% aliquot of the daily excretion was composited. In both trials, 10 ml of 6N hydrochloric acid was added initially to the composite sample container and daily to the urine collection vessels to preserve the urine samples. All composite samples were kept under refrigeration until analyzed.

Chemical analyses. Feed, refusal and fecal samples were dried at 50°C for 72 hr and allowed to air equilibrate for the same period of time. The samples were then ground through a 1 mm mesh screen of a Wiley Mill. Complete proximate analysis according to A.O.A.C. (1975) methods, was conducted on feed, refusal and fecal samples while only crude protein was determined on the urine samples. Acid-detergent fiber was determined according to Van Soest (1963). Digestibility coefficients of each respective nutrient, percent digestible nutrients and nitrogen utilization parameters were calculated.

The pH of the silages was determined according to McCullough (1978). Uric acid content of the excreta and the resultant silages was determined spectrophotometrically after Li_2CO_3 extraction (Pudelkiewicz et al., 1967).

Statistical analyses. Since animals were paired according to age and weight in trial 1, significant differences in digestibility and nitrogen utilization parameters were determined using a paired-t test. In trial 2, orthognal comparisons were used to determine significant differences in digestibility and nitrogen utilization parameters. The comparisons of interest are presented in Table 1. In the first comparison, the untreated control silage was compared to the treated silages. The second

comparison determined the differential effects of silage treated with a bacterial additive (Silabac) or an inorganic acid additive (o-phosphoric acid) on nutritive value. The last comparison was used to determine the possible interaction between the two additives.

Table 1. Orthogonal Comparisons of Silage Additives Used in Trial 2

	Caged layer excreta-corn stover silage			
Comparisons	Untreated control	Silabac	o-Phosphoric acid	Silabac plus phosphoric acid
1	+3	-1	-1	-1
2	0	+1	-1	0
3	0	+1	+1	-2

Rumen Parameter Study

A study was conducted to determine the changes in ruminal pH, volatile fatty acid concentration and protozoa numbers while ruminants adapt to a different ration. The objectives of this study were twofold: (1) to determine ruminal adaptation from a hay diet to an excreta silage diet, from an excreta silage diet to a hay diet and then back to an excreta silage diet; (2) to determine the effect of caged layer excreta-corn stover silage on ruminal parameters.

Description of trial. Three mature Suffolk wether sheep, fitted with permanent rumen fistulas, were taken off pasture supplemented with long hay and placed on the experimental regime. Two experimental diets were used: (1) a tall fescue-red clover hay and (2) a caged layer

excreta-corn stover silage. The hay contained 88.4% dry matter. The hay dry matter contained 15.3% crude protein, 2.0% ether extract, 29.9% crude fiber, 7.5% ash, 45.3% N-free extract and 46.5% acid-detergent fiber. The excreta silage was a 50-50 mixture of the two silages in trail 1. The calculated composition of the mixed silage was 47.3% dry matter, and, on a dry-matter basis, crude protein 12.3%, ether extract 1.5%, crude fiber 28.8%, ash 10.0%, N-free extract 47.5% and acid-detergent fiber 46.3%.

At the beginning of the trial, a tall fescue-red clover hay was fed for a period of three days. This period was followed by an abrupt dietary change to the excreta silage. The silage was fed for 18 days. The sheep were then abruptly changed back to the tall fescue-red clover hay and remained on this diet for a period of 9 days. And finally, the diet was switched back to the excreta silage. During this period the silage was fed for 7 days.

The fistulated wethers were housed in a 1 m x 2 m pens containing wood shavings as bedding. No further restraints on animal movements were made and limited physical contact between sheep was possible. The animals were fed at 8 am and 4 pm. When the dietary treatment was tall fescue-red clover hay, 2.0 kg was offered. When the excreta silage was fed, 2.35 kg/sheep was offered.

Sampling procedure. Duplicate 100 to 120 ml rumen fluid samples were taken every 2 days from each sheep, via the fistula, by evacuation. These samples were taken 5 hours after the morning feeding. The pH of the duplicate samples was determined as quickly as possible with a pH meter standardized with 4.0 and 7.0 solutions. The 10 ml aliquot of

rumen fluid was added to 10 ml of 40% formalin to preserve a protozoa for later counting. And finally an 80 ml sample of rumen fluid was placed in a plastic bag, cooled in water and then frozen for later VFA analysis.

Chemical analyses. Protozoa numbers by species were counted on each rumen sample. The methods used were similar to those of Boyne et al. (1957) and Purser and Moir (1959). A 1 ml aliquot of the formalin-preserved rumen fluid was mixed with 2 drops of brilliant green dye and allowed to stand for at least 4 hours. After diluting the stained sample with 9 ml of 30% glycerol, a 1 ml aliquot was pipetted into a Sedwick-Rafter counting chamber. A calibrated stage microscope was fitted with an eyepiece which projected a gridded field with an area of .25 mm^2 onto the counting chamber. Fifty fields were counted and then the counting chamber was rotated 180^{o} and another 50 field count was made. The average of these two counts was used in calculating the number of protozoa per ml of rumen fluid.

Volatile fatty acid analysis were performed on only one of the duplicate rumen samples. The method used for sample preparation and gas-liquid chromatography quantification was similar to that of Erwin et al. (1961).

Statistical analysis. Regression equations were formulated with day as the independent variable for each individual feeding period for pH, VFA's and protozoa. The linear regression equation for the individual periods was:

$$Y = a + b_1 \text{ (day)}.$$

where: Y = dependent variable.

a = intercept.

day = day of adaptation.

b_1 = the regression coefficient for the dependent variable on the independent variable = day.

The quadratic regression equation for the individual periods was:

$$Y = a + b_1 (day) + b_2 (day)^2.$$

where:

Y = dependent variable.

a = intercept.

day = day of adaptation.

b_1, b_2 = the regression coefficient for the dependent variable on the independent variable = day, day^2.

