UTILIZATION OF CORN SILAGE GROWN BY CONVENTIONAL AND SUSTAINABLE METHODS FED WITH DIFFERENT NITROGEN SUPPLEMENTS

by

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Abstract

A metabolism trial and a feedlot finishing trial were conducted with silage made from corn (*Zea mays* L.)forage grown by conventional and sustainable methods. For the metabolism trial, 24 wether lambs were allotted to four diets: 1) conventional corn silage supplemented with urea, 2) conventional corn silage supplemented with soybean meal (SBM), 3) sustainable corn silage supplemented with urea, and 4) sustainable corn silage supplemented with broiler litter. Apparent DM digestibilities were 65.9, 69.3, 63.8, 66.2%, for the respective diets. Apparent digestibilities of NDF, ADF, and cellulose were lower ($P < .05$) for the urea-supplemented diets than the SBM and broiler litter supplemented diets. Sheep fed sustainable silage supplemented with broiler litter had the highest ($P < .05$) fecal N excretion, due to at least partly to the highest ($P < .05$) N intake. Total N excretion was similar ($P > .05$) among sheep fed all diets. Sheep fed conventional and sustainable silages supplemented with urea were in negative N balance (-1.04, and -.38, respectively). Sheep fed the conventional silage supplemented with SBM and sustainable silage supplemented with broiler litter had similar ($P > .05$) positive N retention.

Conventional and sustainable silages were fed to feedlot steers and supplemented with either SBM or broiler litter. Conventional steers had a higher ($P < .05$) live weight (421 kg) upon entering the feedlot than the steers fed the sustainable diet (390 kg). Difference in ADG did not become apparent until the second-to-last 28-d period, at which time the conventional steers had a higher ($P < .05$) ADG than the steers fed the sustainable diet. Cattle fed the sustainable diet tended to consume more feed ($P > .05$) and had lower gain/feed ($P < .05$) than those fed the conventional diet. At slaughter, cattle fed the conventional diet were heavier ($P < .05$), (596 vs 541kg). Carcass maturity, marbling, backfat, percent kidney, pelvic and heart (KPH) fat, and quality grade were similar ($P > .05$) for the cattle fed the two diets. Carcass weight, ribeye muscle area, yield grade and dressing percentage were higher for the cattle fed the conventional diet, reflecting higher liveweight than cattle fed the sustainable diet.

Key words: Corn silage, Broiler litter, Apparent digestibility, Soybean meal, Performance, Sustainable.

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Chapter I.

Introduction

With environmental concern growing exponentially each year, traditional farming methods are becoming the subject of change. A research and education grants program was started in 1987 in hopes of creating alternatives to some conventional farming practices that could benefit from being more environmentally friendly (Madden and O'Connell, 1990). Traditional cropping methods are being replaced with lower input alternatives accompanied by less chemical application to the land. Pesticides, herbicides, fertilizers, and fossil fuel are chemical inputs that are the focus the of reductions. Low-input alternatives are crop rotation for weed control, biological control of insects, and legume utilization to supply soil N. A consequence of heavy chemical and mechanical land applications are land erosion, water pollution, and endangered human health.

An alternative to the traditional feedlot diet of high corn (*Zea mays* L.) grain, limited forage, and SBM is a diet of corn silage and protein supplement. For example, the land from which the corn is grown for the silage may be farmed with fewer chemical and mechanical inputs. The source of protein for supplementing the feedlot diet is also a candidate for change. Corn silage is an excellent source of energy and fiber for growing animals, but requires high input, including the manpower needed to farm the land and harvest the corn plant, machinery to chop and pack the plant for ensiling, and chemicals applied to the land or plant, and silage additives. Therefore, the system of farming the land to produce corn forage presents an opportunity to reduce the number of inputs in making corn silage.

Low-input systems from which the corn is grown for corn silage should not alter fermentation or nutritive quality, only decrease chemical input.

Furthermore, low-input systems have been shown to produce corn for less money and chemical input than a conventional system.

The practice of feeding poultry litter to livestock decreases additional farm waste and disposal problems, while allowing for a low cost alternative to traditional protein supplements. Processed broiler litter is a N source which supplies nutrients that are recycled waste.

This study was conducted to determine the fermentation, and nutritional qualities of a conventional and sustainable corn silage, the digestibility of the respective corn silages supplemented with different N sources, and feedlot performance of cattle fattened on N supplemented conventional and sustainable corn silages.

Chapter II.

Review of Literature

Silage Fermentation

The Ensiling Process. Photosynthesis ceases shortly after the plant is cut, and respiration begins, producing CO_2. Simultaneously, the plant enzymes hydrolyze non-structural carbohydrates (Edwards and McDonald, 1978). Once the plant is in an anaerobic environment, and O_2 is depleted, microorganisms present on the plant ferment water soluble carbohydrates (WSC) to organic acids.

Through recording the changes (at 30 h, 14 d, and 58 d of ensiling) of carbohydrate, organic acids and ethanol concentrations, a profile of the phases cut forage undergoes during fermentation can be understood (McDonald et al., 1968). In wilted grass (34.7% DM) silage, the concentration of glucose decreased from 4.5 to 2.6% by d 58 of ensiling. Lactic acid and acetic acid production begins at 30 h after the beginning of ensiling, while butyric and propionic acids are not produced until 58 d post ensiling and after d 58, respectively. Ethanol production begins immediately.

During fermentation lactic acid, acetic acid, CO_2, and mannitol are produced. Fermentation is dominated by lactic acid bacteria and lactic acid accumulates until the pH reaches approximately 4, at which point further fermentation is inhibited and the environment is stabilized. The low pH inhibits clostridial bacteria from growing. Clostridial bacteria, flourishing at a higher pH, ferment lactic acid to butyric acid.

The elimination of oxygen when the corn plant is packed and sealed in the silo ensures anaerobic fermentation when WSC are sufficient (McDonald et al., 1968). Fermentation of the WSC results in a drop in pH which inhibits further breakdown of WSC and protein (Woolford, 1972; Ruxton et al., 1975). When butyric acid bacteria are allowed to flourish in higher pH environments, butyric acid levels are higher, which lowers silage quality (McDonald and Whittenbury, 1973). Lactic acid concentration, WSC concentration, and pH are reliable tests of successful preservation and fermentation of the corn plant.

In anaerobic conditions both homo- and hetero-fermentative lactobacilli flourish (Wilkinson, 1978), which inhibit spore forming bacteria because of the low pH and acidic environment (Woolford, 1972). A pH of 3 will inhibit the lactobacilli as well as the spore formers. Homofermentative bacteria are the preferred lactobacilli since their primary fermentation product is lactic acid (McDonald et al., 1973). Heterofermentative lactobacilli produce CO_2, ethanol, and mannitol, in addition to lactic acid. The fermentation process may not begin immediately. Lactic acid production may not commence until several hours after ensiling (Greenhill, 1964a).

Parameters distinguishing a well preserved corn silage include a pH between 3.75 to 4, less than .2% butyric acid (DM basis), 3 to 13% lactic acid (DM basis), and less than 11% NH_3-N of the total N (Catchpoole and Henzell, 1971). Successful preservation is affected by plant DM, date of harvest, extent of packing, exclusion of air, additive addition, and chop size.

The substrates for lactic acid production are glucose, fructose, sucrose and fructosans (Whittenbury et al., 1967), the supply of which may need to be increased when inorganic ions of the ensiled plant react with the fermented organic acids (Smith, 1962). This is because the inorganic ions buffer the reaction of sugar to acid. Hemicellulose, the only structural carbohydrate having a role in fermentation, may be broken down, releasing arabinose and xylose (Dewar et al., 1963). The role of CO_2, ethanol, and mannitol are not completely understood. Muck et al. (1992) measured no change in lactic acid, acetic acid or enterobacteria under increased CO_2 concentration, indicating that CO_2 is not an antagonist of bacteria populations during fermentation. The influence of CO_2 in decreasing yeast activity has been documented (Lumsden et al., 1987).

The analyzed fraction of CP (N X 6.25) includes NPN in addition to protein N. Of the total CP analyzed in silage, one-half is in the form of NPN (Waldo, 1968; Buchanan-Smith and Yao, 1978). As WSC are converted to organic acids, the protein in the corn plant is broken down to NPN by enzymatic proteolysis (Hughes, 1970). The proportion of NPN is extensively ruminal degradable (Howie, 1988). As the NPN and NH_3-N contents of silage increase so does the ruminal production of NH_3-N (McDonald and Edwards, 1976). The high level of N being solubilized in the rumen, liberating large amounts of NH_3 is inherent to the highly degradable nature of silage protein. Water-soluble N includes NH_3-N, amide-N, and amino-N, in addition to unidentifiable N sources, while protein is the fraction which is water insoluble (McDonald and Edwards, 1976). Amines are formed from the decarboxylation of amino acids and ammonia is the product of deamination (McDonald and Edwards, 1976). Insoluble protein represents the fraction of CP that is insoluble in the rumen but potentially degraded by the microbes (Makoni et al., 1991).

At corn harvest, 75 to 85% of the total N is in the form of protein N (Wilkinson, 1978), while water-soluble N constitutes 13% of the total N (Makoni et al., 1991). The water-soluble N increases to a maximum of 42% of the total N at d 20 post ensiling. Enzymatic proteolysis of plant proteins plateaus at 12 h after ensiling and diminishes by d 5 of ensiling (Bergen et al., 1974). The pool of NPN consists of approximately 30% amino-N, 10% NH_3-N, 1% amide-N and the remainder unidentified (Bergen et al., 1974; Buchanan-Smith and Yao, 1978). The proteolysis to NH_3-N increases, while hot water insoluble N decreases in grass-legume silage that has been wilted (Makoni et al., 1991).

Packing the chopped corn plant is necessary to exclude air (Ruxton et al., 1975). Increasing the pressure of packing from 0 to.68 atm did not result in effluent in ensiling corn silage that contained 30.7% DM or greater, indicating no loss of DM through effluent production (Geasler and Henderson, 1970a). Increasing pressure of the silo is more important for proper packing of higher DM plants than for packing lower dry matter plants (Greenhill, 1964b). Greenhill (1964a) concluded that if only a small amount of air is trapped inside a silo after absolute sealing, the oxygen is quickly used up by the respiring plant, and therefore is not a concern for establishing anaerobic conditions. The oxygen allowed to remain between the plant particles is a reflection of the extent of compaction. Breaking and crushing the plant increases the surface area exposed to the oxygen and opens cells to allow release of cell contents. As a result, respiration by the plant particles is expedited (Simpson, 1961). Once the silo is opened during feeding, secondary fermentation of the silage occurs through anaerobic breakdown (Leaver, 1975).