CHAPTER IV

RESULTS AND DISCUSSION

Trial 1

Silage composition. The nutrient composition of corn stover (CS), caged layer excreta (CLE) and the resultant silages are presented in Table 2. On a dry matter basis (DMB), CS contained 33.7% crude fiber (CF), 54.4% nitrogen-free extract (NFE) and only 6.1% crude protein (CP) which is similar to values reported in the N.R.C. (1969) tables of average nutrient composition of feedstuffs while ash and ether extract (EE), 4.9 and .89% on a DMB, respectively, were slightly lower. The CLE dry matter contained 39.3% CP, which is comparable to values reported by El-Sabban et al. (1969), Smith et al. (1977), Smith et al. (1979) and Barth and Mohammed (1980). The ash content (33.1% on a DMB) was slightly higher than other values presented for fresh CLE (Smith et al., 1978; Evans et al., 1978a).

The pH of the silages indicated proper fermentation and acid production. Since a pH of lower than 5.0 was obtained, the destruction of Salmonella and other pathogens should have occurred according to McCaskey and Anthony (1975). During the trial, no adverse affects on animal health due to CLE silage-feeding were noticed.

The dry matter (DM) percentages of the silages were 48.8 and 45.8% for the 18% CLE and the 30% CLE silages, respectively. The 30% CLE silage contained proportionally more CP, EE and ash and less NFE. Acid-detergent fiber and CF were similar for both silages. The ADF in these silages was less than that reported in corn stalklage or ammonia-treated

Table 2. Nutrient Composition of Ration Constituents and Rations in Trial 1

Constituent or ration	Dry matter,%[b]	Crude protein,%[a]	Ether extract,%[a]	Crude fiber,%[a]	Ash,%[a]	Nitrogen-free extract,%[a]	Acid detergent fiber,%[a]	Uric acid mg/g[a]	pH
Ration constituents									
Corn stover	90.2	6.1	0.89	33.7	4.9	54.4	51.7	—	—
Caged layer excreta	22.8	39.3	1.53	16.8	33.1	4.1	23.1	25.5	—
Caged Layer excreta-corn stover silages									
18% caged layer excreta	48.8	10.5	1.30	29.2	8.2	50.9	46.2	4.57	4.6
30% caged layer excreta	45.8	14.0	1.69	28.3	11.8	44.2	46.4	7.18	5.0

[a]Dry-matter basis.

[b]Fresh basis.

stalklage (Holloway et al., 1977). This is due to the fact that more corn stover, as a percent by weight, was present in their silage as compared to the silages in this study. Also it has been reported that adding non-protein nitrogen (NPN), urea in particular, decreased the structural components of the stalklages and one of these structural components is ADF (Colenbrander et al., 1971). Barth and Mohammed reported that 80% CLE-CS silage contained 40% dry matter. On a dry matter basis, their silage contained more CP (23.2%) and ash (16.1%) and less EE (.70%), CF (26.7%) and NFE (33.3%) than either of the silages reported here. The CLE used in their study contained approximately 39% CP on DMB.

The uric acid (mg/gm) content of the CLE and the silages is reported in table 2. The values for CLE agree well with those previously presented (Oltjen and Dinius (1976); Evans et al., 1978a). The amounts of uric acid in the silages was intermediate to those fed by Oltjen and Dinius (1976). It is important to note that the content of uric acid in these silages is proportional to the amount of CLE present in the silage as expected.

Apparent nutrient digestibilities. Dry matter intakes (DMI) and apparent nutrient digestibilities are presented in Table 3. The DMI of the silages were similar and were slightly lower than the 1.3 kg/day suggested to be fed to 80 kg ewes (N.R.C., 1975). No significant differences were found between the 18 and 30% silages for DM digestibility, organic matter digestibility (OMD), CF digestibility or ADF digestibility ($P > .05$). However, Barth and Mohammed (1980) reported higher DM, OM, CF and ADF digestibilities (50.4, 54.4, 56.9, 49.2%, respectively)

Table 3. Ration Intake and Apparent Nutrient Digestibility in Trial 1

Variable	Caged layer excreta-corn stover silages	
	18% CLE	30% CLE
Number of wethers	6	6
Body weight, kg	86.3	87.5
N in ration, %	1.7	2.3
Dry matter intake, kg/day	1.2	1.2
Apparent digestion coefficients, %		
Dry matter	46.4	47.1
Organic matter	48.9	49.8
Crude protein	59.4[a]	65.2[b]
Ether extract	71.5[c]	75.2[d]
Crude fiber	47.6	50.0
N-free extract	46.9[c]	43.8[d]
Acid detergent fiber	35.0	36.5
Total digestible nutrients, %	46.1	45.5

[a,b]Means on the same line with different superscript are significantly different (P<.01).

[c,d]Means on the same line with different superscript are significantly different (P<.05).

for their 80% CLE silage than for the silages in this study. Also, the ADF digestibilities in this study were similar to those of corn stover stalklage but were less than those of ammonia-treated stalklage, in the study by Holloway et al. (1977). A significant difference, due to diet, was found for CP, EE and NFE digestibilities. The 30% silage supported higher CP ($P<.01$) and EE ($P<.05$) digestibilities, which were both probably due to the fact that in the higher excreta silage a smaller proportion of the total fecal N or EE is represented by the metabolic fecal nitrogen or ether extract which automatically results in higher apparent digestion coefficients. These apparent digestibilities can be corrected for the metabolic losses to obtain true digestibility. Barth and Mohammed (1980), reported apparent crude protein digestibility (CPD) of 80.7% and an ether extract digestibility of 11.3% for 80% CLE silage (23.2% CP and .70% EE). The major reason for their increased CP digestibility and decreased EE digestibility was most likely due to differences in apparent and true digestibilities. In their study the CP was higher and the EE lower than in this study.

Total digestible nutrients were not affected by dietary treatment ($P>.05$) and TDN of both silages was lower than the 55% TDN required for maintenance of 80 kg ewes (N.R.C., 1975). Barth and Mohammed (1980) reported a TDN of 45.8 which agrees well with values reported in this study. In their study and in this study the high ash contents of the diets may be the major factor causing these low TDN values.

Nitrogen utilization. Table 4 presents nitrogen (N) utilization parameters for the CLE silages. As expected, nitrogen intake (g/day) was significantly greater for animals fed the 30% CLE silage ($P<.01$) and

Table 4. Nitrogen Utilization Parameters in Trial 1

Variable	Caged layer excreta-corn stover silages	
	18% CLE	30% CLE
N intake, g/day	19.70[g]	25.64[h]
Fecal N, g/day	8.00[g]	8.96[h]
Urinary N, g/day	11.21[g]	22.71[h]
N retention, g/day	8.51[g]	1.94[h]
Metabolic fecal N, g/day[a]	5.08	4.99
Endogenous urinary N, g/day[b]	2.93	2.98
True N digestibility, %[c]	85.09	84.68
Absorbed N retained, %[d]	50.42[g]	9.80[h]
Intake N retained, %[e]	9.77[g]	-22.85[h]
Net protein utilization, %[f]	36.06[g]	8.36[h]
Net protein value, %	4.51[g]	1.17[h]

[a]Metabolic fecal N = 4.35 x kg DM intake per day (Anderson et al., 1959).

[b]Endogenous urinary N = 0.034 x kg body weight (Anderson et al., 1959).

[c]True N digestibility = N intake - (fecal N - metabolic fecal N) /N intake x 100.

[d]Biological value of proteins (Anderson et al., 1969) calculated by the Thomas-Mitchell method.

[e]Intake N retained = N intake - fecal N - urinary N/N intake.

[f]Net protein utilization = absorbed N retained x true N digestibility/100.

[g,h]Means on the same line with different superscripts are significantly different (P<.01).

for both silages it was higher than the 18.6 g/day required for maintenance of 80 kg ewes (N.R.C., 1975). An unexpectedly higher ($P<.01$) urinary N was observed when the 30% CLE silage was fed. This high urinary excretion resulted in significantly lower N retention, absorbed N retained, intake N retained, net protein utilization (NPU) and net protein value for the 30% CLE silage as compared to the 18% CLE silage. The increased urinary N, when feeding CLE, has also been reported by Oltjen and Dinius (1976). One probable reason for these high N excretions is due to the increased ash in high NPN-containing diets. High ash in the diet decreased the energy content of the dietary dry matter due to dilution and it is well known that with low energy diets less non-protein nitrogen is utilized and therefore increased amounts are excreted.

Barth and Mohammed (1980) reported N retention of 2.8 gm/day with an 80% CLE silage (23.2% CP and 16.1% ash) which was slightly higher than that of the 30% CLE silage but three times lower than that of the 18% CLE silage. This latter difference could possibly be explained by the increased (16.1%) ash in their silage. Conversely, true N digestibility (92.4%) and NPV (7.0%) were higher in their study. NPV should have been higher since their silages contained considerably more CP even though they contained less NPU. The reason for the differences in true digestibility of their CLE silage and the silages in this study is not readily apparent.

Trial 2

Silage composition. The nutrient composition of the silages and their constituents are presented in Table 5. The corn stover used in

Table 5. Nutrient Composition of Ration Constituents and Rations in Trial 2

Constituent or ration	Dry matter,%[b]	Crude protein,%[a]	Ether extract,%[a]	Crude fiber,%[a]	Ash,%[a]	Nitrogen-free extract,%[a]	Acid detergent fiber,%[a]	Uric acid mg/g[a]
Ration constituents								
Corn stover	89.0	6.1	0.71	28.0	7.3	57.9	43.4	—
Caged layer excreta	31.0	24.2	2.20	10.7	38.3	24.6	18.1	7.05
Caged layer excreta-corn stover silages								
No additive	58.4	9.2	1.22	27.9	12.5	49.1	42.5	5.98
Plus Silabac	53.5	8.6	0.96	28.0	11.4	51.1	42.4	3.30
Plus phosphoric acid	55.2	8.4	0.85	30.4	9.4	51.0	45.0	3.63
Plus Silabac and phosphoric acid	61.6	10.1	1.20	28.2	15.2	44.8	40.9	9.38

[a]Dry-matter basis.

[b]Fresh basis.

this trial was similar to that used in trial 1 except for a slightly lower CF and ADF content in the latter. The CLE used in this trial had been allowed to accumulate under the cages of the laying hens for approximately six months. This caused drastic changes in the composition of the excreta as compared to those used in trial 1. Ash, DM, EE and NFE were 16, 37 and 44% lower, respectively, while CF and ADF were 36 and 22% lower, respectively. These changes are consistent with reports of compositional changes in CLE upon storage (Evans et al., 1978a). Since DM and CP of the CLE was erroneously assumed to be relatively constant prior to conducting this trial, the proportion of CLE, CS and water for the ensiling mixture in this trial were calculated from the DM and CP values of CLE used in trial 1. This resulted in somewhat higher DM and lower CP silages than desired. Proper ensiling of the mixture occurred as evidenced by pH values (Table 6). Again, since proper ensiling did occur and pathogens present were destroyed, no adverse affects on animal health were noticed. After ensiling the pH of all additive-treated silages was lower than that of the control silage. Since the pH of the ensiling mass of the control treatment was higher, change in pH units during the ensiling process cannot directly be compared. A more valid comparison is to consider increases in hydrogen ion concentration during ensiling (Table 6). Using this method, it is evident that silage additives promoted increased acid production.