Poorly-preserved silages are marked by increases in butyric and acetic acids above pH of 4 (Wilkinson, 1985). Silages that have a high moisture content (30 to 35% DM) with low WSC have the greatest probability of poor preservation (Vetter and Von Glan, 1978). If there is not a sufficient concentration of WSC, the supply is exhausted before pH drops to a level at which clostridial growth is inhibited. Secondary fermentation refers to the fermentation of lactic acid to butyric acid which is associated with energy and DM loss.

When the moisture level of the silage is excessive, the plant juices seep from the silo. The low pH is corrosive to metal and concrete. The lowest DM which produces no effluent is 30% (Miller and Clifton, 1965; Castle and Watson, 1973). The biochemical demand for oxygen for silage effluent is 150 times greater than that of human sewage (Messer, 1975). Thus, the waste produced by poorly-preserved silage affects the amount of DM available for feeding and the quality of the ground water. The DM content of silage is confounded by maturity. The DM and maturity affect the degree of compaction, waste of the ensiling process and nutritive quality.

The chop size of the silage has been shown to affect the nutrient composition and digestibility. Miller et al. (1969) found lower DM digestibility when chop was decreased from 1.3 cm to 1.07 cm. A smaller size chop (.9 cm) resulted in lower DM digestibility than a medium chop (1.9 cm) (Geasler and Henderson, 1970b). More recently, Savoie et al. (1992) found no effect of chop length of grass silage on minimizing silage storage losses.

Aerobic Degradation. Upon opening of the silo, microorganisms utilize residual sugars and organic acids in the silage which contribute to silage deterioration in aerobic environments (Spoelstra et al., 1988). During the exposure to air, yeast and mold populations increase within the first few days (Moon et al., 1980). In addition, acetic acid bacteria and acetic acid increase gradually while ethanol concentration decreases (Spoelstra et al., 1988). Woolford (1976) found yeast inoculated to grass silage increased lactic acid, acetic acid and ethanol concentrations. Whether aerobic degradation is due to bacteria or yeasts remains unresolved (Woolford, 1989). Regardless of the nature of microorganisms which degrade silage, a main objective of ensiling is to minimize these losses to the silage, which is marked by increases in temperature and pH, and decreases in lactic acid and WSC (Woolford, 1976).

Additves. In order to promote anaerobic fermentation and minimize degradation losses, additives may be added to the corn plant prior to ensiling. Among these additions are acids and their salts, enzymes, sterilizers, bacteria, and sugar (Clark, 1988). The use of additives has not been shown to be necessary for proper silage making, however, the benefits remain nebulous and research is currently being conducted concerning the beneficial role of additives. The objective of addition of nutritive sources to silage is to provide carbohydrates for acid production, salts of the organic acids, and increasing nutritive value.

The addition of corn grain to silage increases carbohydrates and DM (Ely, 1978). Ground shelled corn was added at a rate of 50 kg/t to Coastal bermuda grass (*Cynodon dactylon*) prior to ensiling (Miller et al., 1963) The pre-ensiled forage and corn mixture had slightly lower post ensiling DM, CP, and NFE. Cracked milo (*Sorghum bicolor* L. Moench) grain added to 42% DM and 62% DM wilted alfalfa had little effect on total VFA or pH (Owen and Senel, 1963). Considering both moisture levels ensiled, milo addition significantly increase acetic and butyric acids. The low moisture (62 % DM) had a final pH of 5.48 and 5.45, with and without milo, respectively. Similarly, the high moisture silage had a pH above 4.

Among the major contributions of molasses addition are increased palatability, DM, acid synthesis, and decreased pH (Ely, 1978). Palatability is enhanced by both pleasant odor and sweet taste of the silage. Molasses promotes fermentation by increasing the WSC concentration to allow for sufficient lactic acid production. Italian ryegrass (*Lolium multiflorum*) containing 16.2% WSC was sprayed with molasses (McDonald et al., 1964). Dry matter and pH values were 15.09% and 4.1 for untreated and 16.64% and 4.0, respectively, for the molasses-treated silages. The effluent loss was 4.4 and 6.2% for the control and molasses-treated silages, respectively. The OM, CP, crude fiber, and NFE concentrations were slightly lower for molasses-treated silages than non-treated silages.

Limestone addition to forage prior to ensiling increases Ca level for nutritional requirements (Ely, 1978). In a review of the effects of $CaCO_3$, increased and decreased carotene content, enhanced palatability, marked by increased DMI are mentioned (Essig, 1968). Due to the low level of Ca and P in corn silage, adding limestone satisfies the Ca deficiency. The conclusion from three feeding trials was the recommendation of .5% $CaCO_3$ (Essig, 1968), which was supported by other research (Ely, 1978). Because of the buffering action of limestone, it prolongs fermentation and increases lactic acid production.

Nitrate is primarily stored in the stems (Li et al., 1992) which are not readily digestible due to the high proportion of cell wall contents. Nitrate is reduced (gains electrons) during fermentation to nitrite and nitrous oxide which inhibit clostridial growth (Spoelstra, 1983). As nitrate is reduced, NH_3 and N-gases are formed, causing the pH to rise. The increase in pH favors clostridial growth which nitric oxide and nitrite tend to inhibit. Although the effect of nitrate as a clostridial inhibitor is positive, nitrate has toxic potential to animals. The conversion of nitrate to nitrite occurs in the gastrointestinal tract of the animal. If the level of nitrite absorbed in the blood is excessive, hypoxia or anoxia results. The nitrite binds to hemoglobin rendering it unable to bind to oxygen, thereby diminishing the oxygen supply for the animal. The addition of NPN or $CaCO_3$ to silage does not reduce nitrate concentration (Li et al., 1992).

The addition of urea has been combined with the addition of $CaCO_3$ since the urea increases CP and $CaCO_3$ increases Ca and carotene (Essig, 1968). Urea was added to corn at a level of .5% since 1944 (Ely, 1978). The addition of urea to corn silage has been shown to improve feed efficiency and milk production, primarily by increasing the CP of the silage. In addition to increasing CP, urea has been shown to increase pH and increase lactic acid in corn stover silage (Colenbrander et al., 1971).

Preservatives. The addition of short chain fatty acids (C1 to C7), including formic, acetic, and propionic acids prevents growth of spore-forming bacteria at pH of 5 and 6 (Woolford, 1976). In discouraging spore-forming bacteria, pH is more critical than specific acids. Longer chain fatty acids (C8 to C12) have anti microbial effects at pH 4. When applied to silage, acids have both negative and beneficial effects on fermentation parameters. Addition of .33% propionic acid did not significantly change DM digestibility or fermentation parameters of corn silage (Leaver, 1975). However, lactic acid (4.7%) added to silage increased wet matter and energy losses, and a combination of lactic and acetic acids had no stimulatory effect over the level of acids added (Byers et al., 1982). Acetic acid and pH decreased as lactic acid increased when lactic acid (4.7%) was added to the chopped corn plant. A significant reduction in DM loss occurred after addition of propionic and formic acids to corn silage (Britt et al., 1975; Leaver, 1975).

A delay in fungal growth and spoilage resulted from propionic and formic acid additions to silage (Britt et al., 1975). The addition of formic acid plus formaldehyde significantly increased WSC and decreased VFA concentration in ryegrass silage, as compared to formic acid addition (Thompson et al., 1981). No differences in VFA or pH were observed from addition of formic acid or formic acid and formaldehyde to ryegrass silage (Rooke et al., 1983). Addition of formic acid and formaldehyde to ryegrass silage decreased organic matter and N digestibility while increasing the amount of protein escaping from the rumen (Thompson et al., 1981). Rooke et al. (1983) found lower N degradation at 8, 12, and 24 h in ryegrass silages treated with formic acid and formic acid plus formaldehyde than untreated silages.

Inoculation of lactic acid bacteria has been shown to be an effective preserver during anaerobic fermentation and aerobic degradation. In feeding out conditions over an 8-wk period, the addition of *Lactobacillus plantarum* resulted in decreased mold and yeast counts (Wohlt, 1989). However, addition of

Lactobacillus acidophilus and *Candida spp.*(yeast) to silage did not affect yeast and mold growth, nor were bacterial populations affected (Moon et al., 1980).

Inoculation of *Lactobacillus plantarum* and *Streptococcus faecium* to grass-legume silage resulted in higher levels of lactic acid bacteria than in untreated silage; however, after 57 d of ensiling there was no difference in lactic acid concentration between treatments (Harrison et al., 1989). Inoculation of *Lactobacillus plantarum* to whole-plant corn silage did not result in different lactic, acetic, propionic, or butyric acid concentrations, compared to uninoculated silage (Luther, 1982). There was no change in lactic acid concentrations due to inoculation of lactic acid bacteria to corn silage and high moisture corn (Schaefer et al., 1989). After 7-d aeration of high moisture corn forage ensiled for 130-d, no significant difference in lactic acid concentration occurred between inoculated lactic acid bacteria silage and uninoculated silage (Phillip and Fellner, 1992). A combination of *L. plantarum* and *Enterococcus faecium* added to the corn plant did not affect acetic acid, lactic acid, ethanol and ammonia-N (Bolsen et al., 1992), contrasting reports of Tengerdy et al. (1991) documenting increased lactic acid concentration in silages inoculated with lactic acid bacteria.

In a feed-out setting, silage temperature was decreased as an effect of *Lactobacilli* inoculant (Wohlt, 1989). Feed refusals of dairy cattle were reduced. Similarly, high moisture ear corn silage inoculated with Ecosyl® (trade name for inoculant) or *Bacillus subtilus* had lower maximum temperature after 7 d exposure to air, and slower rising temperature than uninoculated silage (Phillip and Fellner, 1992). No differences in temperature between lactic acid bacteria inoculated silages and uninoculated silages were reported by Wittenberg (1983).

Lactic acid bacteria inoculant had no significant effect on nutrient digestibility of corn silage (Wittenberg, 1983). The addition of *Lactobacillus plantarum* did not affect CP or availability of CP during an 8-wk period (Wohlt, 1989). *Lactobaccilus plantarum* inoculated whole corn plant silage had significantly higher apparent OM and DM digestibility, compared to the uninoculated silage (Luther, 1982). Grass-legume silage inoculated with *Lactobacillus plantarium* and *Streptococcus faecium* had higher IVDMD and *in vitro* digestibility of ADF than uninoculated silages (Harrison et al., 1989). Digestibility of ADF was significantly lower in silages inoculated with mixtures of *Lactobacillus plantarum, Serratia urbidaea*, or *Streptococcus thermophilus* than untreated silages (Phillip and Fellner, 1992). Lactic acid bacteria and cell wall enzymes added to freshly-cut alfalfa significantly decreased NDF from 38.8 to 34.8% (Tengerdy et al., 1991). Molasses plus lactobacilli inoculant added to wilted bermuda grass silage increased *in vitro* OM digestibility (Umana et al., 1991).