The DM of the silages ranged from 53.5 to 61.6% which is higher than those in trial 1 but within the range of successful ensiling mixtures. The CP of the Silabac and the phosphoric acid-supplemented silages was approximately 8.5% on a DMB which is lower than the requirement of 75-80 kg ewes (8.9%) (N.R.C., 1975) while the control

Table 6. The pH of the Caged Layer Excreta-Corn Stover Mixtures Before and After Ensiling

Mixtures	pH		Change in hydrogen ion concentration, X 10^{-6}
	Before Ensiling	After Ensiling	
Control	8.32	5.10	7.87
Silabac added	7.54	4.91	12.42
Phosphoric acid added	7.67	4.85	14.23
Silabac and phosphoric acid added	7.71	4.87	13.75

silage and the Silabac plus phosphoric acid silage were above this maintenance level and similar to the CP content of the 18% CLE silage in trial 1.

Since these silages contained the same proportion of excreta, corn stover and water, the variable nutrient composition was unexpected. Possible reasons for this are the differential nutrient content in the different layers of accumulated excreta and the difficulty in properly sampling this material. The older excreta, which are located toward the bottom of the pile, contains more DM and, therefore, when it is used as a ration constituent more excreta and less water are added than when fresher excreta are used.

The uric acid content of the excreta and the silages is also presented in Table 5. The value presented for the excreta is much lower than that in trial 1. Since the method used to determine uric acid involves using the enzyme uricase, it is possible that inhibition of the enzyme occurred due to the presence of certain substances in the excreta. It has been found that uricase is inhibited by the concentration of xanthine in the sample (van Pilsum, 1953). The xanthine content of excreta could have been high enough to inhibit uricase while being diluted in the silages to permit accurate readings. This would explain the higher uric acid content of the silages as compared to that of the excreta but does not explain the variation among the silages. This, again, is probably due to the difficulty in sampling excreta to be added to the ensiling material.

Apparent nutrient digestibility. Dry matter intake and nutrient digestibilities are presented in Table 7 while orthogonal comparisons of

Table 7. Ration Intake and Apparent Nutrient Digestibility in Trial 2

Variable	Caged layer excreta-corn stover silages			
	Control	+ Silabac	+ Phosphoric acid	+ Phosphoric acid + Silabac
Number of wethers	4	4	4	4
Body weight, kg	77.2	75.1	73.9	74.7
N in ration, %[a]	1.48	1.37	1.34	1.62
Dry matter intake, kg/day	1.22	.970	.983	1.14
Apparent digestion coefficients, %				
Dry matter	36.9	40.8	39.6	42.2
Organic matter	40.7	42.8	45.0	44.2
Crude protein	47.5	40.5	31.3	45.9
Ether extract	66.0	58.8	66.0	75.6
Crude fiber	39.5	44.1	47.6	43.4
N-free extract	41.8	46.4	45.4	43.5
Acid-detergent fiber	33.3	31.1	37.1	36.2
Total digestible nutrients, %	37.7	40.8	41.8	38.5

[a]Dry-matter basis.

DM intake and nutrient digestibilities are presented in Table 8. DM intake was higher for the control silage than for the mean of silages containing additives ($p<.05$) and DM intake of the silage containing both additives was greater ($p<.10$) than the mean intake of the Silabac and phosphoric acid silages. Since DM intake is known to affect nutrient digestibility, a covariance analysis was used to remove its effect on digestibility. Using this covariant, the mean dry matter digestibility of the additive silages was higher ($p<.01$) than the control silage indicating that all additives improved DM digestibility. There were no differences between Silabac and phosphoric acid treated silages ($p>.05$). With regard to Silabac, these results agree with those of Bolsen et al. (1980b) who reported increased DM digestibility in alfalfa silage treated with lactobacillus over the control but they are in contrast to those by LaBarbera et al. (1980) who reported no difference in nutrient digestibility in silages treated with or without Silabac. In the present study, using both additives together was not better than using only one if considering only DM digestibility.

Organic matter digestibilities were similar across treatments but a trend ($p<.15$) for higher OM digestibility in the additive treated silages was noticed. Crude protein digestibilities also were analyzed using a covariance analysis; crude protein intake was used as a covariant since the intake by sheep of this nutrient was different. The CP digestibilities were low and there was no significant differences between the control silage and the mean CP digestibility of the additive silages. This suggests that silage additives, in this study, did not improve the CP availability. However, control silage CP digestibility was quite variable and ranged from 37.1 to 55.4%; an equally wide

Table 8. Orthogonal Comparisons of Dry Matter Intake and Nutrient Digestibility for Trial 2

	Comparisons					
	1		2		3	
Variable	No additive (control)	Mean of additives	Silabac additive	Phosphoric acid additive	Mean of individual additive	Combination of additives
Dry matter intake, kg/day	1.22[c]	1.03[d]	.970	.983	.977[e]	1.14[f]
Apparent digestion coefficients, %						
Dry matter	36.9[a]	40.9[b]	40.8	39.6	40.2	42.2
Organic matter	40.7	44.0	42.8	45.0	43.9	44.2
Crude protein	47.5	39.2	40.5[c]	31.3[d]	35.9	45.9
Ether extract	66.0	66.8	58.8[c]	66.0[d]	62.4[a]	75.6[b]
Crude fiber	39.5[c]	45.0[d]	44.1	47.6	45.9	43.4
N-free extract	41.4[e]	45.1[f]	46.4	45.4	45.9	43.5
Acid-detergent fiber	33.3	34.8	31.1[c]	37.1[d]	34.1	36.2
Total digestible nutrients %	37.7[c]	40.4[d]	40.8	41.8	41.3[c]	38.5[d]

[a,b]Values within a comparison not sharing a common superscript are significantly different ($P<.01$).

[c,d]Values within a comparison not sharing a common superscript are significantly different ($P<.05$).

[e,f]Values within a comparison not sharing a common superscript are significantly different ($P<.10$).

variation in CP digestibility was also found in the Silabac silage. These large intraclass variations probably are responsible for the lack of significant differences. However, CP digestibility of phosphoric acid silage was significantly lower ($p<.05$) than that of the Silabac silage. This is in agreement with other findings in which problems associated with feeding phosphoric acid silages were encountered (King, 1943; Lepard et al., 1937).