Nutritional Value of the Corn Plant

Composition of the Corn Plant. The corn plant consists of the stem, leaves, and ear, contents of which change with growth (Wilkinson, 1978). The ear includes the grain, cob, and husks. Sugars stored in the leaves travel to the ear corn kernel in the form of starch as growth progresses to maturity (Kilkenny, 1978). As the sugars leave the leaves, the CP declines (Johnson et al., 1966b). Crude protein declines as the plant matures (Johnson and McClure, 1968; Joanning et al., 1981).

The ear makes up 60% of the DM at maturity (Wilkinson, 1978). The non-structural carbohydrates comprising WSC (including starch) are in greater proportion in the ear, as compared to the other parts of the corn. The corn grain increases from 20% of the DM in immature silage to 46% in mature silage (Joanning et al., 1981). Consequently, the non grain fraction (leaf, stalk, and husk and cob) decreases from 80% to 54%. Of the nongrain portion of immature and mature corn plants, leaf, stalk, and husk and cob fractions accounted for 38, 31, 31%, respectively. Changes in nutrient composition are slight, as illustrated by non-significant differences in CP, NDF, and ADF at early (September 18) and late (October 4) harvests (Mir et al., 1992).

Digestibility. The contribution of the ear to total DM gives corn a relatively lower cell wall content than other mature grasses (Wilkinson, 1978). *In vitro* digestibility of the entire plant remains relatively constant throughout the water, milk and dough stages of kernel development (Calder et al., 1977). The stalk and leaf portions of the growing corn plant decrease in digestibility over time, while digestibility of the ears does not significantly change. The stalk and leaf contain high concentrations of cell wall contents which contribute to their low digestibility. Based on proportion of the total DM, the ears constitute more mass than the stems and leaves. Thus, as the stem, leaves, and ears mature, the higher digestibility of the ears balances the comparatively lower digestibility of the stem and leaves. Thus, overall quality does not drastically change over time. As DM increases with maturity, cellulose content decreases, largely due to ear growth (Johnson and McClure, 1966; Andrieu, 1976).

The moisture level of the corn plant and fermented silage may affect quality to variable degrees. As the moisture level of corn grain increases from 11% to 26%, digestibilities of nutrients increase with the exception of ash (Perry and Stewart, 1979). Regardless of corn silage moisture, DM, CP, and crude fiber digestibilities remained unaffected. Goering et al. (1969) found higher DM silage (45% DM) was less digestible than lower DM silage (30% DM). Geasler and Henderson (1970b) found higher DM digestibility (69.15%) of 43.3% DM silage when compared to 30.7% DM silage (65.95%).

The milk-early dough and dough-dent stages of corn, with DM averages of 24% and 27%, respectively, are the most digestible and show little variation (Johnson and McClure, 1966; Calder et al., 1977; Kilkenny, 1978). Perry et al.(1968) found that DM digestibility was not correlated with harvest date *per se*. Dry matter digestibility did not significantly vary (with the exception of one harvest date) among periodic harvests between September and May during 2 yr of harvests. *In vivo* digestibility of CP of silages harvested from the water (August 25), milk (mid-September), and dough stage (October 7) continued to decrease with maturity (46, 41, 38% respectively) (Calder et al., 1977). Two-year average CP digestibility values of the respective corn harvests, treated with urea, had increased average CP digestibilities, but digestibility decreased between the water (75%) and later harvests (69 and 63%, respectively). Decreased nutritive quality is a consequence of late harvest, if harvest occurs after the first killing frost (Calder et al., 1977). Sudweeks and Ely (1978) found no effect due to increasing chop length (.62, 1.27, 1.91 cm) on DM, CP, ADF, and NDF digestibilities.

Silage Intake and Performance. Silage is a high energy feed and its intake is governed by a complex set of animal and plant relationships. The concentrations of organic acids, pH (Wilkins et al., 1971), length of silage particles (Apolani and Chestnut, 1985) and protein supplementation (Goering et al., 1969) have been shown to influence silage intake.

Levels of acetic acid and NH_3 (expressed as percent of total N) are indicators of poor silage fermentation or silage deterioration, and have been negatively correlated with silage intake (Wilkins et al., 1971). Infusion of acetic acid into the rumen significantly decreased intake of hay (Egan, 1972). Lactic acid concentration of total acid concentration, and percent DM and N have been positively correlated with intake. Digestibility and intake have not been shown to be significantly correlated (Goering et al., 1969;Wilkins et al., 1971; Egan, 1974; Joanning et al., 1981).

Corn silages of 29.8 and 31.0% DM had DM digestibility of 67.8 (Goering et al.,1969). Corn silages of 35.4 and 45.7% DM had DM digestibilities of 60.1 and 65.3%, respectively. The significant differences in DM concentration and digestibilities did not result in different DMI of Holstein steers and heifers. The average DMI of both high and low DM silages increased from 6.58 to 8.53% of BW $^{.75}$ when the silages were supplemented with soybean meal.

Joanning et al. (1981) found that steers fed a corn silage diet of lower digestibility *ad libitum* twice daily did not have lower DMI than those fed a silage of higher digestibility. Intake of digestible energy per day was 40% greater when the silage of either digestibility was supplemented with grain. The intake of well preserved silage appears to be governed by rumen fill rather than digestibility value.

Production of dairy cows was not compromised by feeding silage made from increasingly mature corn (Huber et al., 1968). Average daily gain was significantly higher in beef heifers fed corn silage of late milk, early dough, and late dough stages compared to those fed corn silage of the mealy endosperm stage (Chamberlain et al., 1971). The increased ADG was accompanied by increased intake. Therefore, enhanced ADG may have been due to the increased consumption rather than as the result of silage quality and (or) harvest date.

Silage particle size did not affect corn silage consumption within and between harvest times (Miller et al., 1969). Apolani and Chestnut (1985) found intake of finely chopped grass to be higher than of smaller cut silage, resulting in increased body weights of sheep. The chop of the silage significantly affected digestibility but no differences in composition resulted. Analysis of the silages of different cut sizes indicated no changes in chemical composition, but as size of the chop decreased, digestibility increased. Enhanced fermentation as result of decreased chop size was suggested.

Nitrogen Supplementation

The dual role of protein in the ruminant diet is N for microbial fermentation and amino acids for post ruminal absorption (NRC, 1984). When corn silage was treated with isonitrogenous amounts of SBM or urea the degradation of amino-N, amide-N, and unidentified non protein-N (NPN)(not including NH_3-N) was not significantly different than in untreated silages (Buchanan-Smith and Yao, 1978). The similar amounts of degradation supports the idea that these NPN fractions in the corn silage are as digestible in the rumen as urea, which is readily broken down to NH_3 in the rumen. *In vitro* digestion of cellulose in silages treated with water-soluble N was lower, as compared to silages treated with urea, suggesting that the water-soluble N in corn silage may exhaust microbial capacity for digestion of other diet components. Protein degradation decreased significantly from 88 to 83% after wilting, demonstrating that the amount of undegraded protein exiting the rumen is low (Makoni et al., 1991). Wilting decreases the moisture of the ensiled forage which decreases the rumen degraded protein fraction and increases the amount leaving the rumen. These results emphasize the importance of N supplementation to a corn silage diet to maximize its nutritive potential.

The extent of protein degradability of the protein supplement had no significant effect on intake or DM digestibility (Gill and England, 1984). Similarly, no changes in NDF or DM digestibilities were recorded after protein supplementation of urea, alfalfa pellets, or SBM to corn silage (Horton et al., 1992). Fish meal supplementation to grass silage resulted in no changes in NDF or DM digestibilities (Petit and Filpot, 1992). Rumen degradability of DM, NDF, CP, and OM was decreased by protein supplementation of fish meal to grass silage (Varvikko and Vanhatalo, 1992). However, CP digestibility was higher in supplemented corn silage diets than in unsupplemented diets, suggesting the protein in the corn grain and corn silage is less available than that of supplemental protein (Horton et al., 1992). Petit and Filpot (1992) showed that protein supplementation increased N digestibility. Protein supplementation had no effect on N retention (Gill and England, 1984). The fraction of instantly degradable N increases, while slowly degradable N decreases in supplemented silage diets (Varvikko and Vanhatalo, 1992).

Soybean Meal. Soybean meal supplemented diets produced slaughter weight steers quicker, but not more efficiently than urea supplemented diets (Horton et al., 1992). The processing of the soybean affects its utilization. Extruded soybeans significantly lowered CP degradation and increased N flow, compared to urea, SBM or a combination of urea and raw soybeans (Chester-Jones et al., 1990). No differences in ADG resulted between feeding extruded soybean, SBM, and urea and raw soybeans. Ground soybeans, not processed, contained more soluble N than SBM or SBM with oil, demonstrated by increased NH_3-N rumen production and microbial attachment to feed particles (Davenport et al., 1987). Thus, heat processing of the soybean for soybean meal is beneficial in denaturing the protein to allow for lower ruminal degradation.

Broiler Litter as an Animal Feed

Chemical Composition. Broiler litter is an excellent source of N and fiber (Bhattacharya and Fontenot, 1965). Average values of DM, CP, crude fiber, and NFE of peanut hull and wood shaving broiler litters were 89, 31.3, 29.7, and 32.5%, respectively (Bhattacharya and Fontenot, 1966). Of the CP, 45% consisted of true protein, 30% of uric acid, 14.3% of NH_3, 2.8% of urea, 3.5% of creatinine, and 4.8% of others. A review of several studies showed poultry litter contained 2.37% Ca, 1.8% P, .54% Na, 1.78% K, .44% Mg, 225 ppm Mn , 451 ppm Fe , 98 ppm Cu , 38 ppm B , 284 ppm Al , 235 ppm Zn , and 11 ppm As, DM basis (Bhattacharya and Taylor, 1975).

Digestibility and Nitrogen Utilization. When broiler litter supplied 25, 50, or 100% of dietary N, and was supplemented to a purified diet, apparent CP digestibility was 70.4, 68.3, and 57.7%, respectively (Bhattacharya and Fontenot, 1965). Urinary N excretion was similar among diets, and fecal N excretion was higher ($P < .01$) at the 100% broiler litter level than for the other diets. When broiler litter was substituted for 25 or 50% of a ground alfalfa (*Medicago sativa* L.) hay-corn grain diet, average apparent CP digestibility was 72.5% for peanut hull and wood shaving broiler litter diets (Bhattacharya and Fontenot, 1966). Feeding ground corn cobs and ears supplemented with broiler litter processed by either dry heat, dry heat and paraformaldehyde, or ethylene oxide resulted in an average apparent CP digestibility of 54.7% (Caswell et al., 1975). All animals were in positive N balance.

Performance. In sheep fed diets of equal CP levels, including 25% or 50% poultry litter in the diet resulted in lower weight gains than diets with no poultry litter (Thomas et al., 1972). Heifer calves fed 12% protein mixture, and ensiled broiler litter for 120 d gained approximately 1.15 kg/d (Creger et al., 1973).