The mean ether extract (EE) digestibility of the silages containing additives and the EE digestibility of the control silage was similar. This similarity was caused by the low EE digestibility on the Silabac treated silage which decreased the mean of the additive silages. The phosphoric acid silage had higher EE digestibility ($p<.05$) than the Silabac silage. The Silabac plus phosphoric acid silage EE digestibility was significantly higher than the mean EE digestibility of the Silabac and phosphoric silages ($p<.01$). This extremely high EE digestibility of the Silabac plus phosphoric acid silage suggests that the combination of these two additives greatly increased the EE content in the silage and therefore digestibility. The crude fiber (CF) digestibility was significantly greater ($p<.05$) for the mean of the additive treated silages. No differences were detected among treated silages although a trend ($p<.15$) toward higher CF digestibility with phosphoric acid silage than that of the Silabac silage was indicated. This would suggest that silage additives increased crude fiber availability for rumen degradation. Coversely, the acid-detergent fiber (ADF) digestibility was similar for the control silage and the mean of the additive treated silages. However, phosphoric acid silage supported increased ($p<.05$) ADF digestibility as compared to Silabac silage. It seems that the acid

increased the availability of fiber, CF and ADF, more so than did Silabac treated silage. Nitrogen-free extract (NFE) digestibility was lower ($p<.10$) for the control silage as compared to the mean of the treated silages. A trend for higher ($p<.12$) NFE digestibility for the mean of the phosphoric acid and Silabac silages than that of the Silabac plus phosphoric acid silage was noticed. These results may indicate that upon ensiling with fermentation aids more components of the NFE fraction are converted to more available compounds such as acetic or latic acids.

The mean total digestible nutrients (TDN) was higher for the additive treated silages ($p<.05$). This difference was mainly due to the increased CF and NFE digestibilities than that of the control silage. The mean TDN of the Silabac and phosphoric acid silages was higher ($p<.05$) than that of the Silabac plus phosphoric acid silage since the Silabac plus phosphoric acid silage contained less NFE and also had a lower NFE digestibility than the Silabac or phosphoric acid silages.

All of the digestibilities and the TDN were lower than those reported in trial 1. The TDN values for this trial were even more below the maintenance level for ewes and were most likely due to the higher ash content in these silages than in those of trial 1.

Nitrogen utilization. Table 9 presents the nitrogen (N) utilization parameters for trial 2. The orthogonal comparisons of N utilization parameters are presented in Table 10. Nitrogen intake was significantly affected by treatment. The control silage supported a higher intake of N than the mean of the other silages ($p<.05$) while the Silabac plus phosphoric acid silage had a highly significantly higher ($p<.01$)

Table 9. Nitrogen Utilization Parameters in Trial 2

Variable	Caged layer excreta-corn stover silages			
	Control	+ Silabac	+ Phosphoric acid	+ Phosphoric acid + Silabac
N intake, g/day	17.70	13.15	12.97	18.41
Fecal N, g/day	9.47	7.74	8.90	9.92
Urinary N, g/day	11.17	9.49	7.74	12.02
N retention, g/day	-2.93	-4.09	-3.67	-3.52
Metabolic fecal N, g/day[a]	5.30	4.22	4.27	4.94
Endogenous urinary N, g/day[b]	2.63	2.55	2.51	2.54
True N digestibility[c], %	76.2	72.7	64.3	72.7
Absorbed N retained[d], %	35.4	27.4	36.0	29.7
Net protein utilization[e], %	27.9	20.2	23.3	21.5
Net protein value, %	2.57	1.85	1.95	2.18

[a]Metabolic fecal N = 4.35 x kg DM intake per day (Anderson et al., 1959).

[b]Endogenous urinary N = 0.034 x kg body weight (Anderson et al., 1959).

[c]True N digestibility = N intake - (fecal N - metabolic fecal N) /N intake x 100.

[d]Biological value of proteins (Anderson et al., 1959) calculated by the Thomas-Mitchell method.

[e]Net protein utilization = absorbed N retained x true N digestibility/100.

Table 10. Orthogonal Comparisons of Nitrogen Utilization Parameters for Trial 2

	Comparisons					
	1		2		3	
Variable	No additive (control)	Mean of additives	Silabac additive	Phosphoric acid additive	Mean of individual additive	Combination of additives
Nitrogen intake, g/day	17.70[c]	14.84[d]	13.15	12.97	13.06[a]	18.41[b]
N retention	-2.93	-3.76	-4.09	-3.67	-3.88	-3.52
True N digestibility	76.2	69.9	72.7[e]	64.3[f]	68.5	72.7
Absorbed N retained	35.4	31.0	27.4	36.0	31.7	29.7
Net protein utilization	27.9	21.7	20.2	23.3	21.7	21.5
Net protein value	2.57	1.99	1.85	1.95	1.27	2.18

[a,b]Values within a comparison not sharing a common superscript are significantly different ($P<.01$).

[c,d]Values within a comparison not sharing a common superscript are significantly different ($P<.05$).

[e,f]Values within a comparison not sharing a common superscript are significantly different ($P<.10$).

N intake than the mean of the Silabac and phosphoric acid silages. These increased N intakes were a function of the higher CP in the control and Silabac plus phosphoric acid silages and the different DM intakes across treatments. Nitrogen intake of all the silages except the Silabac plus phosphoric acid silage was below the maintenance level for ewes (17.8g N/day, N.R.C., 1975). Since the N intake was affected by treatment, a covariant was used to remove the effect of differential N intakes on N utilization parameters. The N retention, absorbed N retained, net protein utilization and net protein value of sheep fed these silages were similar ($p>.10$). The N retention was negative and markedly differed from those in trial 1. The lower N utilization parameters were probably due to the higher ash, lower CP and lower energy content of these silages than those of trial 1. Since the highest (non-significant) N utilization was found in the control silage, it suggested that possibly silage additives adversely affected N utilization. An explanation for this is not readily apparent. The true N digestibility of the control silage and the mean N digestibility of the other silages were similar although a significantly higher ($p<.10$) N digestibility was found with the Silabac plus phosphoric acid silage as compared to the mean of the Silabac and phosphoric acid silages. The major reason for not being able to determine a difference in the latter case was due to the large intraclass variation in true N digestibility of sheep fed the control silage while the former difference was due to the lower true N digestibility of the phosphoric acid silage. This again, suggests problems associated with feeding phosphoric acid silage.

Rumen Parameter Study

The fistulated sheep in this study consumed an average of 1.8 kg/day of hay during the first hay phase. Initially, upon feeding the CLE silage, each sheep consumed only 2.0 kg of the 2.4 kg/day offered. After five days of the CLE silage feeding, all of the sheep were consuming the entire 2.4 kg/day offered. When the hay was reintroduced, the animals immediately consumed the entire 2.0 kg/day. The sheep readily accepted the CLE silage when it was offered in the last phase; consumption was approximately 2.0 kg/day. The DM intake of the sheep on each dietary phase was 1.6, 1.1, 1.8 and 1.0 kg/day, respectively.

Predicted values for pH, volatile fatty acid concentration and protozoa numbers were calculated from linear or quadratic regression equations for various days after initial CLE silage feeding. The equations are presented in Table 11.

Volatile fatty acid concentration and pH during dietary changes. The initial values for the first hay phase and the predicted values calculated from equations in Table 11 are presented in Table 12. The total VFA (mM/l) increased slightly upon feeding CLE silage but this was most likely due to a carryover effect of the hay feeding in phase 1, because subsquent feeding of the silage caused large decreases in total VFA. The decrease was still occurring as the diet was changed to hay, which again supported higher total VFA concentrations. During this second hay feeding, the concentration of VFA increased to that above pre-silage feeding and promptly decreased due to refeeding of silage. These changes were expected since the hay ration contained considerably more fermentable nutrients than the CLE silage. The decrease in total VFA concentration was in contrast to

Table 11. Prediction Equations for Rumen Parameters

Variables	Silage Days 2 - 18	Hay Days 18 - 26	Silage Days 26 - 34
pH	$Y^b = 6.42^c + .021^d(X)^e$	Y = 7.114 - .028(X)	Y = 6.092 + .0125(X)
Total VFA, mM/l	Y = 113.434 - 2.422(X)	Y = -27.973 + 5.942(X)	Y = 289.080 - 6.205(X)
Acetate, mM/l	Y = 81.098 - 2.073(X)	Y = -5.994 + 3.341(X)	Y = 173.113 - 3.523(X)
Propionate, mM/l	Y = 22.674 - .247(X)	Y = -6.052 + 1.261(X)	Y = 66.108 - 1.421(X)
Butyrate, mM/l	Y = 6.523 - .072(X)	Y = -5.702 + .640(X)	Y = 34.390 - .868(X)
Other VFA[a], mM/l	Y = 3.139 - .030(X)	Y = 2.082 + .306(X)	Y = 15.469 - .392(X)
Total Protozoa	Y = 198114.71 - 20898.53(X) + 811.60(X^2)[f]	Y = -195575.87 + 15872.38(X)	Y = 836760 - 22993.33(X)
Entodinia	Y = 116735.37 - 3208.57(X)	Y = -172972.70 + 14215.24(X)	Y = 772013.33 - 21246.67(X)
Diplodinia	Y = 6238.55 - 114.31(X)	Y = -17899.68 + 1300.95(X)	Y = -21693.33 + 1126.67(X)
Dasytricha	Y = 2247.23 - 156.52(X)	Y = -7874.29 + 555.71(X) - 5.95(X^2)	Y = 9400.00 - 266.67(X)
Isotricha	Y = 3931.67 - 330.63(X) + 5.72(X^2)	Y = 4708.57 - 614.76(X) + 20.24(X^2)	Y = 287840 - 18573.33(X) + 300(X^2)

[a] Include isobutyrate, isovalerate and valerate.

[b] Predicted value.

[c] Intercept.

[d] Linear regression coefficient for X.

[e] X = Day.

[f] X^2 = Day ^{2}.

Table 12. Predicted Ruminal pH and Volatile Fatty Acid Levels During Dietary Changes

Day of Trial	pH	Total VFA (mM/l)	VFA, molar percent			
			Acetate	Propionate	Butyrate	Other acids[a]
			Hay, days 0 - 2			
1	6.38	95.3	71.7	19.4	6.3	2.6
			Silage, days 2 - 18			
5	6.53	101.3	69.8	21.1	6.1	3.0
10	6.63	89.2	67.7	22.6	6.5	3.4
15	6.74	77.1	64.9	24.6	7.0	3.5
			Hay, days 18 - 26			
20	6.55	90.9	66.9	21.0	7.8	4.4
25	6.41	120.6	64.3	21.1	8.5	4.6
			Silage, days 26 - 34			
30	6.47	102.9	65.5	22.8	8.2	3.6

[a]Includes isobutyrate, isovalerate and valerate.

data by Oltjen and Dinius (1976) who reported that total VFA concentration was not affected by CLE feeding, however, their rations contained more fermentable carbohydrates, supplied by timothy hay and cracked corn.

Molar percent acetate decreased slightly upon feeding CLE silage but the concentration of acetate, the product of the molar percent acetate and the total VFA concentration, decreased dramatically (69 to 50 mM/l). Initially, following the reintroduction of hay, the molar percent increased but then decreased during the remainder of that period. However, during those days the concentration of acetate increased from 50 to 61 to 78 mM/l.