Production of cattle fed poultry litter was summarized from eight experiments by Smith and Wheeler (1979). The comparison of traditionally-fed cattle and litter-fed cattle showed mean ADG to be .99 and .94 kg/d, respectively. Dry matter intake was 10.3 kg/d (.3kg/d higher than traditionally-fed) when 24% of DM fed was poultry litter. Feed efficiency (feed/gain) of cattle fed poultry litter and traditionally-fed was 11.4 and 10.4, respectively.

Differences in milk production were summarized from 10 experiments (Smith and Wheeler, 1979). Milk production was 18.42 and 18.17 kg/d, by traditionally-fed and poultry waste-fed cows, respectively. Milk fat and DMI were higher for cows fed diets containing poultry waste than traditional diets.

Performance of 30 steers and heifers fed corn silage-corn grain supplemented with 0, 30, 45 or 60% of the corn silage DM as deep stacked broiler litter was studied (Chester-Jones et al., 1984). Steers fed the 45% litter diet had the highest DMI and ADG, 12 kg and 1.18 kg/d, respectively. Similar ADG for steers and heifers resulted from feeding 45 and 30% litter.

Ensiling with Corn Forage. Wood shaving broiler litter was filtered through 2-cm screen, then blended with 25 kg of corn forage harvested at 30% or 40%, DM basis (Harmon et al., 1975a). Two-kg mixtures of corn forage and 15, 30, or 45% broiler litter were ensiled for 61 d for the 30% DM forage and 63 d for the 40% DM forage. Pre-ensiled 83% DM broiler litter contained 26.8% CP, 23% crude fiber, 32% NFE, and 16.7% ash, DM basis. The average chemical components for the corn forages were: 7.8% CP, 22.6% crude fiber, 63.3% NFE, and 3.9% ash, DM basis and 31.5% DM. The ensiled mixture of both maturities resulted in higher DM with increasing amount of broiler litter added to the mixture. Similarly, CP, ether extract, and ash increased with increasing amounts of broiler litter. However, crude fiber did not increase with increasing amounts of broiler litter. Ensiling broiler litter with 30% DM corn forage did not change ($P >$ .01) crude fiber. Ensiling broiler litter with 40% DM forage increased DP at the 45% litter mixture. Less mature corn forage (30% DM) or more mature corn forage (40% DM) ensiled with 30% broiler litter had CP digestibilities of 67 and 64%, respectively. Sheep fed the more mature corn ensiled with 15 or 30% broiler litter diets had higher N retentions, compared to sheep consuming the less mature corn silage-litter diet, urea supplemented , or unsupplemented diet.

Corn forage ensiled with 30% broiler litter, DM basis was supplemented with SBM or not supplemented (McClure et al., 1979). Average data of 3 yr shows ADG and final BW of beef heifers were not different between the corn-litter silage supplemented with SBM and unsupplemented corn-litter silage.

Furthermore, control corn silage supplemented with SBM had similar ADG and final weight to the corn-litter silage fed heifers.

Deep Stacking Broiler Litter. Twenty tons of wood shaving base broiler litter were stacked at a depth of 1.22 m, measuring 3.05 m X 9.15 m, in a covered building open on all sides (Hovatter et al., 1979). Six thermistor probes were placed at alternating depths of 45.7 cm and 81.3 cm in the stack. Initial temperatures were 28 and 29°C, at depths of 45.7 cm and 81.3 cm, respectively. Peak temperatures at these depths were 50 and 51° C on d 4 and d 8, respectively. Through the process of anaerobic fermentation, as noted by temperature increase, coliforms are eliminated (Dana et al., 1979; Hovatter et al., 1979). Deepstacking broiler litter allows for heating and curing, which prepares it for feeding (McClure and Fontenot, 1982).

Ensiling vs. Deep Stacked. Seventy percent corn was ensiled with 30% broiler litter (DM basis) or deep stacked broiler litter was mixed at the time of feeding with the corn forage, to compose the same proportions (McClure and Fontenot, 1982). Three years of performance data of cattle fed these diets show final BW, ADG and feed efficiency to be similar. Deepstacked broiler litter of 35% moisture and ensiled 50% moisture had similar CP values of 33.1 and 34.2%, respectively (Abdelmawla et al., 1988). The NDF values were 35.8 and 41.3%, respectively, for deepstacked and ensiled litter. Ensiled broiler litter had significantly higher CP digestibility than deep stacked, however, N retention was similar.

Health Aspects of Feeding Animal Waste. In a review of broiler litter as a feed, Fontenot (1991) outlined regulations concerning feeding broiler litter. In 1967 FDA issued a statement (21 CFR 500.4) not sanctioning the use of poultry litter as an animal feed because of lack of information on its safety. In 1980, this policy was revoked by (45 FR 86272), delegating the responsibility of regulating the use of broiler litter to individual states. The American Association of American Feed Control Officials (AAFCO) has a regulation for feeding animal waste. Processing of the waste must produce pathogen-free waste. A withdrawal of 15 d is needed for milk or egg producing animals, if documentation cannot be supplied showing the animals from which the waste came from were not administered drugs.

In a review concerning the health aspects of feeding broiler litter, Fontenot and Webb (1975) cited no resulting disease problems of beef cattle, sheep or dairy cattle fed broiler litter. The only health related effect resulting from feeding broiler litter was Cu toxicity in sheep fed 25 and 50% broiler litter containing 195 ppm Cu of the diet. No deleterious effects on humans who consume meat, milk, or eggs of animals fed broiler litter have resulted. Furthermore, the review reported the taste of meat, milk, and eggs has not been compromised.

An unconfirmed report of botulism from Scotland occurred in cattle grazing land dressed with broiler litter that included poultry carcasses (Appleyard and Mollison, 1985), followed by confirmed outbreaks of botulism in cattle grazing land treated with broiler litter including carcasses (Gibson, 1986). The anaerobic bacterium *Clostridium botulinum* type C was detected. This bacterium releases the toxin that causes motor paralysis leading to death (Neil et al., 1989). Another confirmed incidence of botulism occurred in cattle consuming ensiled broiler litter rather than dry broiler litter (McLoughlin et al., 1988). The ensiled litter included poultry carcasses similar to that of the cases involving pasture fed litter. The botulinum toxin was recovered in 50% of the carcasses, but none was detected in the litter. A further investigation with this ensiled litter was conducted with two calves in a feeding trial (Neil et al.,1989). Results show toxin presence in one blood sample through the 66-d trial with symptoms of muscle incoordination occurring 49 d after ensiled litter consumption began. The incidents described above all occurred from feeding poultry litter which contained poultry carcasses. Broiler litter containing dead birds should not be used for broiler litter which is composted (Ruffin and McCaskey, 1990). No health problems associated with feeding broiler litter have been reported in the U.S. (Fontenot, 1991).

Chapter III.

Conventional and Sustainable Corn Silages Fed with Different Nitrogen Supplements

OBJECTIVES

The objectives of the research project were to determine 1) the fermentation characteristics of corn produced by conventional and sustainable methods, 2) the chemical composition of the silages used in the diets, 3) the digestibility and metabolism of the silages supplemented with different N sources, and 4) the performance and carcass quality of steers fed the corn silages with supplemental N.

EXPERIMENTAL PROCEDURE

Conventional and sustainable whole farm systems, producing beef steers from weaning to slaughter, were compared at the Kentland farm (366 m elevation, 12' 30° north latitude, 35' 37.5° west longitude). Cattle begin grazing forages approximately November 1 of each year, and continue on pasture until they are finished on a high corn silage diet during a feedlot finishing period. The soil is dominated by the Shottower series (Hapludults typic, fine-loamy, mixed mesic). Two methods (conventional and sustainable) of growing corn for silage during the finishing period were used.

The conventional system represents the best current technology available. The two pastures in the conventional system were fescue (*Festuca arundinacea* schreb.) fertilized with N and fescue-red clover (*Trifolium pratense* L.). Corn and alfalfa were grown in a 5-yr rotation. The sustainable system represents low chemical and mechanical alternatives to conventional methods of farming. Pastures for the sustainable system were fescue-alfalfa with no N fertilization. Corn for silage was grown in rotation with, wheat (*Triticum aestivum*)/rye (*Secale cereale*), alfalfa (*Medicago sativa*), and alfalfa. When sufficient pasture was not available hay was fed to conventional and sustainable cattle. Corn harvested for silage for our experiment was in yr 4 of these rotations.

For the conventional corn, a rye cover crop was sprayed with .7 kg A.I./ha paraquat: 1,1 dimethyl-4, 4'-bipyridinium ion (Gramoxone® , ICI Americas, Wilmington, DE); 3.36 kg A.I./ha alachor: 2-chloro-2', 6'-diethyl-N-(mehtoxymethyl)-acetanilide (Lasso MT®, Monsanto, St Louis, MO); 1.68 kg A.I./ha atrazine: 2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine (Atrex 90® ,Ciba-Geigy, Greensboro, NC); 1.23 kg A.I./ha simazine: 2-chloro-4, 6-bis(ethylamino)-*s*-triazine (Princep caliber 90®,Ciba-Geigy, Greensboro, NC); .05 L A.I./ha esfenvalerate: (s)-cyano (3-phenolyphenyl) methyl-(s)-4-chloro-alpha-(1-methyl) benzenacetate, (Asana®, Dupont, Wilmington, DE); with .946 L/100 L compatibility agent and .946 L/100 L surfactant immediately prior to planting. To inhibit resistant broad leaf weeds .28 kg A.I./ha dicamba: 3,6-dichloro-2 methoxy-benzoic acid (Banvel®, Sandoz, Des Plaines, IL) was applied to all conventional plots on June 29, 1992. The conventional corn was fertilized with 27. 4 t/ha cattle manure on April 16 and April 17, 1992, then 112.1 kg/ha N (30% urea solution) on June 25,1992.

Rye cover in the sustainable system was rolled down using a disk immediately before corn planting. Immediately prior to planting, 2.8kg A.I./ha glyphosate: N(phosphonomethy D glycine (Roundup®, Monsanto, St.Louis, MO) was applied (broadcast) to kill alfalfa and rye. The sustainable corn plots were fertilized with 31.17 t/ha of cattle manure on April 9, 10, 13, and 14, 1992, followed by, 90.8 kg/ha N (30% urea solution) on June 25, 1992. Corn was planted using a specialized planter called "Buffadeer", which strip tills the land into which the seed is planted.

Sustainable and conventional corn plots were seeded with "Pioneer 3140" on May 1,1992, and were planted at a rate of 59,280 seed/ha for a final stand of 54,362 plants/ha. Sustainable corn was harvested on September 29, and September 30, 1992. Conventional corn was harvested on September 30, and October 1, 1992.

Corn for both systems was grown by the two methods in a randomized complete block design with four replications. Each replicated plot was .6 ha. Corn grown by the conventional and sustainable methods was harvested, ensiled, and fed in a metabolism trial and a feedlot trial.