The molar percent propionate increased upon feeding CLE silage. This increase was due to the large decrease in total VFA concentration (101 to 77 mM/l) while the propionate concentration remained relatively constant (21 to 19 mM/l). The constant propionate concentration is unexplainable since the silage is not high in starch or energy. Increased ruminal propionate is usually associated with high grain diets and not forages, such as CLE silage.

Predicted molar percent butyrate increased upon introducing CLE silage. This increase continued when the hay was refed suggesting that butyrate producing rumen microbes increased when the animals were fed CLE silage. The microbes then were able to utilze the nutrients in the hay to produce even more butyrate.

The ruminal pH increased as CLE silage was fed which, as expected, was inversely realted to the total VFA concentration. The increase in pH continued throughout the feeding of CLE silage indicating that complete adaptation had not yet occurred. The higher pH was characteristic of low quality roughages rather than a silage (Church, 1976). The uric acid present in the silages may also be resposible for the rise in ruminal pH,

since NH_3 may be released as a degradation product. When hay was refed the ruminal pH quickly decreased to pre-CLE silage feeding levels.

Protozoa concentration during dietary changes. The predicted numbers of protozoa and the number of individual protozoa species are presented in Table 13. Since the pH of the rumen was well above 6.0, this factor should not adversely affect protozoa numbers, according to Warner (1961). However, total protozoa concentration decreased after CLE silage was fed. The reason for this decrease is related to the decreased substrates available for protozal utilization. Entodinia and Diplodinia utilize granular starch while Dasytrichs and Isotrichs ferment mainly soluble sugars. The soluble sugars and starch available in CLE silage is less than of the hay. The soluble sugar content should be low in this silage since most of them should have been fermented to lactic and acetic acids during ensiling. One other possible reason for the decreased protozoa numbers may be that rate of passage may be greater for the CLE silage thus flushing the protozoa through the rumen. The protozoa numbers increased rapidly upon refeeding hay which suggests that one of the above hypotheses is probably correct.

Endotinia, Dasytrichs and Isotrichs followed the same pattern as the total protozoa (i.e. decreased when CLE silage was fed). The negative value predicted for Dasytricha on day 15 was due to using regression equations to predict values. Biologically, that value would represent an absence of that species. Diplodinia initially increased upon feeding CLE silage but then decreased during the remainder of that phase. However, the predicted values during CLE silage feeding remained above that of the previous hay feeding. The reason for these higher numbers of

Table 13. Predicted Ruminal Protozoa Concentrations During Dietary Changes

	Protozoa, X 10^4/ml				
Day of trial	Total	Entodinia	Diplodinia	Dasytricha	Isotricha
	—— Hay, days 0 - 2 ——				
1	12.12	11.10	.38	.27	.13
	—— Silage, days 2 - 18 ——				
5	11.56	10.07	.57	.15	.24
10	9.21	8.46	.51	.07	.12
15	6.86	6.86	.45	-.01	.03
	—— Hay, days 18 - 26 ——				
20	12.18	11.13	.81	.09	.05
25	20.12	18.24	1.46	.23	.20
	—— Silage, days 26 - 34 ——				
30	14.69	13.46	1.21	.14	.06

Diplodinia was not apparent since Entodinia, which utilizes the same substrates as Diplodinia, decreased rapidly upon CLE silage feeding.

CHAPTER V

SUMMARY

Two total collection trials were conducted to determine the nutrient digestibility and nitrogen utilization of caged layer excreta-corn stover silages treated with or without silage additives. In trial 1, silages were produced from 18 or 30% excreta, 50% corn stover and various amounts of water to achieve 50% moisture silages, and fed to 12 mature wether sheep.

The pH, after ensiling, was 4.6 for the 18% excreta silage and 5.0 for the 30% excreta silage. The 18% excreta and the 30% excreta silages contained: 48.8 and 45.8% dry matter; and on a dry matter basis, 10.5 and 14.0% crude protein; 1.30 and 1.69% ether extract; 29.2 and 28.5% crude fiber; 8.2 and 11.8% ash; 50.9 and 44.2% nitrogen-free extract; 46.2 and 46.4% acid-detergent fiber; and 4.57 and 7.18 mg/g uric acid, respectively. Dry matter intake of the 18% excreta silage was 1.17 kg/day and was similar to the 1.15 kg/day of the 30% excreta silage. Apparent digestion coefficients for the 18% and the 30% excreta silages were: dry matter, 46.4 and 47.1%; organic matter, 48.9 and 49.8%; crude protein, 59.4 and 65.2%; ether extract, 71.5 and 75.2%; crude fiber, 47.6 and 50.0%; nitrogen-free extract, 46.9 and 43.8%; and acid-detergent fiber, 35.0 and 36.5%, respectively. Total digestible nutrients were 46.1 for the 18% excreta silage and 45.5 for the 30% excreta silage. Dry matter, organic matter, crude fiber and acid-detergent fiber digestibilities were similar across treatment ($p>.05$). A significant increase in the digestibility of crude protein ($p<.01$) and ether extract ($p<.05$) was found for the 30% excreta silage while the 18% excreta silage supported higher ($p<.05$) nitrogen-free extract digestibility.

The nitrogen intake, nitrogen retention, true nitrogen digestibility, absorbed nitrogen retained, intake nitrogen retained, net protein utilization and net protein value of the 18% excreta silage were 19.7 g/day, 8.51 g/day, 85.09%, 50.42%, 9.77%, 36.06% and 4.51%, respectively, while for the 30% excreta silage they were 25.6 g/day, 1.94 g/day, 84.68%, 9.80%, -22.85%, 8.36% and 1.17%, respectively. The nitrogen intake was higher ($p<.01$) for the 30% excreta silage. All of the other nitrogen utilization parameters except true nitrogen digestibility were significantly higher ($p<.01$) for the 18% excreta silage. The true nitrogen digestibility was similar ($p>.05$) for both silages.

In trial 2, 16 wether sheep were used to determine the effect of silage additives on fermentation of excreta silage, nutrient digestibility and nitrogen utilization. The silage treatments were: no additives (control), Silabac (a bacterial additive), phosphoric acid (an acid additive) or the combination of Silabac and phosphoric acid. The level of excreta used in this trial was 22.5%; the corn stover was 50% of the ensiling material and again water was added to produce a 50% moisture silage.

The nutritional composition of the silages was quite variable. The dry matter of the silages treated with no additives (control), Silabac, phosphoric acid or the combination of the latter two was 58.4, 53.5, 55.2 and 61.6%, respectively; other nutrients, on a dry matter basis were: crude protein, 9.2, 8.6, 8.4 and 10.1%; ether extract, 1.22, 0.96, 0.85 and 1.20%; crude fiber, 27.9, 28.0, 30.4 and 28.2%; ash 12.5, 11.4, 9.4 and 15.2%; nitrogen-free extract, 49.1, 51.1, 51.0 and 44.8%; acid-deterent fiber, 42.5, 42.4, 45.0 and 40.9% and uric acid 5.98, 3.30, 3.63 and 9.38 mg/g, respectively.

Dry matter intake was 1.22, 0.97, 0.98 and 1.14 kg/day for the silages containing no additives, Silabac, phosphoric acid and the combination of both additives, respectively. Apparent digestion coefficients for these silages were: dry matter, 36.9, 40.8, 39.6 and 42.2%; organic matter, 40.7, 42.8, 45.0 and 44.2%; crude protein, 47.5, 40.5,31.3 and 45.9%; ether extract, 66.0, 58.8, 66.0 and 75.6%; crude fiber, 39.5, 44.1, 47.6 and 43.4%; nitrogen-free extract, 41.8, 46.4, 45.4 and 43.5%; and acid-detergent fiber, 33.3, 31.1, 37.1 and 36.2%, respectively. Total digestible nutrients were 37.7, 40.8, 41.8 and 38.5% for these silages, respectively. Dry matter digestibility was higher ($p<.01$) for the additive treated silages than that of the control silage although the organic matter digestibility was similar for all silages. The crude protein digestibility was higher ($p<.05$) for the Silabac treated silage than that of the phosphoric acid silage. However, ether extract digestibility was higher ($p<.05$) for the phosphoric acid silage than that of the silage treated with Silabac. Silage made with the combination of additives had higher ($p<.01$) ether extract digestibility than the mean of Silabac and phosphoric acid silages. Crude fiber dibestibility was higher ($p<.05$) for all the treated silages while there were no differences among treated silages ($p<.10$). Conversely, phosphoric acid treated silages supported higher ($p<.05$) acid-detergent fiber digestibility than that of the Silabac treated silage but the control silage and the mean of the additive treated silages had similar acid-detergent fiber digestibility ($p<.10$). Total digestible nutrients were higher ($p<.05$) with the additive treated silages than the control silage. A higher TDN ($p<.05$) was obtained when the additives were used singly rather than in combination.

Nitrogen intakes were 17.7, 13.2, 13.0 and 18.4 g/day for the control, Silabac, phosphoric acid and Silabac plus phosphoric acid silages, respectively. The nitrogen retention, true nitrogen digestibility, absorbed nitrogen retained, net protein utilization and net protein value for these silages were -2.93, -4.09, -3.67 and -3.52 g/day; 76.2, 72.7, 64.3 and 72.7%; 35.4, 27.4, 36.0 and 29.7%; 27.9, 20.2, 23.3 and 21,5% and 2.57, 1.85, 1.95 and 2.18%, respectively. Nitrogen intake was higher ($p<.05$) for the control silage than for the mean of the additvie treated silages while the silage treated with the combination of additives had higher nitrogen intake than that of the silages treated with the individual additives. The only other difference in nitrogen utilization was that of a higher ($p<.10$) true nitrogen digestibility with the Silabac treated silage over that of the phosphoric acid treated silage.

In addition, the changes in ruminal pH, volatile fatty acid and protozoa concentration were monitored as sheep were adapting to caged layer excreta-corn stover silage. To study ruminal changes, three fistulated wethers were initially fed hay and then abruptly changed to excreta silage. Also, the ruminal changes, when hay was reintroduced and when silage was offered after the latter hay period, were observed.

Regression equations were formulated for each phase with day or day^2 as the independent variables and pH, volatile fatty acid and protozoa concentrations as the dependent variables. Predicted values were calculated from these equations for certain days of the study. These predicted values indicated that ruminal pH increased (6.38 to 6.74) when feeding excreta silage and promptly decreased when hay was refed (6.74 to 6.41). Total volatile fatty acid concentration decreased upon silage feeding (101.3 to 77.1 mM/l) and dramatically increased when hay was refed (77.1

to 120.6 mM/l). Molar percent acetate decreased (71.7 to 64.9%) upon silage feeding and increased slightly upon hay feeding (64.9 to 66.9%). Conversely, molar percent propionate increased (19.4 to 24.6%) during silage feeding but remained constant upon refeeding hay (21.0%). Molar percent butyrate increased while sheep were on the silage (6.3 to 7.0%) and increased further when hay was refed (7.0 to 8.5) and collectively the molar percent of other acids followed the same pattern as butyrate.

Predicted protozoa concentrations, total, Entodinia, Dasytricha and Isotricha decreased when silage was fed but increased rapidly upon reintroduction of hay: total, 13.19 to 6.86 to 20.12 X 10^4/ml; Entodinia, 11.10 to 6.86 to 18.24 X 10^4/ml; Dasytrich, .27 to -.01 to .23 X 10^4/ml; Isotricha, .13 to .03 to .20 X 10^4/ml. Conversely, Diplodinia initially increased when silage was fed and then decreased (.38 to .57 to .45 X 10^4/ml). However, this protozoa did increase upon refeeding hay (.45 to 1.46 X 10^4/ml).

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