Metabolism Trial

For the metabolism trial, corn was packed into 16 208-L metal drums (eight per treatment) by trampling. The drums were double-lined with .06-mm polyethylene bags. Air was excluded by pressing the bag manually, then separately tying the two bags to ensure sealing, similar to procedure used by Abdelmawla et al. (1988). The plastic bag was pulled closely against the packed silage, twisted, then tied with a rubber-coated wire tie. Then, the outermost bag was tied, similar to the first.

Twenty-four crossbred (1/2 Dorset, 1/4 Finn, and 1/4 Rambouillet) wethers were weighed (average BW 44 kg), blocked by weight and allotted at random to the following four diets 1) conventional silage supplemented with urea, 2) conventional silage supplemented with SBM, 3) sustainable silage supplemented with urea, and 4) sustainable silage supplemented with broiler litter. The sheep were confined to metabolism stalls, similar to those described by Briggs and Gallup (1949), which allowed for separated fecal and urine collection. The sheep were fed at 600 and 1800 daily during a 5-d adjustment, 7-d preliminary and collection period. Before the adjustment period the diet consisted of corn grain (40.5%), mixed grass-legume (50.5%), SBM (3.5%), sugarcane molasses (5%) and salt (.50%, DM basis), after which the experimental diets were substituted at 10% increments at each feeding, until 100% of the experimental diets were reached. The 5-d adjustment period consisted of adjusting DMI to a level of minimal or no feed refusal.

The diets were formulated to contain 11% CP, DM basis, and were fed in individual polyethylene lined feed troughs. Refusals weighing less than 100 g were fed back to the animal at the following feeding. Water was available except during the 2h feeding period. Vitamins A (500,000 I.U.) and D (75,000 I.U.) were injected intramuscularly before the adjustment period.

The fecal material was collected in polyethylene lined metal pans, transferred daily to cloth bags, and dried in forced draft oven at a maximum of 60° C. At the end of the 7-d collection the fecal material for each animal was mixed in a large plastic bag, weighed, and subsampled for chemical analyses. One subsample, weighing approximately 100 g was dried in a forced draft oven at 100° C until a constant weight was reached. This DM weight was recorded and used for the total fecal DM output . The remainder of the fecal sample was ground through 1-mm screen in a Wiley mill and stored in air tight plastic cups.

Urine was collected daily in new, plastic milk jugs in 15 mL of 50% HCl diluted in 500 ml distilled water. The urine collection was diluted to 2000 g and subsampled by taking 40 mL (2%). Daily urine subsamples were stored in air tight plastic jars and refrigerated. At the end of the trial the urine was mixed to distribute settled matter, subsampled, placed in plastic cups and refrigerated until analysis.

Corn silages and supplements were sampled at each feeding, beginning 2 d prior to the 7 d collection until 2 d prior the end of the collection. The silage samples were sealed, and immediately frozen for later analysis. The supplement samples were placed in plastic bags, sealed and stored at room temperature. Refusals were frozen at -20°C and kept for analysis.

Ruminal fluid samples were collected 3 h post feeding on the day following the last collection, using a vacuum pump and stomach tube equipped with a screen filter. Samples were strained immediately through four layers of cheese cloth and pH was determined electrometrically. A 5-mL subsample was placed in a plastic storage tube containing 1 mL of 25% metaphosphoric acid.

Blood samples were taken in blood tubes with no additive from the jugular vein 6 h-post feeding, the day following the last collection. After collection, the tubes were immediately centrifuged, and serum was separated and frozen.

Chemical Analyses. Dry matter determinations of samples were made by drying duplicate 100-g sample (in the case of sufficient sample mass) in a forced-draft oven at a maximum of 65°C until a constant weight was reached. Dry matter and ash determinations were conducted according to A.O.A.C. (1990) procedures. The dried samples were ground in a Wiley mill with a 1-mm screen and analyzed for NDF, using amylase treatment to degrade starch (Robertson and VanSoest, 1981). Lignin, ADF and cellulose were determined according to VanSoest (1967) procedures, modified by Goering and VanSoest (1970).

Kjeldahl N was determined on dried, ground supplement samples and on wet homogenized silage samples (A.O.A.C., 1990). A subsample of the corn silage from each day of collection, consisting of samples from the AM and PM feedings, was blended in the Osterizer blender in order to homogenize it for CP analysis.

Silage extracts of the initial silage samples were obtained by homogenizing 25-g wet material with 225 ml distilled water in a Osterizer blender.

The homogenate was filtered through four layers of cheese cloth. The filtrate was used for determination of pH (electrometrically), lactic acid concentration (Barker and Summerson, 1941, modified by Pennington and Sutherland, 1956) and WSC (Dubois et al., 1956, modified by Johnson et al., 1966). Volatile fatty acids were measured by gas chromatograph. The carrier gas used was N_2. The glass column measured 1.83m X 2 mm (internal diameter), which was packed with GP 10% SP-1200, 1% H_3PO_4 on 80/100 chromsorb WAW, supplied by Supelco, Bellefonte, PA. The injector temperature was set at 115°C with a sample run time of 10 m for both the silage and the ruminal fluid VFA.

The concentration of urea in the blood serum was determined using the Sigma® (St. Louis, MO), single-reagent system. In the morning of the ruminal fluid and blood collections, feeding was staggered every 4 m for each animal, to allow for sufficient collection time.

Statistical Analyses. The data were analyzed by procedures for a randomized block design. Analyses of apparent digestibility values, blood urea N (BUN), and ruminal pH and VFA were based on six observations per treatment. All data were analyzed by general linear model (GLM) procedures of the SAS (1985). Treatment means were compared by Tukey's pairwise comparisons.

Feedlot Trial

For silage to be fed in the feedlot, two sausage silos (Ag Bag™, Warrenton, OR) were packed with corn forage from the designated treatment corn crops.

Forty-eight Angus steers were blocked by weight into six blocks of eight steers each. The cattle within each block were allotted at random to two treatments for each of four replications. Both groups grazed until October 22, 1992, at which time the steers from each field replication were allotted at random to four pairs of pens, and the cattle in each of the two treatments were allotted at random to the two pens within each pair. Conventional cattle occupied pens 2, 3, 6, 8 and sustainable cattle occupied pens 1, 4, 5, and 7.

The diet in the feedlot for the conventional cattle began with 36% silage, 60% hay, and 4% SBM, and gradually modified to a final composition of 96.5% silage and 3.5% SBM. The sustainable cattle began with 35% silage, 58% hay, and 7% broiler litter increasing silage and broiler litter proportions to a final composition of 94% silage and 6% broiler litter. Both diets were formulated for 12% CP level. Cattle were fed once daily in the morning, with the silage and supplements being mixed in a silage feeding wagon, prior to placement in the trough. Refusals were removed at weekly intervals and weighed. All cattle were implanted with zeranol every 90 d from the beginning of grazing until they were finished. Monensin was fed at 250 mg/d and vitamin A at 24,000 I.U. in the vitamin premix, mixed with diet.

The silage from the feedlot silos and the supplements were sampled once weekly, and sealed in plastic bags. Supplement samples were stored at room temperature and the silage was frozen at -20°C. Samples of three consecutive weeks were composited at the end of the 15-wk sampling period and analyzed as described for the metabolism samples.

Slaughter. The last weigh day of the animals on feedlot study was March 10, 1993, after which the sustainable cattle were fed SBM instead of broiler litter. At the end of the 14-d withdrawal period the cattle were shipped to Philadelphia, Pennsylvania for slaughter (approximately 660 km).

Statistical Analyses. The experimental design was a randomized complete block. The feedlot silages were sampled and tested as either conventional or sustainable and analyses of the feedlot silage were based on five observations per treatment. The two treatments were compared using GLM (SAS, 1985). The daily gain and carcass data were compared using the individual animal data within four replications per treatment. Pen means were used for analysis of feed intake and feed efficiency. The two treatments were compared using GLM.

RESULTS AND DISCUSSION

Metabolism Trial

Fermentation Characteristics of the Silages. As indicated by the fermentation characteristics (Table 1), both silages ensiled satisfactorily. Average pH values for the conventional and sustainable silages were 3.73 and 3.79, respectively. The acceptable range for pH is 3.5 to 5.8 (Bolsen et al., 1992). Li et al.(1992) observed a pH of 3.8, at 1.2 m from the top of the silo, compared to pH of 4.21 at .3m from the top of the silo. The pH has been recorded to fluctuate during the ensiling period.

The conventional and sustainable pre-ensiled corn had similar ($P > .05$) mean WSC, DM basis (5.57 and 6.28%, respectively). Silo drums were not designated for a specific treatment, therefore, individual diet silages were not analyzed. The levels of pre-ensiled WSC were higher than the mean post-ensiled WSC concentrations, indicating some WSC fermentation. The WSC concentration of pre-ensiled corn used in the metabolism trial was marginal, considering the range of 6 to 8%, DM basis, given by Woolford (1972).

After ensiling, the WSC concentration averaged 3.86 and 5.69%, DM basis, respectively, for the conventional and sustainable silages. There was variation of WSC within sources of silages. Mean lactic acid concentrations, DM basis were 3.58 and 3.23% for the sustainable and conventional silages, respectively. The concentration of lactic acid has been shown to be variable at different locations of measurements. For example a lower concentration of 1.30%, DM basis, was measured at .3 m while 3.21% was measured at 1.2 m from the top of the silo (Wittenberg et al., 1983). Lactic acid content of the DM (5.57%) was increased by ethanol and a combination of ethanol and acetic acid, when added to

TABLE 1. **FERMENTATION CHARACTERISTICS OF CORN SILAGES FED TO SHEEP IN METABOLISM TRIAL**

Item	Kind of silage and supplement				
	Conventional		Sustainable		
	Urea	SBM	Urea	Broiler Litter	SE
pH	3.74^{ab}	3.72^{b}	3.79^{a}	3.79^{a}	.018
Water soluble carbohydrates[d]					
Pre-ensiled[e]	5.57		6.28		.822
Post-ensiled	3.40^{a}	4.32^{ab}	6.28^{c}	5.10^{bc}	.485
Lactic acid[d]	3.49^{ab}	2.89^{a}	2.95^{a}	4.24^{b}	.292

[a,b,c] Different superscripts on same row represent significant differences ($P < .05$).

[d] DM basis.

[e] Pre-ensiled WSC means are based on silage type.

pre-ensiled corn forage (Byers et al., 1982). The range of lactic acid concentration in successfully ensiled corn forage is wide. Type of silo has been shown to influence lactic acid concentration, and to a greater extent, WSC content (Viera et al., 1988).

The total VFA concentration of the conventional silages supplemented with urea and SBM and sustainable silage supplemented with urea and broiler litter were .620, .601, .593 and .629%, DM basis, respectively (Table 2). Concentrations of acetic and propionic acids were not different ($P > .05$) among silages. Concentration of isobutyric acid of conventional silage supplemented with SBM was (.0038) lower ($P < .05$) than sustainable silage supplemented with urea (.0065). Sustainable silage supplemented with broiler litter had statistically similar isobutyric acid concentration (.004) to the other silages. The concentration of butyric acid was higher ($P < .05$) for sustainable silage supplemented with broiler litter (.008) than the conventional silages (not detected). The statistical significance of the differences have no apparent biological importance. The concentrations of isovaleric and valeric acids were not different ($P > .05$) among the silages. Silage VFA in this study are slightly lower than those reported by Rony et al., (1984), who reported mean total VFA of .835%, DM basis, with acetic and propionic accounting for .785 and .02%, respectively. These previously reported values were accompanied by a larger standard error than in this experiment. Additionally, the column used by Rony et al. (1984) was stainless steel, whereas a glass column was used in this study.

Chemical Composition of Silages and Supplements. The average DM of the conventional and sustainable silages were 36.4 and 33.9%, respectively (Table 3). Slightly higher DM of the conventional silage than the sustainable silage reflects differences in DM prior to ensiling (31.36 and 29.88%)

TABLE 2. **VOLATILE FATTY ACID CONCENTRATIONS OF CORN SILAGES FED IN METABOLISM TRIAL**

VFA	Kind of silage and supplement				
	Conventional[a]		Sustainable[a]		
	Urea	SBM	Urea	Broiler Litter	SE
	-----------------------	---%, DM basis---	-----------------------		
Acetic	.556	.563	.518	.565	.058
Propionic	.059	.034	.064	.051	.009
Isobutyric	.005^{bc}	.004^{b}	.007^{c}	.004^{bc}	.000
Butyric	.000^{b}	.000^{b}	.002^{bc}	.008^{c}	.002
Isovaleric	.000	.000	.002	.000	.000
Valeric	.000	.000	.000	.000	.000
Total	.620	.601	.593	.629	.066

[a] Values represent the least squares means of seven twice-daily samples.
[b,c] Means in same row with different superscripts are significantly different ($P < .05$).

TABLE 3. **CHEMICAL COMPOSITION OF CORN SILAGES AND SUPPLEMENTS FED IN THE METABOLISM TRIAL**

Item	Diet no.	DM	CP	NDF	ADF	Lignin	Cellulose	Ash
		--------------------------%, DM basis--------------						
Silages								
Conventional	1	36.4	6.20	46.3	25.0	3.3	21.8	2.4
	2	36.4	6.44	46.9	25.8	3.6	22.2	2.6
Sustainable	3	34.4	6.43	46.4	25.5	3.5	22.4	3.0
	4	33.3	7.28	43.3	24.1	3.3	20.9	2.8
SE		1.19	.217	1.13	.737	.14	.590	.118
Supplements								
Urea		99	287	-	-	-	-	-
Soybean meal		91	52.4	8.6	6.31	1.22	5.51	6.25
Broiler litter		85	23.7	43.4	28.5	5.7	16.8	26.7

[a] Values represent the average of twice-daily samples for 7 d.

for the conventional and sustainable silages, respectively (Appendix Table 1). Corn silage can be successfully ensiled at 42 to 45% DM (Byers et al., 1982), which is a more mature stage than the stage when our corn was harvested. However, harvesting at a less mature stage (less than 30 to 35% DM) will compromise DM yields (Daynard and Hunter, 1975).

The CP of the conventional silages was similar (6.20 and 6.32%, DM basis) and slightly lower than for sustainable silages (6.43 and 7.28%). The sustainable silage supplemented with the broiler litter accounting for most of the higher CP% silage average. The values are lower than reported by Valdez et al.(1988) for 25% DM corn silage (9.0% CP). Wittenberg et al. (1983) reported a CP value of 7.4%. The NRC (1984) lists 33% DM well eared corn silage as having 8.1% CP. Increasing DM tends to decrease crude protein (Wilkinson, 1978). At a similar DM as used in this investigation Calder et al. (1977) reported a lower CP value (5.1%). The CP of the corn silages fed in the metabolism trial are well within the acceptable protein levels of ensiled corn forage.

Average NDF and ADF values of the conventional (46.6 and 25.4%, respectively) and sustainable silages (44.85 and 24.8%, respectively) were similar. Lignin, cellulose and ash were similar for conventional and sustainable silages (3.5, 22, and 2.5; 24.4, 3.4 and 2.9%, respectively). Concentrations of NDF and ADF of 65 and 43%, respectively, were reported by Valdez et al. (1988) for 25% DM corn silage. Wittenberg et al.(1980) reported higher ADF (30%) than in our study.

The chemical composition of urea, soybean meal, and broiler litter are comparable to previous reported values. Urea DM and CP (99 and 287%, DM basis, respectively) are identical to those reported by NRC (1984). The values of DM, CP, NDF, ADF, cellulose, and ash for SBM in this experiment (91, 52.4, 8.6, 6.31, 5.1, and 6.25%, DM basis respectively) are similar to NRC (1984) values (90, 55.1, 8, 6, 5, 6.5%, respectively).

Broiler litter fed in the metabolism trial contained 23.7% CP,43.4% NDF, and 26.7% ash, DM basis. The CP and ash reported by NRC (1984) for dehydrated-poultry manure and litter were 24.5, and 22.0 %, respectively. Broiler litter analyzed and fed by Harmon et al. (1975a) contained slightly higher CP, and lower ash than broiler litter analyzed in this experiment. The average value for CP presented by Bhattacharya and Taylor (1975), representing analyses from different sources, was 28%.

Apparent Digestibility. Dry matter digestibility (Table 4) was not different ($P > .05$) between the conventional and sustainable silage diets supplemented with urea (65.9 and 63.8%, respectively). Conventional silage supplemented with SBM had higher ($P < .05$) DM digestibility than silages supplemented with urea, but not higher than sustainable silage supplemented with broiler litter. Supplementation of corn silage with SBM has been shown to increase apparent DM digestibility compared to urea supplementation (Horton et al., 1992). In corn silage-urea supplemented diets of increasing maturities, DM digestibilities decreased slightly to 68% after the milk-early dough and dough-dent stages (Johnson and McClure, 1966a). Similarly, Bergen et al. (1974) found DM digestibility of corn silage-urea diets to be 67.7%. Horton et al. (1992) reported similar values to those determined in this study for corn silage-corn grain supplemented with SBM and urea.

The apparent digestibility of CP was lower ($P < .05$) for sustainable silage supplemented with broiler litter (51.9%) than for the other diets. The

TABLE 4. **APPARENT DIGESTION COEFFICIENTS[a] OF PROTEIN SUPPLEMENTED CORN SILAGE DIETS WHEN FED TO SHEEP**

	Kind of silage and supplement				
	Conventional		Sustainable		
Component	Urea	Soybean meal	Urea	Broiler litter	SE
Dry matter	65.9^{c}	69.3^{b}	63.8^{c}	66.2^{bc}	1.1
Crude protein	63.9^{b}	63.8^{b}	59.1^{b}	51.9^{c}	1.6
NDF	44.9^{b}	52.0^{c}	40.7^{b}	52.8^{c}	1.8
ADF	43.1^{b}	50.7^{c}	38.5^{b}	49.3^{c}	1.8
Cellulose	72.7^{b}	77.5^{c}	72.3^{b}	78.8^{c}	.8

[a] Each value represents the mean value of six sheep.

[b,c] Means in the same row with different superscripts differ ($P < .05$).

sustainable and conventional corn silage diets supplemented with urea had similar ($P > .05$) CP digestibilities (63.9 and 59.1%, respectively). Horton et al. (1992) reported CP digestibility of silage supplemented with SBM, fed to steers, of 56.4%, which is lower than the value determined in this study (63.8%). The CP digestibility of the conventional silage supplemented with SBM was similar ($P > .05$) to that of the urea supplemented diets. Previous average apparent N digestibility of corn cob and corn starch supplemented with SBM or dried poultry waste were 64.9 and 58.3%, respectively (Tinnimit et al., 1972). The CP digestibility of SBM is similar to values obtained in this trial, while the reported CP digestion coefficient of the broiler litter diet is higher than the value in this experiment. The average percentage of poultry feces and SBM fed by Tinnimit et al. (1972) were 26 and 10.6%, respectively. The percentage of DM consumed by sheep in this experiment, consisting of SBM (8%) and broiler litter (20%) are slightly different than the amounts fed by Tinnimit et al. (1972). Corn forage of less maturity (29% DM) ensiled with 15% broiler litter had higher CP digestibility (60%) than more mature (40% DM) corn forage (55%) (Harmon et al., 1975b). Similarly, less mature corn forage ensiled with 30% broiler litter had higher CP digestibility than the more mature silage. When those corn forages were ensiled with .5% urea, CP digestibilities were higher than the values of this study. Perhaps, the fact that the urea and broiler litter were ensiled with the corn forage and not supplemented, accounts for the differences.

Apparent digestibilities of NDF, ADF, cellulose were similar ($P > .05$) for the conventional silage supplemented with urea (44.9, 43.1, 72.7%, respectively), and sustainable corn silages (40.7, 38.5, and 72.3%, respectively). Values were higher ($P < .05$) for diets supplemented with SBM and broiler litter. Higher crude fiber digestibility resulted when ground corn grain and corn cobs were supplemented with broiler litter, compared to SBM supplementation

(Caswell et al., 1978). The lower digestibilities of components in urea-supplemented silages, as compared to the other treatments, in the present study, are similar to those previously reported by Horton et al. (1992). Cellulose digestibility significantly decreased from a value of 72% at the blister stage to 47% at maturity (Johnson and McClure, 1966). Values for cellulose digestibility in this study agree with higher digestibility for less mature corn. There were no differences ($P > .05$) between the cellulose digestibility of the SBM (77.5%) and broiler litter (78.8%) supplemented diets, which were higher ($P < .05$) than for the conventional- and sustainable-urea supplemented diets.

Nitrogen Balance. Intake of N was different ($P < .05$) among all diets (Table 5). Intake was lower for the conventional and sustainable silages supplemented with urea (10.97 and 11.09 g/d, respectively) than conventional silage supplemented with SBM (11.45 g/d) and sustainable silage supplemented with broiler litter (12.25 g/d). Fecal N excretion was highest ($P < .05$) for the animals fed sustainable silage supplemented with broiler litter (5.90 g/d), reflecting, at least in part, the higher N intake. The fecal N excretion of the animals fed conventional silage supplemented with SBM (4.10 g/d) was not different ($P > .05$) from fecal excretion of animals fed the conventional and sustainable urea-supplemented silages (3.93 and 4.70 g/d, respectively), which were different ($P > .05$) from each other.

Animals fed conventional silages supplemented with urea and SBM absorbed more N ($P < .05$) than animals fed sustainable silages supplemented with urea and broiler litter. Similarly, when absorption was expressed as a percentage of intake, the values were higher ($P < .05$) for the animals fed the conventional silages than the animals fed the sustainable silage diets. Animals fed sustainable silage supplemented with broiler litter absorbed the least ($P < .05$), when expressed as percentage of N intake, compared to the animals fed the other diets.

TABLE 5. **NITROGEN UTILIZATION OF SHEEP FED CORN SILAGE PROTEIN SUPPLEMENTED DIETS**

Item	Kind of silage and supplement				
	Conventional		Sustainable		
	Urea	Soybean meal	Urea	Broiler litter	SE
Intake, g/d	10.97^{e}	11.45^{c}	11.09^{d}	12.25^{b}	.022
Excretion, g/d					
Fecal	3.93^{d}	4.10^{cd}	4.70^{c}	5.90^{b}	.155
Urinary	8.09^{b}	6.65^{bc}	6.77^{bc}	5.86^{c}	.371
Total	12.02^{b}	10.75^{b}	11.47^{b}	11.43^{b}	.372
Absorption					
g/d	7.05^{b}	7.36^{b}	6.39^{c}	6.35^{c}	.148
% of intake	64.21^{b}	64.22^{b}	57.62^{c}	51.84^{d}	1.31
Retention					
g/d	-1.04^{c}	$.71^{b}$	$-.38^{bc}$	$.49^{b}$	.364
% of intake	-	6.19^{b}	-	3.99^{b}	3.13

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[a] Each value represents the mean of six animals.

[b,c,d] Means in the same row with different subscripts differ ($P < .05$)

Urinary N excretion was similar ($P > .05$) for the animals fed the conventional silage supplemented with SBM and sustainable silages supplemented with urea and broiler litter (6.65, 6.77 and 5.86 g/d, respectively). Lambs fed conventional silage supplemented with urea had higher ($P < .05$) urinary excretion (8.09 g/d) than those fed broiler litter supplemented silage and tended to be higher than for lambs fed conventional silage supplemented with SBM and sustainable silage supplemented with urea. Despite differences among the fecal and urinary excretions, total N excretion was not different ($P > .05$) among sheep fed all diets. For animals fed conventional silages supplemented with urea and SBM, total N excretion was 12.02 and 10.75 g/d, respectively, while animals fed sustainable silage supplemented with urea and broiler litter had total N excretions of 11.47 and 11.43 g/d, respectively.

Nitrogen retention was similar for animals fed conventional silage supplemented with SBM (.71 g/d) and animals fed sustainable silage supplemented with broiler litter (.49 g/d). These retentions, when expressed as percentage of intake, were similar ($P > .05$) also. The animals fed the conventional and sustainable silages supplemented with urea had similar ($P > .05$) negative N balances (-1.04 and -.38 g/d, respectively). Animals fed the sustainable silage supplemented with urea tended to have lower ($P > .05$) N retention, compared to the SBM and broiler litter fed animals.

The ruminal pH of the conventional and sustainable urea-supplemented diets were 6.60 and 6.80, respectively (Table 6). Feeding the SBM and broiler litter diets resulted in ruminal pH values of 6.88 and 6.59, respectively. The ruminal pH of the animals fed the diets were not different ($P > .05$). Caswell et al. (1975) reported ruminal pH values of 6.5, 6.42, and 6.62 for diets supplemented with broiler litter processed by dry heat, dry heat and paraformaldehyde, or ethylene oxide, respectively.

TABLE 6. **RUMINAL FLUID PH AND BLOOD UREA NITROGEN OF SHEEP FED PROTEIN SUPPLEMENTED CORN DIETS**

Item	Kind of silage and supplement				
	Conventional		Sustainable		
	Urea	Soybean meal	Urea	Broiler litter	SE
Ruminal fluid pH[a]	6.60	6.88	6.80	6.59	.119
Blood urea (mg/100 mL)[a]	12.1	9.85	11.8	10.7	.993

[a] Each value represents the mean of six sheep

Values in same row with different superscripts are significantly different ($P < .05$).

The blood urea N (BUN) of the animals fed the conventional and sustainable urea-supplemented diets were 12.1 and 11.8 mg/100mL, respectively. The blood urea of the animals fed the SBM and broiler litter supplemented diets were 9.85 and 10.7 mg/100mL, respectively. The BUN of the animals did not differ ($P > .05$) among diets. Caswell et al. (1975) reported BUN values of 17.4, 14.3, and 11.8 mg/100mL, for animals fed supplemented broiler litter processed by dry heat, dry heat and paraformaldeyde, or ethylene oxide, respectively. Plasma urea N (PUN) values of animals fed urea and SBM supplemented corn silage-corn grain diets (8.0 and 7.6 mg/100mL) reported by Davenport et al. (1987) were lower than the BUN values determined in this study. The values for low level of SBM supplemented diet was 6.4 mg/100mL (Davenport et al., 1987), while a high level of supplementary SBM resulted in PUN of 10.7 mg/100mL. The value of 9.85 mg/100mL for sheep fed corn silage-SBM is similar to the BUN value resulting from the high level of SBM supplement in this experiment.

Total VFA concentration was not different ($P > .05$) among sheep fed the different diets (Table 7). Animals fed the conventional and sustainable silages supplemented with urea had total ruminal VFA concentrations of 37.6 and 47.4 μmol/mL, respectively. Total VFA concentrations of ruminal fluid of sheep fed conventional silage supplemented with SBM and sustainable silage supplemented with broiler litter were 42.7 and 51.4 μmol/mL, respectively. Animals fed the sustainable silage supplemented with broiler litter had higher ($P < .05$) acetic acid (67.8% of the total VFA concentration) than the animals fed the conventional silages supplemented with urea (57.3%) or SBM (59%), but similar to the animals fed sustainable silage supplemented with urea (60.1%).

Propionic and isobutyric acid proportions were similar ($P > .05$) for all animals fed the treatment diets. Propionic acid is a major glucose precursor and has been shown to be in lower proportion in ruminal fluid of ruminants fed silage

TABLE 7. **RUMINAL VOLATILE FATTY ACID CONCENTRATIONS OF SHEEP FED PROTEIN SUPPLEMENTED CORN SILAGE DIETS**

	Kind of silage and supplement				
VFA	Conventional		Sustainable		
	Urea	SBM	Urea	Broiler litter	SE
Total ,µmol/ml	37.6	42.7	47.4	51.4	4.06
Mol/100mol					
Acetic	57.33^{b}	59.0^{b}	60.07^{bc}	67.8^{c}	2.29
Propionic	29.60	25.5	22.8	20.1	1.33
Isobutyric	.748	.662	.829	.594	.039
Butyric	10.3^{c}	13.5^{b}	14.54^{b}	10.4^{bc}	.739
Isovaleric	.991	.706	.991	.639	.052
Valeric	.925	.720	.796	.417	.046

[a] Each value represents the least squares mean of six sheep.

[b,c] Values in same row with different superscripts are different ($P < .05$).

compared to other roughage diets (Leng et al., 1967). A lower propionic acid concentration in the silage may influence the quantity generated in the rumen, and thus may affect the amount of glucose used for energy. Butyric acid proportion was lower ($P < .05$) for animals fed the conventional silage supplemented with urea (10.3%) than the conventional-SBM (13.5%) and sustainable-urea (14.5%) diets, and similar ($P > .05$) to animals fed sustainable silage supplemented with broiler litter (10.4%). Animals fed sustainable silage supplemented with broiler litter had a similar level of butyric acid (10.4%) as the animals fed the other diets. Isovaleric and valeric acid proportions were not different ($P > .05$) among animals fed the diets. Concentrations of VFA, expressed as percentage of the total VFA present in the rumen fluid are similar to those reported by Gill and Beever (1982) and Horton et al. (1992).

Feedlot Trial

Fermentation Characteristics of Corn Silage. The corn silages fed in the feedlot were well preserved. Conventional and sustainable silages had mean pH values of 3.75 and 3.74, respectively (Table 8). The pre-ensiled WSC of corn forage was similar between the conventional (8.39%, DM basis) and sustainable (8.70%) silages. The range of 6 to 8% WSC (DM basis) supports successful lactic acid fermentation (Woolford, 1972). The WSC concentration for the ensiled conventional silage (6.44%) was not different ($P > .05$) from the sustainable silage (5.64%). The values indicated considerable fermentation. Lactic acid concentration tended to be lower ($P > .05$) for conventional than sustainable silage (4.07 and 5.77%, DM basis, respectively).

Total VFA concentration (Table 9) was not different ($P > .05$) for the conventional silage (1.07%, DM basis) and sustainable silage (.886%), nor did individual acid concentrations differ. The total VFA concentrations are similar to

TABLE 8. **FERMENTATION CHARACTERISTICS OF CORN SILAGE FED IN FEEDLOT**

	Type of corn silage		
Item	Conventional	Sustainable	SE
pH	3.75	3.74	.022
WSC[a]			
Pre-Ensiled	8.39	8.70	.714
Post-ensiled	6.44	5.64	1.49
Lactic acid[a]	4.07	5.77	.860

[a] DM basis

TABLE 9. VOLATILE FATTY ACID CONCENTRATIONS IN CORN SILAGES FED IN FEEDLOT

	Type of corn silage		
VFA	Conventional[a]	Sustainable[a]	SE
	----------%, DM basis-----------		
Acetic	.896	.718	.150
Propionic	.063	.035	.015
Isobutyric	.007	.039	.016
Butyric	.096	.094	.050
Isovaleric	.002	.000	.000
Valeric	.003	.000	.001
Total	1.07	.886	.182

[a] Values represent the least squares means of five three consecutive weekly sampling periods.

[b] DM basis

the previous reported concentration (.835%) for corn silage (Rony et al., 1984). Mean acetic and propionic acid concentrations of both silages were .807 and .049%, respectively. Acetic and propionic acid concentrations are similar to previously reported values (Rony et al., 1984). In the present study mean isobutyric, butyric, isovaleric, and valeric acid concentrations of the silages were .023, .095, .001, .002%, DM basis, respectively.

The chemical composition of the feedlot silages and supplements are given in table 10. Conventional silage analyzed 37.3% DM, which was composed of 6.51% CP, 46% NDF, 25.7% ADF, 3.52% lignin, 21.9% cellulose, and 2.67% ash, DM basis. Sustainable silage contained 33.8% DM which consisted of 7.37% CP, 46.1% NDF, 26.4% ADF, 3.46% lignin, 22.6% cellulose, 3.39% ash, DM basis. Values for both treatment silages were similar except for DM and CP. The values are similar to those reported by Harmon et al. (1975a) and Wittenberg et al. (1980).

The CP of SBM (47.2%) and broiler litter (22.5%) is comparable to NRC (1984) values of 52.4 and 24.5%, DM basis, respectively. Mean CP of broiler litter analyzed in several reports summarized by Bhattacharya and Taylor (1975) was higher (28%) than the CP of the broiler litter in this study.

The initial live weight of calves fed the conventional diet and calves fed the sustainable diet at the beginning of the grazing phase was not different. However, upon entrance to the feedlot, steers fed the conventional diet weighed more ($P < .05$) than steers fed the sustainable diet (421 vs 390 kg) (Table 11). Difference in ADG did not become apparent until the second to last 28d period, at which time steers fed the conventional diet had a higher ($P < .05$) ADG than steers fed the sustainable diet (1.44 vs 1.14, respectively). For the fifth period ADG was higher ($P < .05$) for steers fed the conventional diet than for steers fed

TABLE 10. **CHEMICAL COMPOSITION OF THE CORN SILAGES AND SUPPLEMENTS FEFD AT THE FEEDLOT**

Item [a]	DM%	CP	NDF	ADF	Lignin	Cellulose	Ash
		---------------------	------------	%, DM basis	------------	------------	---------------------
Silages							
Conventional	37.3	6.51	46.0	25.7	3.52	21.9	2.67
Sustainable	33.8	7.57	46.1	26.4	3.46	22.6	3.39
SE	.961	.449	.961	.264	.335	.178	.154
Supplements							
Soybean Meal	91	4.73	6.41	.347	2.57	6.61	47.2
Broiler litter	84	45.7	31.0	1.95	7.88	27.5	22.5

[a] Values represent the mean of the five consecutive 3-wk sampling periods.

TABLE 11. **PERFORMANCE[a] OF STEERS FED CONVENTIONAL OR SUSTAINABLE SILAGE SUPPLEMENTED WITH SOYBEAN MEAL OR BROILER LITTER**

Item	Type of corn silage		
	Conventional	Sustainable	SE
	--------------------kg------------------		
Initial wt, 11/91	203^{b}	203^{b}	3.58
Wt at end of grazing	421^{b}	390^{c}	5.36
Final wt	596^{b}	541^{c}	13.0
Daily gain, feedlot			
First period[d]	.164	.537	.089
Second period	1.91	1.59	.106
Third period	1.63	1.54	.124
Fourth period	1.44^{b}	1.14^{c}	.095
Fifth period	1.05^{b}	.612^{c}	.094
Periods 1 through 5	1.25^{b}	1.09^{c}	.035
DMI, d	9.67	10.6	.416
Gain/ feed	.123^{b}	.102^{c}	.004
Initial through feedlot daily gain	.835^{b}	.717^{c}	.012

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[a] Each value represents the least squares means of 4 replications consisting of six animals each.

[b,c] Means in the same row with different superscripts are different ($P < .05$).

[d] Each period represents 28 d in the feedlot.

the sustainable diet (1.05 vs .612 kg). For the entire feedlot feeding period daily gains were higher (*P* < .05) for cattle fed the conventional silage diet than those fed the sustainable diet. Average daily gain from pasture grazing through finishing was higher (*P* < .05) for cattle fed the conventional diet compared to the cattle fed the sustainable diet (.835 vs .717 kg). The difference in overall ADG is a result of both difference in ADG on pasture and in the fourth and fifth periods of finishing.

Final live weight of both groups was in the normal range of finishing yearling beef steers. At the end of the fifth period cattle fed the conventional diet weighed more (*P* < .05) than cattle fed the sustainable diet (596 vs 541 kg, respectively). The DMI tended to be lower for cattle fed the conventional diet than cattle fed the sustainable diet (9.67 vs. 10.59 kg). Cattle fed the sustainable diet entered the feedlot at a lower weight tended to consume more feed, but gained less weight, which resulted in a lower (*P* < .05) gain/feed, compared to cattle fed the conventional diet (.102 vs .123 kg). Lower weight entering the feedlot for cattle fed the sustainable diet was never completely compensated. Weight entering into the feedlot overall daily gains were higher (*P* < .05) for cattle fed the conventional silage diet.

Silage is a high energy feed compared to the fresh forage (McDonald, 1991). The energy of corn silage is largely reflective of the DM, since as DM increases the grain content increases because the sugars are transported from the leaves to the grain and stored as starch (Perry et al., 1968). The DE of well eared corn silage is 3.09 Mcal/kg (NRC, 1984). The DE of broiler litter is lower (2.91 Mcal/kg) than SBM (3.84 Mcal/kg) (NRC, 1984). The difference between the NE_g of SBM and broiler litter is .52 Mcal/kg (NRC, 1984). The difference between the NE_m of SBM and broiler litter is .58 Mcal/kg. The lower values of broiler litter compared to SBM may have had an influence on the lack of compensatory growth of cattle fed the sustainable diet.

Carcass data of the steers fed the conventional and sustainable diets are presented in Table 12. The average carcass weight of the cattle fed the conventional diet (334 kg) was greater ($P < .05$) than for cattle fed the sustainable diet (297 kg). Maturity of both groups was similar. The carcasses were A maturity, meaning they were considered to be under 30 mo of age. Marbling score and back fat thickness were similar ($P > .05$) between the cattle fed the conventional and sustainable diets (4.03 and .371 cm, respectively). Horton et al. (1992) reported higher fat thickness (.95 cm) of animals fed corn silage- corn grain supplemented with SBM than the value of this feeding trial; however, the previously reported marbling score (small) is similar to the values for the carcasses of both treatments in this trial. Animals fed ensiled broiler litter had lower backfat (.20 cm) (McClure and Fontenot, 1989) than the backfat of the animals fed corn silage supplemented with broiler litter in this feeding trial. However, the cattle in the present trial were heavier. McClure and Fontenot (1989) reported the carcasses of animals fed ensiled corn forage-broiler litter had comparable marbling and quality values (3.71 and 11.23, respectively) to those of this study fed corn silage supplemented with broiler litter (3.86 and 10.7, respectively).

Ribeye muscle area was greater ($P < .05$) for the animals fed the conventional diet (74.3 cm^2) than the cattle fed the sustainable diet (70.5cm^2), resulting at least partly from the difference in carcass weight. No difference resulted in percentage of KPH fat of 1.04%, or quality grade (high select) of the cattle fed the conventional and sustainable diets.

Dressing percent and yield grade were higher for the animals fed the conventional diets (55.9% and 2.25, respectively) than the animals fed the sustainable diets (54.8% and 2.00, respectively). The different ($P < .05$) carcass weights reflect the higher live weight of the cattle fed the conventional diet as compared to the cattle fed the sustainable diet.

TABLE 12. **CARCASS DATA OF THE STEERS FINISHED AT THE WHITETHORNE FEEDLOT**[a]

	Type of corn silage		
Item	Conventional	Sustainable	SE
Hot carcass wt., kg	334[b]	297[c]	3.85
Maturity[d]	1.41	1.18	.136
Marbling[e]	4.19	3.86	.172
Back fat, cm	1.02	.869	.254
Ribeye, cm^2	74.3[b]	70.5[c]	1.24
Kidney, pelvic and heart fat, %	1.16	.912	.091
Quality grade[f]	11.3	10.7	.664
Yield grade	2.25[b]	2.00[c]	.088
Dressing percent	55.9[b]	54.8[c]	.271

[a] Each value represents the least squares means of 4 replications of six animals each.

[b,c] Values within a row with a different superscript significantly differ ($P < .05$).

[d] Code: A=1; B=2.

[e] Code: 3-slight; 4-small; 5-modest; etc.

[f] Code: 11= high select; 12=low choice; 13-avg. choice; etc.

Quality grade for each group was high select. Select meat is commonly sold in grocery stores as "economy beef". Yield grade is within the more desirable range. Yield grade is based on adjusted 12th rib back fat, ribeye muscle area, hot carcass weight, and percent KPH. Therefore, it is largely a reflection of the low degree of fatness in the carcasses.

SUMMARY

Corn silages fed in the metabolism and feedlot feeding trials were well preserved, as indicated by pH and lactic acid, being in the normal range for well preserved silages. Chemical composition of the corn silages was similar. Average DM was approximately 36 and 34% for the conventional and sustainable silages, respectively. Crude protein, NDF, ADF, lignin, and cellulose values were similar between conventional and sustainable silages.

Conventional and sustainable corn silages supplemented with urea in the metabolism trial provided a comparison of the corn silages. Apparent digestibility of DM, CP, NDF, ADF, and cellulose of the two diets were similar ($P > .05$). Total N excretion of the sheep consuming these diets was not different ($P > .05$). Absorption of N, expressed as a percentage of the intake, was higher ($P < .05$) for the sheep fed the conventional silage supplemented with urea than the sheep fed the sustainable silage supplemented with urea. However, sheep consuming the urea-supplemented silages were in negative N balance with no difference between the two diets.

Generally, in the metabolism trial, results were similar for the conventional silage supplemented with SBM and the sustainable silage supplemented with broiler litter. Apparent DM digestibility was similar ($P > .05$) between the conventional silage supplemented with SBM compared to the sustainable silage supplemented with broiler litter. Apparent digestibility of CP of sustainable silage supplemented with broiler litter was lower ($P < .05$) than the conventional silage supplemented with SBM. However, the CP level in both feedlot diets exceeded the requirement for steers (NRC, 1984). Apparent digestibility of NDF, ADF, and cellulose was similar ($P > .05$) between the diets.

Total N excretion was similar ($P > .05$) of sheep fed the conventional silage supplemented with SBM and sheep fed sustainable silage supplemented with broiler litter. Absorption of N, expressed as g/d and expressed as a percent of intake, was higher ($P < .05$) for sheep fed conventional silage supplemented with SBM than sheep fed sustainable silage supplemented with broiler litter. Retention of N, expressed in g/d, tended to be higher for wethers fed conventional silage supplemented with SBM than sheep fed sustainable silage supplemented with broiler litter.

Cattle fed conventional silage supplemented with SBM entered the feedlot heavier, had an overall higher ADG, and finished at a heavier live weight than cattle fed the sustainable silage supplemented with broiler litter. The differences in performance can not be attributed to differences in the conventional and sustainable silages since chemical composition and digestibility when supplemented with urea were similar. Digestible energy of the corn silage supplemented with SBM was 3.11 Mcal/kg, while the DE of the corn silage supplemented with broiler litter was 3.07 Mcal/kg. The small difference in DE concentration does not explain the difference in performance of the feedlot cattle. In fact, the daily intake of DE per head was actually numerically higher for the cattle fed the sustainable silage (30.1 vs 32.5 Mcal).

Differences in carcass weight, yeild grade, ribeye muscle area, and dressing percentage partly reflect the higher live weight of the cattle fed the conventional silage supplemented with SBM than the cattle fed the sustainable silage supplemented with broiler litter. Performance of the feedlot cattle and carcass characteristics are the results of an entire system of beef production. Analysis of feedlot performance and carcass characteristics should be in consideration of the system by which the cattle were produced.

Chapter IV.

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APPENDIX TABLE 1. **DRY MATTER CONTENT OF PRE-ENSILED CORN FORAGE FED IN THE METABOLISM TRIAL**

Treatment	Silo	Dry matter, %[a]
Conventional	1	31.13
	2	33.15
	3	31.73
	4	29.34
	avg	31.36
Sustainable	1	26.77
	2	32.36
	3	32.17
	4	28.21
	avg	29.88

[a] Means represent values of two silos.

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